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DOKTORA TEZİ

**AN EARLY CRISIS SIGNALING FRAMEWORK:
MACROECONOMIC RELATIONS AND TIME LAG
BETWEEN NOMINAL AND REAL VARIABLES**

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ÖZ

ERKEN KRİZ UYARICI SİSTEMİ: MAKROEKONOMİK İLİŞKİLER VE NOMİNAL VE REEL DEĞİŞKENLER ARASINDAKİ GECİKME SÜRESİ

Yhlas SOVBETOV

Yakın geçmişimizdeki 2008 Global Resesyonundan sonra erken kriz uyarıcı sistemlere (EWS) olan ilgi yeniden alevlendi. Mevcut EWS literatürünün çoğunluğu ekonominin nominal yönlerini temsil eden parasal kur krizlerine ve finansal krizlerine odaklı olup genel olarak kısa vadeli etkileşimlere yoğunlaşır. Bu literatürler ekonominin reel faktörlerini dikkate almaz iken makroekonomik durgunluklar, spekulatif ataklar, varlık balonları ve uluslararası finansal resesyonlar gibi diğer çeşit krizleri de ihmal ederler. Daha önemlisi ise, literatürdeki mevcut EWS sistemlerin çoğu 2008 Global Resesyonu tahmin etmekte yetersiz kalmışlardır. Bu da bu alanda daha geniş araştırmalar yapılması gerektiğini ortaya koymuştur.

Bu bağlamda, bu tez, mevcut EWS sistemlerini birçok yönden geliştiren ve güçlendiren yepyeni bir model ortaya koymayı amaçlamaktadır. İlk olarak, bu tez birçok reel ve nominal makroekonomik göstergelerin etkileşimlerini de kullanarak çeşitli finansal, ekonomik, bankacılık ve döviz krizlerini dikkate alan daha genel görünümlü bir EWS modeli sunar.

İkincisi, bu tez yeni ortaya konulan EWS modelini mevcut literatürdeki çalışmaların çoğunluğunda olduğu gibi yalnızca ABD, İngiltere ve AB gibi az sayıdaki ülkeler üzerinde değil, aksine 41 gelişmiş, gelişmekte olan ve az gelişmiş ülkelerden oluşan en büyük örneklem üzerinde test etmektedir.

Üçüncüsü, mevcut literatür büyük ölçüde uzun dönem sonuçları dikkate almayan statik özelliklerdeki modelleri kullanır. Bu tez ise bunu Almon'un (1965) yaklaşımı altında Gecikmesi Dağıtılmış Logit Tekniğini (DLL) kullanarak aşmaktadır. Bu tekniği çok değişkenli logit çerçevesinde kullanarak EWS modeline dinamik özellikler katarak daha güçlü bir model ortaya koymaktadır. Bu özel teknik, tüm

göstergelerin kümülatif ve gecikmeli etkilerini doğru şekilde ele almamıza yardımcı olmaktadır. Başka bir deyişle, bu teknik literatürde sıkça ihmal edilen krizin öncü göstergelerinin uzun vadeli etki ve etkileşimini de hesaba katmaktadır.

Dördüncüsü, bu çalışma literatürde sıkça kullanılan göstergelerin yanı sıra daha önce hiç kullanılmamış birkaç yeni göstergeleri de kullanmaktadır. EWS'nin modellenmesinde ekonomik ve finansal krizler için öncü göstergelerin belirlenmesi kritik rolü oynar. Ancak bu göstergelerin belirlenmesi esas olarak “kriz”in nasıl tanımlandığına bağlı olarak değişmektedir. Krizleri indekslerle tanımlayan mevcut literatürden farklı olarak, bu tez krizi doğrudan reel çıktılarda daralma/küçülme olarak ele almaktadır. Bu bağlamda, bu çalışma Phillips Curve ve Okun Kanunu gibi ampirik olarak kanıtlanmış makroekonomik ilişkileri de kullanarak reel ve nominal göstergelerin etkileşimlerini de EWS modeline entegre etmeye çalışır. Biz bu tezde bu ampirik ilişkilerin yaklaşmakta olan krizler için erken sinyaller veren öncü göstergeler olarak kullanılabileceklerini de ortaya koyuyoruz. Başka bir deyişle, Phillips eğrisi ve Okun yasasının kavramsal/teorik davranışları ekonominin iki ayrı ortamında değişmektedir: (1) Ekonomik temellerin büyük ölçüde sağlam ve sürdürülebilir olduğu sakin dönemlerde; ve (2) Ekonomik değişkenlerin daha sürdürülebilir bir seviyeye veya büyüme yoluna ulaşmadan önce bir ayarlama sürecinden geçtiği durgunluk dönemlerinde.

Beşincisi, EWS modellerinin performansını ölçme konusunda eşik değeri belirleme tekniği büyük rol oynar. Mevcut literatürde bu alandaki eksikliklerden ötürü, bu tez aynı zamanda optimal eşik değerinin belirlenmesi için iki yeni teknik de sunmaktadır: (1) Sahte-Gerçek oranı (ϕ) ve (2) Riskten Kaçınma oranı (Ω).

Mevcut literatürde eşik belirleme tekniği olarak sıkça kullanılan KLR Gürültü-Sinyal oranının iki noktada yetersiz kalmaktadır. İlk olarak, bu teknik “yanlış alarmlar” (tip II hata –gerçekleşmeyecek bir sahte kriz için verilen yanlış/sahte alarm sonucunda önleyici eylemlerde bulunma maliyeti) ve “kaçırılan alarmlar” (tip I hata – yaklaşmakta olan gerçek kriz için verilmeyen alarm sonucunda oluşan maliyet) arasında ayırım yapmadan her iki maliyeti de eşit değerde görür. Bu nedenle, biz KLR Gürültü-Sinyal oranını riskli eşik tekniği olarak görüyoruz. Ayrıca, bu tekniğe göre tip II hata olasılığı sıfır olduğu zamanlarda, tip I hata olasılığının hiç bir önemi kalmayacaktır. Çünkü KLR Gürültü-Sinyal oranı bu durumlarda sıfır değerini alacaktır (tip I hata olasılığı 0.01 veya 0.99 olmasını ayırt edemeyecektir). Başka bir

deyişle, bu teknik, sahte/yanlış alarmları sıfırlamak uğruna daha fazla gerçek alarmı kaçırmayı göze alır. Bu nedenle, bu teknik öncelikli olarak potansiyel krizi öngörmeyi ve önlemeyi amaçlamamaktadır, ancak kriz dışı olaylar için sahte/yanlış alarmları en aza indirmeyi amaçlamaktadır. Bu ise, EWS modellerinin amaçlarına uygun değildir. Uygun bir eşik değeri belirleme tekniği, EWS modelinin kaçırılan kriz olaylarını en aza indirmesine (veya öngörülen/tahmin edilen kriz olaylarını en üst düzeye çıkarmasına) yardımcı olmalıdır. Bu bağlamda, DLL EWS modelimizi, iki yeni önerilen tekniğimiz de dahil olmak üzere dört farklı eşik değeri belirleme tekniği altında karşılaştırmalı olarak analiz ediyoruz. Sonuç olarak, ortaya koyduğumuz bu iki yeni eşik belirleme tekniği mevcut tekniklere kıyasla daha iyi tahmin oranlarını sunduğunu ve EWS modelimizin genel performansını daha da optimize edilebileceğimizi gösteriyoruz. Ortalama olarak, modelimiz toplam 1319 kriz dönemlerin % 96,36'sını (1271 kriz dönemi) önceden tahmin ederken, toplam 3995 sakin ekonomik dönemlerin yalnızca %12,32'sinde (492 sakin dönem) yanlış/sahte alarm vermiştir.

Anahtar Kelimeler: Erken Kriz Tahmini; Krizin Öncü Göstergeleri; Eşik Değer Belirleme Teknikleri; Beklenen Enflasyon; İşsizlik; Phillips Eğrisi; Okun Yasası; Logit Modeller.

ABSTRACT

AN EARLY CRISIS SIGNALING FRAMEWORK: MACROECONOMIC RELATIONS AND TIME LAG BETWEEN NOMINAL AND REAL VARIABLES

Yhlas SOVBETOV

After most recent 2008 Global Recession, the interest in early crisis warning (EWS) system has been rekindled. Majority of existing EWS literature has short-run implications and it mainly focuses on currency crashes and financial crises that represent nominal aspects of the economy. It neglects real aspects of the economy and other types of imbalances such as macroeconomic crises, speculative bubbles and crashes, international financial crises, and wider economic crises. Moreover majority of existing EWS models failed to predict 2008 Global recession which leaves plenty rooms for research studies.

In this respect, this thesis attempt to establish a brand-new EWS system that improves existing ones in several patterns. First, it offers more generalized outlook by accounting various types of financial, economic, banking, and currency crises by using a set of real and nominal macroeconomic indicators.

Second, it considers the largest sample size for EWS by covering 41 countries from developed, emerging, and frontier markets. While the existing literature mainly studies few developed countries such as the US, the UK, and the EU.

Third, the existing literature largely uses static models that ignore long-run implications. This thesis employs more robust methodology of Distributed Lag Logit technique (DLL) under Almon's (1965) approach in multivariate logit framework that wields dynamics aspects as well. This specific methodology helps us to capture cumulative and delayed effects of all indicators accurately. In other words, it integrates often neglected long-run impacts of leading indicators on crisis.

Fourth, the study takes into account most prominent leading indicators alongside with few new indicators that have not been used before. The selection of appropriate leading indicators of economic and financial turmoil also plays a crucial role in modelling EWS. However, the selection mainly depends on how the term "crisis" is defined. Unlike the literature that often defines the crisis using self-built indexes, the thesis considers it as shrinks in real output straight-forwardly. In this respect, it attempts to integrate real and nominal variables in the EWS model by utilizing empirically proven macroeconomic relations such as Phillips Curve and Okun's Law. We show that these empirical relations emerge early signals for upcoming imbalances. In other words, notional behaviour of the Phillips curve and Okun's law changes during two states of economy: Tranquil periods, when economic fundamentals are largely sound and sustainable; and Recessionary periods, when economic variables go through an adjustment process before reaching a more sustainable level or growth path.

Fifth, the thesis also offers two brand-new techniques for optimal threshold selection, namely, False-to-True ratio (ϕ) and Risk Aversion rate (Ω) due problems in existing threshold techniques. The literature largely uses KLR Noise-to-Signal ratio as a threshold selection technique in order to gauge signals. However, it fails to distinguish consequences of "false alarms" (type II error - cost of taking pre-emptive action in response to a false alarm for non-crisis events) and "missed alarms" (type I error - cost of missed alarm for upcoming actual crisis). Therefore, we regard noise-to-signal ratio as risky threshold technique. Moreover, when probability of type II error is zero, the KLR's noise-to-signal ratio will derive zero notwithstanding to probability of type I error (there will be no difference whether it is 0.01 or 0.99). In other words, the noise-to-signal technique prefers to undertake more missed signal rates for the sake of nulling false signal rate. Thus, this technique does not primarily aim to predict and prevent potential crisis, but aims to minimize false alarms for non-crisis events. This is not in line with objectives of EWS models. A proper threshold selection technique should help EWS model to minimize missed crisis events (or maximize predicted crisis events). In this respect, we evaluate our DLL EWS model under four different threshold techniques comparatively including our two newly proposed techniques. As a result, we show that performance of our model can be optimized with our new threshold selection techniques which derive better prediction rates comparing to existing techniques. Averagely, our model correctly predicts

96.36% (1271 crisis quarters) of 1319 total crisis events (quarters) in advance, while issuing only 12.32% (492 tranquil quarters) false signals during 3995 tranquil periods.

Keywords: Early Crisis Prediction; Leading Indicators of Crisis; Threshold Techniques; Expected Inflation; Unemployment; Phillips Curve; Okun's Law; Logit Models.



PREFACE

The basis for this research originally stemmed from rekindled academic interest in developing better early crisis warning (EWS) system after failure of existing ones predicting Global Recession in 2008. In this respect, this thesis attempts to establish a new generalized EWS that accounts various types of financial, economic, banking, and currency crises by using a set of real and nominal macroeconomic indicators. The thesis shows empirical performance of new EWS model across 41 countries from developed, emerging, and frontier markets between the periods of 1980-2016. As a result, it accurately predicts, averagely, 96.36% (1271 crisis quarters) of 1319 total crisis events (quarters) in advance leaving a considerable time to dispose the shocks completely or mitigate their impact. Meantime, the new model issues only 12.32% (492 tranquil quarters) false signals during 3995 tranquil periods.

In addition, the thesis also offers new threshold selection techniques in evaluation of EWS model. It comparatively shows how our new technique increases efficiency and accuracy of the newly proposed EWS model.

Hereby, I confirm that this thesis is original, unpublished, independent work of mine with my supervisor Professor Muhittin Kaplan. We have generated few research articles from this thesis and have submitted to double-blind reviewed international academic journals recently and awaiting their publications.

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LIST OF ABBREVIATIONS

EWS	: Early Crisis Warning System
Eq.	: Equation
PC	: Phillips Curve
EAPC	: Expectation Augmented Phillips Curve
NCPC	: NewClassical Phillips Curve
NKPC	: New Keynesian Phillips Curve
KLR	: Kaminski, Lorezondo and Reinhart (1998)
DLL	: Distributed Lag Logit model
EWS	: Early Crisis Warning System
Eq.	: Equation
PC	: Phillips Curve
EAPC	: Expectation Augmented Phillips Curve
NCPC	: New Classical Phillips Curve
NKPC	: New Keynesian Phillips Curve
KLR	: Kaminski, Lorezondo and Reinhart (1998)
DLL	: Distributed Lag Logit model
ARDL	: Autoregressive Distributed Lag
BL	: Backward-looking
BOPY	: Balance of payment pressure
BP LM	: Breusch-Pagan Lagrange Multiplier test
CLI	: Composite Leading Indicator Index
CMT	: Index of Currency Market Turbulence
CON	: Contagion Effect
CONPI	: Construction production index
CPI	: Inflationary pressure
CRDY	: Banking Credit bubble
CUSUM	: Cumulative Sum of Squares of Residuals
DH	: Dumitrescu-Hurlin approach
DOLS	: Dynamics OLS
ECM	: Error-Correction Model
EMP	: Exchange Market Pressure
FE	: Dixit-effects
FL	: Forward-looking

GOVY	: Government Balance pressure
HP	: Hodrick-Prescott filter
IPI	: Industrial Production Index
MC	: Marginal Costs
NAIRU	: Non-accelerating inflation rate of unemployment
OIL	: World Oil Prices
PMG	: Pooled Mean Group
PMI	: Purchasing Managers' Index
RE	: Random-effects
RECM	: Restricted Error-Correction Model
REER	: Real Effective Exchange rate pressure
RESMON	: Liquidity and Foreign Reserves pressure
RFE	: Redundant Fixed Effects test
SIC	: Schwarz information criterion
SOLS	: Stepwise OLS
SPEX	: Speculations and expectations
STR	: Structural and behavioural changes
TUC	: Unit Total Costs
UD	: Unemployment Pressure
UECM	: Unrestricted Error-Correction Model
ULC	: Unit Labor Costs
UNLC	: Unit Non-Labor Costs

INTRODUCTION

The importance and aim of the study

Consequences of all types of economic and financial crises are often dramatic. It negatively affects whole societies from poor to rich and from youngest to elderly people. Since 1980's the world has witnessed a number of financial crashes and economic disturbances that have revealed two facts. First, regardless of countries' level of development, economic disturbances cause macroeconomic aggregates and indicators to get worsen for all sectors, all social classes and individuals in all around the world. Although they are often portrayed as short-term events, in some countries their effects seem to have a long memory leading to high unemployment (high inflation) and reduced economic activity (output) to linger which may cause lasting consequences. In this respect, widely accepted empirical relations such as Phillips Curve and Okun's Law can be useful tools to assess theoretical linkages between crisis and macroeconomic variables (inflation-unemployment-output). These relations can also be an early signalling indicator of crisis as inflation and unemployment play critical role in economic disturbances and the disturbances are considered as shrinkages in output. Thus, any structural changes in dynamics of these empirical relationships might generate macroeconomic imbalances.

Second, in many cases crises are "*fast and furious*" contagious due to tight trade interlinkages among globalized countries. This contagiousness might cause significant structural changes in the economy. Thus, affected countries have often required international financial assistance to mitigate turbulence they experience and to limit severe costs of such spillover. To cope with these consequences of contagiousness, international organizations such as IMF, Worldbank, and the US Federal Reserve bank have long been trying to develop an Early Warning System (EWS) models with an ability of predicting when and how shifts and shocks occur. The IMF staffs had taken the pioneering role in developing EWS models: Kaminsky, Lizondo and Reinhart (1998) and Berg and Pattillo (1999) have been regarded as core studies in this field. These studies show that monitoring a suitable set of early warning indicators is a key for the optimal timing of macro-prudential measures that target to anticipate, detect, and prevent (or at least mitigate) risks of disturbances on

economic activities. In this respect, the EWS models are crucial for policy-makers and financial regulatory authorities that allow them to identify potential weaknesses and vulnerabilities of the economy in advance, leaving a considerable time to dispose the shocks completely or reduce their impact.

However, poor performances of such models have rendered capabilities of existing EWS models to be questioned in four strands. First, their failure in forecasting global financial recession of 2008-2009 has rekindled interest in developing new and more generalized EWS which comprise various types of macroeconomic variables rather than focusing only on currency crashes as majority of early models did. Although there are various types of EWS models which are specifically designed according to types of crises (*i.e. explanatory indicators of EWS for currency crashes are different comparing to indicators of EWS models for labour market shocks or for banking crises*), the literature lacks of offering a common (generalized) EWS framework that is capable of predicting various types of imbalances in the economy including economic, financial, banking, and currency turmoil. The vast amount of existing models has limited predicative power capability.

Second, existing EWS models mainly treat the crises as short-run events, thus they ignore their long-run impacts and consequences. Majority of these models is fairly static models that neglect lag and delayed effects of indicators on real macroeconomic variables which might emerge in long-run. These effects might be captured and fixed by integrating optimal lags for indicators into the model. Meantime, it also converts the models into dynamic form.

Third, existing EWS models ignore structural and behavioural shifts in real and nominal macroeconomic variables which might have a key role in signalling upcoming crisis. In this regard, utilization of Phillips Curve and Okun's law might be useful tool as these empirical relations represent interactions of real and nominal aspects of the economy. Therefore, we initially check if structural breaks or behavioural changes in these interactions are leading or lagging indicators for the crisis.

Fourth, existing EWS models have shortcomings in terms of accounting contagiousness thoroughly. Majority of studies use single proxy of national stock equity market in order to account contagiousness through speculations and

expectations in the market. However, contagiousness coming from global external shocks and country-specific shocks are often ignored.

In this respect, this study aims to improve existing literature in several patterns. The study primarily aims to establish more generalized EWS model that accounts both short- and long-run impacts of leading indicators on crisis using Distributed Lag Logit estimation methodology. Besides, it also elaborates contagiousness factor seriously by capturing its effect through three dimensions: (1) It uses speculations and expectations in the market in order to proxy speculative contagion effects; (2) It uses reciprocal trade links and trade interconnectedness of countries in order to reflect country-specific shocks; and (3) It uses world crude oil price index in order to fix external/global shocks.

Moreover, the study also attempts to incorporate real and nominal variables in EWS model. It utilizes empirically proven macroeconomic relations such as Phillips curve and Okun's law in building the EWS model crediting that these empirical relations might be early signalling indicators of upcoming economic imbalances due to three reasons.

First, these empirical relations show aforementioned interactions between real and nominal aspects of the economy. So, nonlinearities or behavioural changes in their dynamics might motivate economic imbalances.

Second, effects of a crisis might produce lasting consequences in macroeconomic relationship with regards to inflation, unemployment, and output. In this respect, incorporating these relationships into the EWS model helps to account often neglected long-run dynamics within the economy.

Third, majority of EWS studies uses inflation straight-forwardly in their models as a leading indicator, while they neglect unemployment variable arguing that it is a lagging indicator for crises. We take this argument seriously by examining Phillips Curve and Okun's Law during tranquil and recessionary periods. On one hand, we show that inflation behave more forward-looking during tranquil periods, while it behaves less forward-looking during recessionary periods. Thus, this behavioural change might be used as a leading indicator for crises. On the other hand, we show that relationship between real output and unemployment is fairly valid under Okun's Law during both tranquil and recessionary periods; however we

observe that Okun's coefficient shrinks during recessionary periods. We also document that Okun's law subjected to cross-section and time variations. Moreover, we demonstrate strong bidirectional causality between these two real variables; thus, unemployment can also be used as a leading indicator for crises. This may yield valuable information that would help to improve robustness of the EWS without leaving a bias.

Problems in theoretical and empirical literature

The existing EWS literature has several rooms for further improvements. First, it mainly covers fiscal deficit problems, currency crashes, and banking crises (Krugman, 1979; Bilson, 1979; Obstfeld, 1994, 1996, 1997; Kaminsky et al, 1998; Kaminsky and Reinhart, 1999), while it neglects other types of imbalances such as macroeconomic crises, speculative bubbles and crashes, international financial crises, and wider economic crises. As the focus of existing literature is limited with specific types of crises, the definition of the "*crisis*" also varies across studies without offering a wide consensus. The most common way of defining "*crisis*" is self-built indexes that consider volatility and vulnerability of indicators by converting them into binary signals; the signal is issued when a given indicator exceeds (or drops below) the critical threshold. This threshold level is determined by deviation multiplier of index that often ranges between 1.5 and 3.0 in current EWS literature¹.

Second, selecting appropriate indicators for EWS models is also challenging issue. Many studies in the literature tend to choose most known financial, banking, and economic indicators straight-forwardly without determining whether they are lagging or leading indicators for the crisis. There is a wide consensus in the literature that producer's pressure, inflationary pressure, fiscal and governmental budget pressure, financial liquidity and banking reserve pressure, banking credit bubble pressure, as well as contagiousness are leading indicators for the recessions. However, the extant literature uses inflation straight-forward as leading indicator for crisis without investigating whether it is a lagging or leading indicator. The first chapter of this study shows that inflation behaves differently during tranquil and recessionary periods under Phillips Curve framework. It reveals that agents in the market tend to behave more forward-looking during tranquil periods, while they

¹ Eichengree at al (1995, 1996) uses deviation multiplier of 1.5, while Bussiere and Fratzscher (2002) and Kaminsky et al (1998) prefer 2.0 and 3.0 respectively.

become more backward-looking during recessionary periods. It implies that inflation is a leading indicator of crisis during tranquil periods, while it turns to a lagging indicator during recessions. In other words, inflation might be a result of the crisis as well as it also might be a cause for the crisis. In this regard, this behavioural change in dynamics of inflation provides us valuable information to be used in our EWS model as early signalling indicator.

Moreover, vast body of exiting literature also neglects unemployment arguing that it is a lagging indicator for crisis. In second chapter of this study, we show that there is a strong bidirectional relationship between real output and unemployment under Okun's Law framework. It indicates that unemployment can also be used as a leading indicator for crises, and its negligence might bring bias on estimates of EWS model. Additionally, the study also observes few changes in Okun's relationship during recessionary periods. Comparing to the tranquil times, the Okun's coefficient shrinks by 10%, while its standard error increases two-fold. Thus, nonlinearities and structural changes in Okun's relationship might be also used as a leading indicator for crisis.

Third, majority of EWS literature partly incorporates contagiousness of the crisis in to the EWS model by bounding it with just stock equity markets. However, Masson (1998) shows that crises might spillover through three different channels: (1) A common external shock such as rise in world crude oil prices, fluctuations in LIBOR and the US interest rates, appreciation of the US dollar, British Pound, Euro or Gold prices might emerge a significant contagiousness; (2) The crises in one country might spillover to other country due to tight trade interconnectedness between these two countries; (3) speculations or expectations in one country might cause shifts in investors (market) sentiments in other countries due to a bandwagon (herding) effect in the market where individual follows other individuals' actions in their decision-making. The problem of the exiting literature is that it often accounts stock equity markets in order to proxy the third of form of contagiousness which is speculation and expectations, while it neglects other two forms of contagiousness.

Fourth, the choice of an appropriate model is another problem in a vast body of existing literature. Although KLR's signalling approach and probit/logit techniques are widely used, few other methodologies are also utilized in developing EWS such as OLS approach by Sachs et al (1996), Bussiere and Mulder (2000), and Frankel

and Saravelos (2012); Artificial neural network by Nag and Mitra (1999), Franck and Schmied (2003), Fioramanti (2008), and Sarlin and Marghescu (2011); Fisher's linear discriminant analysis by Burkart and Coudert (2002); Markov switching approach by Abiad (2003); Binary classification trees method by Duttagupta and Cashin (2011); Random forest technique by Alessi and Detken (2011) that bootstraps and aggregates a multitude of decision trees; Multiple Indicator Multiple Cause (MIMIC) model by Rose and Spiegel (2012); Machine learning methods (k-Nearest Neighbors, Extreme Learning Machines, Support Vector Machines) by Holopainen and Sarlin (2016); and Dynamic binary probit model by Kauppi and Saikkonen (2008), Bismans and Majetti (2013), Candelon et al. (2014), and Antunes et al (2016). However, all of them fail to anticipate the Great Recession of 2008-2009 which triggered many studies attempt to develop more robust EWS (Rose and Spiegel, 2012; Frankel and Saravelos, 2012; Bismans and Majetti, 2013; Candelon et al, 2014; Antunes et al, 2016; Holopainen and Sarlin, 2016). For instance, Holopainen and Sarlin (2016) conduct cross-validate and recursive horse race of conventional statistical (OLS, Logit/Probit, Discriminant Analysis/Quadratic Discriminant Analysis, Signalling Approach, Trees approach, Random Forest approach) and more recent machine learning methods (k-Nearest Neighbours, Extreme Learning Machines, Support Vector Machines). He finds that recent machine learning approaches outperform conventional statistical methods.

On the other hand, majority of above mentioned techniques do not incorporate dynamic lags of indicators. According to Bismans and Majetti (2013), Candelon et al (2014), and Antunes et al (2016) adding dynamic components to the EWS substantially improves its predictability and accuracy. Thus, we believe signalling indicators in the model should be allowed for dynamics lags.

The last problem in the EWS literature is optimal threshold selection methodology. Many studies in the literature use signalling approach pioneered by Kaminsky et al (1998) and Kaminsky and Reinhart (1999) (hereinafter KLR). This KLR approach utilizes Noise-to-Signal ratio as a threshold selection technique in order to gauge signals. However, it has two shortcomings. The first shortfall of this technique is that it fails to distinguish consequences of "*false alarms*" (type II error) and "*missed alarms*" (type I error). In other words, there will a trade-off between two sides: (1) Cost of taking pre-emptive action in response to a false alarm for non-

crisis events (type II error); (2) Cost of missed alarm for upcoming actual crisis (type I error). In this respect, it is argued that missing alarms for actual crisis events might be extremely costly comparing to the cost of taking preventive actions as a result of false alarms for non-crisis events (Demirguc-Kunt and Detragiache, 2000). For this reason, we regard noise-to-signal ratio as risky threshold technique.

The second shortfall of the KLR's noise-to-signal technique is that when probability of type II error is zero, the ratio will derive 0 notwithstanding to probability of type I error (there will be no difference whether it is 0.01 or 0.99). In other words, the noise-to-signal technique prefers to undertake more missed signal rates for the sake of nulling false signal rate. Thus, this technique does not primarily aim to predict and prevent potential crisis, but aims to minimize false alarms for non-crisis events. This is not in line with objectives of EWS models. A proper threshold selection technique should help EWS model to minimize missed crisis events (or maximize predicted crisis events).

Contribution of the study

The contribution of the study is several folds. First, it offers more generalized early crisis warning framework that accounts for various types of financial, economic, banking, and currency crises by using a set of real and nominal macroeconomic indicators. Second, it considers the largest sample size for EWS by covering 41 countries from developed, emerging, and frontier markets. While the existing literature mainly studies few developed countries such as the US, the UK, and the EU. Third, it employs more robust methodology of Distributed Lag Logit technique (DLL) under Almon's (1965) approach in multivariate framework. This specific methodology helps us to capture cumulative and delayed effects of all indicators accurately. In other words, it integrates often neglected long-run impacts of leading indicators on crisis. Crediting to Bismans and Majetti (2013), Candelon et al (2014), and Antunes et al (2016), the study considers only lags of indicators in the EWS model. Although the lags are bounded with maximum -6 periods (past 6 quarters), the study allows them to be dynamic. Put differently, the system will automatically determine lag length of each indicator separately using Schwarz information criterion (SIC).

Fourth, the study takes into account most prominent leading indicators alongside with few new indicators that have not been used before. The selection of appropriate leading indicators of economic and financial turmoil also plays a crucial role in modelling EWS. However, the selection mainly depends on how the term “*crisis*” is defined. Unlike the literature that often defines the crisis using self-built indexes, the study considers it as shrinks in real output straight-forwardly due to two reasons: (1) The real output is one of the primary indicators used to gauge the health of a country's economy as it summarizes aggregated demand and supply. Any shrinkage in real output might negatively affect whole economy by generating dramatic consequences. Being a real variable, it attracts wide concern in both macroeconomics and finance; (2) The study aims to build more generalized EWS and, for the sake of this aim, shrinkages in real output will be an ideal definition of the crisis.

Following existing literature, the study elaborates a sizeable set of leading indicators that might add turmoil pressure on countries' economic and financial activities and eventually generate an impact on real output. In this respect, it considers fluctuations in Purchasing Managers' Index (*PMI*), Construction production index (*CONPI*), and Industrial Production Index (*IPI*) as core leading indicators of the crises. However, due to high correlations between them, the study makes a Composite Leading Indicator (*CLI*) index as below.

$$CLI_{at} = \frac{1}{\sigma_{PMI}} PMI_{at} + \frac{1}{\sigma_{CONPI}} CONPI_{at} + \frac{1}{\sigma_{IPI}} IPI_{at} \quad (1.01)$$

where the weights of the components are assigned on the basis to equalize their volatility in order to prevent one dominating the *CLI*. In third chapter, the study shows that fluctuations of this *CLI* index add significant contribution into EWS model by providing early signals of turning points in business cycles.

Besides, the study takes into account Inflationary (*CPI*) and Unemployment (*UD*) pressures as they might have leading impacts on the real output due to empirically proven macroeconomic relationships of the Phillips and Okun's respectively. Plus, the study also considers structural changes of these relationships as leading indicator of the crisis, because in further chapters, we show that notional behaviour of the Phillips curve and Okun's law changes during recessionary period.

In this respect, we reveal that empirical Phillips relationship weakens and inflation tends to behave less forward-looking (more backward-looking) during recessionary periods, whereas it tends to be more forward-looking (less backward-looking) during tranquil periods. We believe it happens due to agents get limited or blurred information regarding future expectations during recessionary periods, therefore, they start to rely on backward-looking inflation. This is a significant observation that might be used as an early signalling indicator in predicting upcoming crisis. However, using inflation straight-forwardly in EWS model might not clearly reflect this observation. Instead, expected inflation will be a proper proxy that reflects both inflationary pressure and behavioural changes in the inflation dynamics. Therefore, we use expected inflation in our EWS model instead of current inflation that has been widely used in the literature. In addition, it is worth noting that this also puts lagging-leading debates of inflation off. Because, the expected inflation is doubtlessly leading indicator for recession events.

On the other hand, this study regards unemployment rate as a leading indicator for crisis, even though many studies consider unemployment rate as lagging indicator as arguing that it follows output with a delay. Because, in second chapter of this study, we show strong bidirectional causality between real output and unemployment rate fluctuations. Therefore, we can use unemployment as a leading indicator in our EWS model without a doubt. Notably, it is important to consider both inflationary and unemployment pressures simultaneously in the EWS model alongside with structural changes in their dynamics as we believe it significantly improves predictability of our EWS. In this regard, to avoid collinearity problem due to potential high correlation between inflation and unemployment indicators, we transformed unemployment rate into binary form (UD) as below.

$$UD_{at} = \begin{cases} 1, & |U_{c,at}| \geq \left| \frac{3}{2} \sigma_{U_c} \right| \text{ or } STR > 0 \\ 0, & otherwise \end{cases} \quad (1.02)$$

where U_c is fluctuation of unemployment rate around its long-run steady equilibrium ($NAIRU$); and STR accounts structural and behavioural changes in the Okun's relationships.

Additionally, the study utilize proxies of Balance of payment ($BOPY$) pressure for fiscal deficits, Government Balance ($GOVY$) pressure for budget

deficits, Real Effective Exchange rate (*REER*) pressure for currency crashes, Liquidity and Foreign Reserves (*RESMON*) pressure and Banking Credit (*CRDY*) bubble for banking crises, World Oil Prices (*OIL*) for external shocks or spillovers, Contagion Effect (*CON*) for trade interconnectedness spillovers, and Speculations and Expectations (*SPEX*) for market speculations of upcoming crises. Unlike existing literature, it disregards interest rate, broad money supply growth, export and imports, and stock market indexes as leading indicator due to various reasons. We believe interest rate is a lagging indicator for crisis as it is tuned by regulatory authorities in response to disturbances in financial flows. We omit broad money supply growth and exports and imports indicators; because their impacts would be already absorbed by inflation rate and balance of payment variables.

On the other hand, we believe that national stock market index is, probably, the most appropriate leading indicator for the market expectation. Although it often has been regarded as a good proxy for many types of crises, we could not to include this indicator due to data limitations for 41 sampled countries for the periods of 1980-2016. For the sake of using stock equity market index, we would have to halve either sample size or analysis period. Thus, we strengthen our EWS model by three alternative indicators crediting Masson (1998) three-dimensional contagiousness.

First, we proxy crisis speculations and expectations (*SPEX*) in the market using Google's data for search trends² and scientific research publications³. For search trends, we gather data for terms such as "*economic crisis*", "*financial crisis*", "*economic slowdown*", "*economic recession*", and "*asset bubble*". For scientific researches, we scan scholarly publications that subject crisis topics. In this respect, we believe that *SPEX* will account shifts in investors' (market) sentiment and expectations significantly. Second, we use fluctuations in world crude oil price index in order to fix spillovers caused by global or common external shocks. Third, considering reciprocal trade links and interdependence of countries, we introduce a brand-new contagion factor (*CON*) that would ideally reflect country-specific spillovers. In further chapters, we show derivation of this variable and how accurately it measures degree of contagion effects between countries. We believe

² <https://trends.google.com/trends/explore?date=all&q=economic%20crisis>

³ https://scholar.google.com/scholar?q=recession&hl=en&as_sdt=0%2C5&as_ylo=1980&as_yhi=1981

that *SPEX* and *CON* will have early signalling power comparing to stock market indexes as fluctuations in these factors will show up in equity market indexes with delay.

Another significant contribution of this study is that it offers two brand-new techniques for optimal threshold selection in the EWS analysis, namely, False-to-True ratio (ϕ) and Risk Aversion rate (Ω). Above (at section 1.2) we have already pointed out problems in threshold selection methods in current literature, especially weaknesses of KLR Noise-to-Signal ratio. In this respect, we show that our two threshold selection techniques overcome these problems and help to evaluate predictive power of the DLL EWS model more accurately. Unlike KLR's Noise-to-Signal ratio, these technique offer fair trade-off between consequences of "*false alarms*" (type II error) and "*missed alarms*" (type I error). The False-to-True ratio (ϕ) delivers optimal threshold level by minimizing total error of EWS model disregarding importance of type I and type II errors. Thus, its main aim is to find threshold level where EWS model works with minimum prediction error. On the other hand, the Risk Aversion rate (Ω) can be regarded as less-risky optimal threshold. This ratio aims to derive minimum total error of EWS model giving emphasizes to type I errors (missed alarms). Put differently, it might tolerate for few more false alarms (type II errors) for the sake of minimizing type I errors (missed alarms). Notably, it would have very similar characteristics with Demirguc-Kunt and Detragiache (2000)'s Loss Function (θ) if the policy-maker gives more weight on type I error. Unlike this Loss Function (θ), Risk Aversion rate (Ω) does not require ex-ante input weights; instead it automatically finds optimal trade-off between type II and overall EWS errors.

In chapter three, we present comparatively evaluate prediction power our generalized DLL EWS model in 41 different countries with KLR's Noise-to-Signal (λ), Demirguc-Kunt and Detragiache (2000)'s Loss Function (θ), and with our two new threshold selection techniques. Hence, we show that Loss Function, Risk Aversion rate, and False-to-True ratio find the same cut-off probability level in nearly half of the sampled countries, while KLR's Noise-to-Signal sets threshold at "*crazy*" levels.

To summarize, this study adds significant contributions to the relevant EWS literature. We summarize its contributions thoroughly in the last general conclusion chapter alongside with limitations and recommendations for the future researches. It is worth noting that apart the main focus of EWS, the study also offers significant

empirical evidences for stability and validity of the Phillips and Okun's relationships for 41 countries separately accounting two states of economy: Tranquil periods, when economic fundamentals are largely sound and sustainable; and Recessionary periods, when economic variables go through an adjustment process before reaching a more sustainable level or growth path. We scrutinize how these empirical relationships behave during tranquil and recessionary periods, and use these observations (information) in our EWS model. Notably, we add another significant contribution to New Keynesian Phillips Curve literature by augmenting the proxy of marginal costs that is widely used to reflect fluctuations in unemployment. Simultaneously with unit labour costs, we also use unit non-labour costs in our hybrid New Keynesian Phillips Curve model. It accounts external costs caused due to real effective exchange rate and international trade balance. We provide evidence for overall significance of unit non-labour costs, and this augmented New Keynesian Phillips Curve model seems to be working better in capturing more variations in current inflation. For robustness, we also incorporate unit labour and non-labour costs into one total unit cost factor, and we show that this variable also improves the model significantly. Thus, we opt either to use unified total unit cost factor or to use both unit labour cost and unit non-labour cost variable simultaneously in the model rather using only unit labour cost variable.

Contribution of the study

The thesis is structured in the following order. Next chapter investigates dynamics of inflation under Traditional, New Classical, and New Keynesian Phillips Curve frameworks focusing on the validity, the stability, and the behaviour of empirically proven inflation-unemployment relationship during tranquil and recessionary periods over 41 different countries from developed, emerging, and frontier markets. Using OLS and Generalized Method of Moments (*GMM*) estimation techniques, it provides evidences from country-specific analysis paying special focus on whether the Phillips relation behaves notionally during both tranquil and recessionary periods or not. For robustness, it also considers cross-sectional panel estimation to obtain clear Phillips relationship by fixing country-specific effects. The study lets the data to decide whether Traditional, New Classical, or hybrid New Keynesian Phillips Curve best describes the dynamics of inflation, and it selects the best specification to check how the model behaves during recessionary periods.

Second chapter examines the dynamics of unemployment under the Okun's Law over 55 countries with quarterly data. It pays special focus on tranquil and recessionary periods in order to find out whether the law is stable during these two states of economy. First, it uses basic OLS technique to replicate original gap-version of Okun's (1962) model with recent data. However, gap-version and differencing methodology might wipe out potential long-run interaction between unemployment and real output. With this reason, it also utilizes ARDL bound testing cointegration analysis in order to measure short- and long-run Okun's coefficient during tranquil and recessionary periods. In ARDL analysis, the study estimates short-run and long-run Okun's coefficients for each country alongside with their error-correction adjustment speeds. For robustness, it also panellizes data for a more general outlook and comparatively provides estimation data for pooled, fixed effects, and random effects specifications under Stepwise OLS, Dynamics OLS, as well as panel ARDL (Pooled Mean Group) frameworks. The study also allows lagged values of explanatory variable (real output) in the model and test overall significance with Stepwise OLS (*SOLS*) and dynamic OLS (*DOLS*) methodologies comparatively giving estimation outcomes of pooled, cross-section fixed (*FE*) effects, and random effects (*RE*) specifications. In addition, it carries causality and impulse-response analyses in order to hypothesize three statements: (1) direction of impact in order to determine which one of unemployment and output is lagged and leading indicator; (2) magnitude of impact to gauge its strength; and (3) impact duration to assess the time lag between unemployment and real output during tranquil and recessionary periods separately.

Third chapter is the core chapter that establishes more generalized EWS which accounts various types of economic and financial crises and improves existing models in several ways. Using large sample size, it incorporates nominal and real variables in the model considering both short- and long-run dynamics. It strengthens the model by capturing contagiousness through three dimensions: (1) Speculations and Expectations in the market (internal shocks); (2) Reciprocal trade interconnectedness of countries for country-specific spillovers (external country-specific shocks); and (3) Index of world crude oil price for global spillovers (external global shocks). The study also takes structural and behavioural changes in dynamics of macroeconomics which is often ignored in vast body of extant literature.

Moreover, the study provides evidence for high predictive performance of EWS in majority of sampled countries basing it on Distributed Lag Logit technique (DLL) under Almon's (1965) approach in multivariate framework. It shows that this specific methodology is useful to capture cumulative and delayed effects of all indicators appropriately by allowing dynamic lag length. Thus, the prediction time lag for each leading indicator varies across sampled countries. Lastly, the study introduces two brand-new optimal threshold selection techniques that ameliorate existing ones significantly. It comparatively shows that these two new threshold selection techniques help to evaluate prediction power of EWS more accurately by minimizing overall incorrectness and maximizing in-sample performance of the model.

At the end, the conclusion chapter provides concluding remarks of the thesis highlighting key findings and original contributions, as well as limitation and recommendation for the future researches. Plus, few appendix tables with brief descriptions are also attached at the very end.



CHAPTER ONE

DYNAMICS OF INFLATION - PHILLIPS CURVE DURING TRANQUIL AND RECESSIONARY PERIODS

1.1. Introduction

The literature of early crisis warning systems (EWS) frequently uses inflation as a signalling indicator in predicting upcoming financial and economic imbalances. However, related literature largely neglects to provide evidence whether inflation is lagging or leading indicator of crises. Moreover, it also ignores structural and behavioural changes in dynamics of inflation during recessionary periods. In common practice, the dynamics of inflation is examined under Phillips (1958) curve framework.

Since its discovery, the Phillips curve, that shows the negative relationship between inflation and unemployment, has played an important role in macroeconomic modelling. In turn, we also believe that this empirical relationship might yield valuable indications to be used in our EWS model due to the fact that the Phillips curve not only represents dynamics of inflation, but also interactions of real and nominal aspects of the economy as well as. Even though empirical literature of the Phillips curve is sizeable enough, there is still no wide consensus on its validity and stability. The literature shows that the Phillips relationship is fragile and varies across countries and time periods, a statistical relationship that appears strong one decade (country) may be weak the next (another). This variability might have some grounds for idiosyncrasy of a country and its economic environment.

In this context, this chapter examines dynamics of inflation focusing on Phillips Curve (PC) framework in order to account whether it comprises any nonlinearities and behavioural changes during different periods and countries. Particularly, we focus on if Phillips relation survives (behaves notionally) during both tranquil and recessionary periods under its three different versions: (1) Traditional PC; (2) Expectation-Augmented PC (EAPC); and (3) Hybrid New Keynesian PC (NKPC). We let the data to decide which of these three versions describes the dynamics of inflation best, and we select the best specification to gauge structural and behavioural changes of inflation during tranquil and recessionary periods.

Moreover, we show how the empirical trade-off between inflation and unemployment varies across a large set of countries and how agents in the market tend to behave differently during tranquil and recessionary periods. This behavioural shift might be a useful tool to improve robustness of the EWS without leaving a bias. In other words, it reveals that inflation might turn to both leading and lagging indicator during two different states of economy. Thus, using inflation straightforwardly in the EWS model might bring bias to estimates. Instead, we argue that expected inflation should be used in EWS model as it is purely leading indicator.

Besides, this chapter has two additional contributions to the Phillips Curve literature. First, it provides new evidences for country-specific Phillips Curve application with up-to-date data of 1980-2016 covering 41 countries from majority of developed countries as well as often neglected developing countries. In this context, we offer new observations about overall validity and stability of the Phillips relationship across sampled countries. Furthermore, we run panel estimation to show clear Phillips relation fixing country-specific effects for robustness. Second, this chapter augments the latest version of Phillips curve (a hybrid New Keynesian Phillips Curve) by incorporating unit non-labour cost in proxying the marginal costs. We show that the augmented hybrid NKPC yields better estimation results comparing to old version and it is more stable across different time periods.

The chapter is structured in following order. The next section briefly reviews the Phillips Curve (PC) model starting from the originally observed correlation between nominal wages and unemployment rate, passing through its augmented version that considers inflation expectations and supply shocks, and ending up with recent New-Keynesian framework. Section 1.3 covers empirical literature. Section 1.4 introduces the methodology and data used to test validity of traditional PC, Expectation-Augmented PC (EAPC), and hybrid form of New Keynesian PC (NKPC) for 41 countries over 1980-2016 periods. The best model that describes the dynamics of inflations is determined and the chosen model is employed to determine how the model behaves during abnormal (recessionary) economic periods. Section 1.5 discusses key findings and the final section concludes.

1.2. Theoretical literature review

The dynamics of inflation are mainly motivated by central banks' monetary policy regimes which require monetary authorities to have a clear understanding of inflation processes in their economy. Theoretically, there are four monetary policy regimes: monetary targeting, exchange rate targeting, inflation targeting, and monetary policy without establishing any "nominal anchor". It is widely observed that majority of advanced economies alongside with several, though not all, emerging market countries have already adopted inflation targeting regimes, whereas majority of developing countries still use monetary targeting regimes (see table 1.01).

Table 1.01. Monetary Regimes and Policy Frameworks of Countries

Regime	Exchange Rate Targeting	Monetary Targeting	Inflation Targeting	Other/No Anchor
Fixed Peg	Bahrain, Cameroon, Cote d'Ivoire, Denmark, Iraq, Jordan, Kuwait, Lebanon, FYR Macedonia, Mali, Morocco, Namibia, Nepal, Qatar, Saudi Arabia, Senegal, Turkmenistan, UAE, Venezuela	Bangladesh, Bolivia, China, DR Congo, Guinea, Malawi, Nigeria, Sri Lanka, Tajikistan, Tanzania, Yemen		Angola, Azerbaijan, Solomon Islands
Crawl-like Peg	Bosnia and Herzegovina, Botswana, Bulgaria, Cambodia, Estonia, Honduras, Iran, Jamaica, Latvia, Liberia, Lithuania, Singapore, Slovakia, Syria, Vietnam	Algeria, Belarus, Burundi, Ethiopia, Gambia, Myanmar, Rwanda, Suriname, Uzbekistan	Argentina, Armenia, Dominican Rep., Guatemala	Costa Rica, Croatia, Egypt, Haiti, Kyrgyzstan, Malaysia, Pakistan, Tunisia.
Floating Peg		Afghanistan, Germany, France, Kenya, Madagascar, Mozambique, Papua New Guinea, Seychelles, Sierra Leone, Switzerland, Taiwan, Ukraine, Uruguay	Albania, Australia, Brazil, Canada, Chile, Colombia, Czech Republic, Georgia, Ghana, Hungary, India, Indonesia, Iceland, Japan, Kazakhstan, Mexico, Moldova, New Zealand, Norway, Paraguay, Peru, Philippines, Poland, Romania, Russian Federation, Serbia, South Africa, South Korea, Sweden, Thailand, Turkey, United Kingdom, United States	Austria, Belgium, Greece, Finland, Ireland, Israel, Italy, Luxembourg, Malta, Mongolia, Netherlands, Portugal, Slovenia, Spain.

Source: IMF Annual Reports 2017⁴

The effectiveness of these adopted monetary policies largely depends on public confidence and expectations of economic agents. Any misleading information about inflation processes might alter this confidence and expectations causing low effectiveness of monetary policy, which may adversely affect the level of uncertainty,

⁴ Annual 2017 Report on Exchange Arrangements and Exchange Restrictions. <https://www.imf.org/en/Publications>

country's risk premium and the level of output in the economy. In this respect, expectations of economic agents have a core role in determining dynamics of inflation. The Phillips Curve is a common practice that incorporates these expectations in an empirical model which aims to examine dynamics of inflation.

Thus, prior to investigation of empirical application of the Phillips curve, it is worth to briefly review its theoretical foundation and we endeavour to follow through its evolution over time. It was William Phillips (1958) who first-time proposed a model of trade-off between nominal price levels and real unemployment rate that has shifted the mainstream of macroeconomics. Phillips in his study observes an inverse correlation: when unemployment goes up, wages start to decrease slowly, and when unemployment drops to low levels, wages tend to rise rapidly. He believes that it happens due to looseness of labour market during high unemployment rates, and tighter when rates are lower. The model in logarithmic form is as:

$$\log(Y + a) = \log(b) + c * \log(X) + \varepsilon_t \quad (1.01)$$

where “*b*” is an intercept, and “*a*” is a constant added to inflation rate to eliminate errors emerged from negative values in logarithm.

Since Phillips (1958), a sizeable supporting literature has been written on this topic. For instance, Samuelson and Solow (1960) replicate Phillip's study for United States assuming that prices are set by a certain mark-up, and find more consistent results. Although Phillips Curve (PC) was widely accepted and used by policy makers who wanted to benefit from the empirical trade-off in early 1960s, it has received a lot of criticism. Indeed, these comments helped the originally portrayed model to evolve over time reflecting the theoretical developments of the last half-century. For instance, Akerlof (2007) notes that equilibrium in the labour market is determined by the real wage, so the PC does not hold as it accounts only nominal wages. Besides, Phelps (1967) and Friedman (1968) also criticize that traditional Phillips curve fails to account expectations accurately. They believe that structural and frictional unemployment is never-ending, so it is the “natural rate” of unemployment at which inflation rate remains stable (latter it became known as non-accelerating inflation rate of unemployment, NAIRU). If government persistently generates inflationary policies to reduce unemployment below this natural rate, there will be a short-run trade-off (Samuelson and Solow, 1960) which is today called as

"Expectation-Augmented Phillips Curve" (EAPC). But after a time, individuals start to show evidence of adaptive expectations (backward-looking) by adjusting their current expectations based on past years inflation. Thus, in turn, it reverts unemployment rate back to its natural level. Therefore, the curve is vertical in long-run, thus unemployment is irrelevant to the level of inflation.

A general equation for EAPC can be expressed as below.

$$\pi_t = \pi_t^e + (\mu + z) - \alpha(u_t - u^*) + \varepsilon_t \quad (1.02)$$

where π_t is an inflation at time t ; π_t^e is expected of future inflation at time t ; μ is a mark-up factor that is used in determination of market prices; z is a shift factor of labour market; u_t and u^* are current (at time t) and NAIRU unemployment rates; and α is a parameter of unemployment. The original Phillip's equation was a special case of Eq. (1.02) where π_t^e was zero. In case of backward-looking EAPC, π_t^e is equal to $\zeta\pi_{t-1}$ since agents are backward-looking. So, equation becomes as $\Delta\pi_t = \frac{\mu+z}{1-\zeta} - \left(\frac{\alpha}{1-\zeta}\right)(u_t - u^*)$. This formulation is often regarded as "traditional" or "accelerationist" Phillips curve because it implies that one can only keep unemployment low at the expense of an increasing inflation rate, and thus an accelerating price level. The key idea is that unemployment has effect on change in rate of inflation, but not on level of the rate of inflation as it was in original case.

Later, Lucas (1976) posits a critique ignoring the short-run trade-off of PC arguing that agents have *rational expectation (forward-looking)* rather than adaptive. Therefore, they account not only recent information, but all available information, and adjust their expectation instantaneously, so that short-run trade-off between inflation and unemployment does not occur. Here, π_t^e is not equal to π_{t-1} anymore, instead, it equates to $E_t(\pi_{t+1})$. This model today is known as "New Classical Phillips Curve" (NCPC) or pure forward-looking EAPC.

New Keynesian perspective has brought another understanding in Phillips curve (dynamics of inflation) relying on stickiness of wages and prices which has impact on unemployment and strength of monetary policy. Roberts (1995) elaborates the Phillips curve under nominal rigidity arguing that nominal prices cannot always adjust to clear markets. Then how prices are set? Well, he improved the curve by introducing a time-contingent price setting frameworks (staggered

contracts) of Taylor (1979, 1980), Rotemberg (1982), and Calvo (1983). This is often called as "*New Keynesian Phillips Curve*" (NKPC). But in this particular type of Phillips Curve, the actual and expected inflation related with unemployment rate indirectly through labour costs, especially real marginal costs (labour share of income). In other words, Phillips' empirical relationship has emerged due to traditional fluctuation of labour costs with unemployment rates. In appendix section A1 section, we show that inflationary pressure in the economy occurs due to output gaps which are originated by labour markets in a business cycle. In this respect, NKPC uses unit labour costs as proxy marginal labour cost.

Thus, a baseline NKPC equation can be expressed as below.

$$\pi_t = \gamma_f E_t \pi_{t+1} + \lambda mc_t + \varepsilon_t \quad (1.03)$$

where γ_f is a structural parameter of forward-looking inflation; λ is responsiveness of inflation to marginal cost gap mc_t ; and ε_t is a random variable stands to capture errors. Fuhrer and Moore (1995) suggest using output gap as a proxy for mc , however, Gali and Gertler (1999) and Mankiw and Reis (2002) observe that NKPC fails to show a good fit with output gap. The difficulty arises in observing and measuring mc with real world data. Hence, Gali and Gertler (1999) show that mc can be derived by a ratio of real wage rate to marginal product of labour in a simple Cobb-Douglas production function. Therefore, they suggest using the real unit labour cost as a proxy for mc in a closed economy. And in case of open economy, exchange rate, import price, or oil price should be inserted into the model in order to capture external effects of real marginal costs.

Later, Gali and Gertler (1999) introduce a hybrid form of this basic NKPC where a fraction ω of firms behave like backward-looking while the remaining $1-\omega$ firms behave as forward-looking in price setting. So, the firms set their price on the basis of following equations.

$$p_t^f = \mu + (1 - \beta\theta) + \sum_{i=0}^{\infty} (\beta\theta)^i E_t \{mc_{t+i}^n\} \quad (1.04)$$

$$p_t^b = p_{t-1}^* + \pi_{t-1} \quad (1.05)$$

where p_t^b and p_t^f are new prices set by ω (backward-looking fraction) and $(1-\omega)$ (forward-looking fraction) of firms respectively; μ is a mark-up factor; β is subjective discount factor; and θ fraction of firms keeps their prices unchanged.

So, index of new prices will be $p_t^* = \omega p_t^b + (1 - \omega)p_t^f$, and aggregate price level in the economy will be $p_t = \theta p_{t-1} + (1 - \theta)p_t^*$ where θ measures the degree of price stickiness or frequency of price adjustments.

So, we re-write Eq.(2.03) in a hybrid form as below.

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t \pi_{t+1} + \lambda mc_t + \varepsilon_t \quad (1.06)$$

where $\lambda = (1-\omega)(1-\theta)(1-\beta)\phi^{-1}$; $\gamma_f = \beta\theta\phi^{-1}$; and $\gamma_b = \omega\phi^{-1}$; with $\phi \equiv \theta + \omega[1 - \theta(1-\beta)]$. Here, γ_f and γ_b are forward- and backward-looking components of inflation. The ω shows degree of backwardness in price; and β is a discount factor. The basic NKPC occurs when $\omega=0$ (thus $\gamma_b=0$), and the hybrid Phillips Curve occurs when $\beta=1$ (thus $\gamma_f + \gamma_b = 1$).

On the other hand, developments in Phillips Curve have never ceased. Akerlof et al. (2000) propose a "near-rational" behaviour towards inflation, i.e. market agents ignore unimportant factors in order to concentrate on important factors. They argue that *"when inflation is low, it may be at most a marginal factor in wage and price decisions, and decision-makers may ignore it entirely"*. Their empirical test reveals a moderate interaction between low inflation and unemployment. They argue that decreasing inflation from 2% to 0% will lead unemployment to grow permanently by 1.5%. Employees often don't aware of real wage cuts as these cuts are hidden within inflation. But they always aware of nominal wage cuts, and really hate these visible cuts. Therefore, employees likely to accept a 2% nominal wage increase while inflation rises by 3% rather than a wage cut of 1% when inflation is zero.

Later, Mankiw and Reis (2002) propose two new approaches in Phillips Curve: (a) *"Sticky Information Phillips Curve"* (SIPC) where firms acquire information infrequently which results in sticky-information; (b) *"State-dependent Sticky Price Phillips Curve"* (SPPC) where firms face menu costs to change prices which leads sticky-prices. They, empirically, compare these two models and find that SIPC gets better fit.

On the other hand, the Great Recession in 2008 has rekindled debate on validity of the accelerationist Phillips relationship once again since the “*stagflation*” (combination of high inflation and high unemployment) in the US in 1970s. For common calibrations of this relationship, the high unemployment rates during the recession should have pushed the inflation rate well below close to zero. Yet in the recent recession unemployment rate in the US rose sharply, but inflation has remained same to its level before 2008. This has led to two puzzles in inflation: (1) The absence of persistent disinflation in the wake of highly negative output gaps during the recession period which is dubbed as “missing deflation” (Stock, 2011; IMF, 2013; Ball and Mazumder, 2019); (2) Unexpectedly low inflation rates during post-recession or moderation period which is called as “missing inflation”. These puzzles have attracted two main explanations. First, Fed and IMF officials (e.g., Bernanke, 2010; IMF, 2013; Watson, 2014; Yellen, 2015; Kiley, 2015; Krugman, 2015; Blanchard, 2016; Mazumder, 2018) assert that inflation expectations have become anchored to Fed's long-run inflation target (2%) due to Fed's strong credibility. Second, Stock (2011) and Gordon (2013) argue that inflation depends not on the aggregate unemployment rate, as in textbook Phillips curves, but rather on the short-term unemployment rate (unemployment less than 27 weeks). They emphasize that short-term unemployment rose less sharply than total unemployment over 2008-2009, and then returned more quickly to pre-recession levels. Notwithstanding these two different explanations, recessions have rendered validity and stability of the Phillips relationship to be questioned.

1.3. Empirical literature review

Although much of recent literature finds that inflation dynamics are forward-looking, and NPKC works as the theory suggests, the remaining fraction of literature documents empirical results that cast a doubt on the validity of Phillips curve. For instance, Fendel et al. (2011) test both traditional and expectation-augmented version of Phillips Curve in G7 countries over October 1989 to December 2007. They observe a significant trade-off between inflation and unemployment throughout all G7 countries, except Italy where traditional Phillips Curve fails to work. However, when they pursue the same analysis with expectation-augmented Phillips Curve they find out that it properly works for all G7 countries where the strongest trade-off appears in Japan and in the US. Rulke (2012) also finds similar trade-off with

expectation-augmented Phillips Curve thorough out six Asian-Pacific countries. He observes that the trade-off magnitude is remarkably larger in Japan and South Korea. On contrary, Mazumder (2014) finds that NKPC fails to explain China's inflation dynamics over the period 1987-2007, whereas the traditional Phillips curve does significantly better.

Russell and Banerjee (2008) study NAIRU Phillips curve under non-stationarity conditions in the series. They observe a positive relationship between inflation and unemployment rate in short run for the United States, so they conclude that the Phillips Curve does not work. Paul (2009) also fails to document the existence of an empirical Phillips curve in India. He states that the relationship is often evasive or absent in less-developed economies. He underlines that liberalization-policy of the early 1990s and supply shocks such as droughts, oil prices were chief reasons behind the absence of Phillips Curve in India. He shows that a short-run Phillips curve works when adjustments for these shocks are taken into account. On the other hand, Ojapinwa and Esan (2013) find a weak Phillips Curve trade-off for Nigeria in short-run, but it disappears in the long-run as inflation and unemployment moves together positively.

Agenor and Bayraktar (2010) study empirical estimations of contracting models of NKPC for eight middle-income countries (Chile, Colombia, Korea, Malaysia, Mexico, Morocco, Tunisia, and Turkey) over 1979-2006 using GMM technique. They elaborate a hybrid NKPC model of Gali and Gertler (1999) with four price specifications where they extend the model by adding more lags and leads in each specification. As a result, their parsimonious (the first three specification) models reveal that backward-looking component of inflation gets larger coefficient than forward-looking one in all sampled countries, except Colombia and South Korea. On contrary, their high-dimension model finds that forward-looking behaviour has relatively larger impact on inflation in Turkey and Mexico. They also document that output gap is key driving force behind the inflation in Columbia and South Korea those appear to be the most forward-looking ones among other countries. And they observe better fit of this model comparing to parsimonious ones, which implies that extended Hybrid NPKC works perfectly throughout the sample.

Abbas and Sgro (2011) investigate inflation dynamics in Australia by testing basic and hybrid NKPC over 1959:Q3-2009:Q2 with OLS, GMM, and 2SLS

methods. They observe that inflation dynamics are mainly forward-looking throughout this period, because the backward-looking component of inflation becomes significant only after 1983, and, moreover, its estimates are (positive but) smaller in magnitude comparing to forward-looking one. Therefore, they conclude that the forward-looking model is consistent and fits better comparing to the hybrid model. And they document a significant evidence for sticky-price in the economy where the length of price adjustment is about 14 months. They also report that NKPC is flatter, but neither the output gap nor marginal cost appears to be statistically significant, therefore, trade-off between unemployment and inflation fails to be valid in Australia.

Equally, Vasicek (2011) also reports that output gap is a better proxy for real marginal cost in Czech Republic and Poland where Hybrid NKPC is valid. However, Tillmann (2009) detects a trade-off between changes in inflation rate and real marginal costs in Euro area only under baseline NPKC pure forward-looking model with Calvo-type contracting schemes. On the other hand, Mazumder (2011) argues that labour income share cannot be a proxy for real marginal cost, because it is countercyclical whereas the proxy should be procyclical on the basis of theory. So, he proposes to use average working hours of employees as proxy which is procyclical.

During Great Recession many economists believed in demise of Phillips Curve as it failed to explain the missing disinflation due to anchored expectations (Stock, 2011; IMF, 2013; Watson, 2014; Yellen, 2015; Kiley, 2015; Krugman, 2015; Blanchard, 2016; Mazumder, 2018; Ball and Mazumder, 2019). However, in a recent paper, Coibion and Gorodnichenko (2015) explain it within the context of Phillips Curve mechanism. They assert that focusing on market expectations might generate misleading outcomes as it was largely "*anchored*" as Bernanke (2010) and many other Fed officials state. Thus, they urge to take into account household expectations which are scaled up during Great Recession in response to sharp increases in oil prices. They believe that it might be a possible explanation for the missing disinflation in that period, and it can be a better proxy for companies' inflation expectations. The households are more responsive to oil prices when they form their future inflation expectations comparing to professional analysts. The survey-based measures of their expectations reflect changes in the price of their

own consumption bundles rather than the overall inflation in the economy. Since gasoline remains as a large portion of consumption of their income, they adjust their position according to the oil price changes. Therefore, the increased household expectations hindered downward adjustment of prices which generated the missing deflation.

Likewise, Ball and Mazumder (2019) document that core inflation since 1985 is well-explained by an expectations-augmented Phillips curve in which expected inflation is measured with professional forecasts and labor market slack is captured by the short-term unemployment rate.

On the other hand, Murphy (2018) argues that short-run response of inflation to the unemployment rate has declined somewhat over time in the US. Therefore, the Phillips curve is relatively flat and in this regard recent “low” inflation statistics are not particularly surprising.

Alternatively, Jorgensen and Lansing (2018) introduce boundedly-rational expectations approach to NKPC to address missing disinflation puzzle that outbreak with Great Recession in 2008. In their model, agents use time-series models, which allow for both permanent and transitory shocks similar to that of Stock and Watson (2007), to forecast inflation and the output gap. They use Kalman filter to gauge weight of current inflation in the agent’s forecast rule and show that Kalman gain for inflation experienced a downward drift during post Great Recession period (2008-2012). This low Kalman gain indicates a low weight of recent inflation in the agent’s forecast rule, which is consistent with the idea of “*well-anchored*” expectations prior and post Great Recession. Thus, they argue that inflation expectations were well-anchored near the central bank’s target rate when the output gap fell sharply during the recession. Besides, Del Negro et al (2015) also test stability and validity of Phillips curve under forward-looking NKPC framework over 1964Q1-2008Q3 in the US with aim to address inflation puzzles. As a result, they find that including mark-up shocks into the model successfully accounts missing disinflation which emerged during Great Recession. They were able to predict a sharp decline in output without forecasting a large drop in inflation.

Conti and Gigante (2018) investigate dynamics of core inflation in Italy between 1999Q1 and 2017Q1 periods with special focus on after Great Recession

periods. As a result they document significant trade-off between core inflation and economic activity when labour market slacks are fixed. They also observe a steepening in the Phillips curve after the Global Financial Crisis, but when controlling for financial indicators, the slope of the Phillips curve turns out to be flatter. Thus, they conclude that financial indicators helps to better characterize the dynamics of core inflation. To conclude, behavioural changes in dynamics of inflation, particularly in recessionary periods, are growing topics in Phillips curve literature since the recent global recession that led to large and persistent output gaps. In this context, examining validity and stability of the Phillips curve might play crucial role in understanding motivations of recessions as well as interactions between real and financial aspects of economy.

1.4. Data and methodology

The paper empirically tests validity and stability of backward-looking EAPC (traditional PC), pure forward-looking EAPC (NCPC), and hybrid NKPC over Q1:1980-Q1:2016 across 41 countries (Appendix table A1) during stable and unstable economic periods to find out whether they behave notionally. The following sub-sections address data and methodology of these three versions of the Phillips Curve.

1.4.1. EAPC Methodology - traditional and NCPC versions

1.4.1.1. Country-individual estimation of EAPC

The traditional PC accounts only backward-looking adaptive expectations, while NCPC uses rational pure forward-looking expectations in the model. In examination of these two versions of PC, we recall eq.1.02.

$$\pi_t = \beta_0 + \beta_1 \pi_t^e + \beta_2 (u_t - u^*) + \varepsilon_t \quad (1.07)$$

where π_t and π_t^e are proxied by first differences of logarithm of *CPI* and expected *CPI inflation* over one year respectively. In above equation, if $\pi_t^e = \pi_{t-1}$, then the model converts to traditional PC that has backward-looking specification. On the other hand, U_t and U^* are proxied by unemployment rate and *NAIRU* respectively in

logarithmic form. Data for these variables are obtained from Thomson Reuters Eikon Datastream, and we added a fixed constant term to all series to handle negative values during transformation into logarithmic form which only shifts β_0 up leaving other variables unaffected.

We estimate eq.(1.07) for three different time periods (1980-2016, 1990-2016, and 2000-2016) in order to capture time-variation of inflation dynamics under traditional and New Classical Phillips Curve framework. This will also provide some evidence for overall validity and stability of the Phillips trade-off over different time periods. We focus these three time periods crediting Ball and Mazumder (2019) who found strong evidence of regime shift in the early 1990s where backward-looking component of inflation starts to lose weight and in the late 1990s where it drops weight remarkable.

Further, we modify eq.(1.07) in order to examine if dynamics of inflation (under classical Phillips curve framework) changes during two states of economy: Tranquil periods, when economic fundamentals are largely sound and sustainable; and Recessionary periods, when economic variables go through an adjustment process before reaching a more sustainable level or growth path.

$$\pi_t = \beta_0 + \beta_1 \pi_t^e + \beta_2 (u_t - u^*) + \beta_3 \pi_t^e DUMMY_R + \beta_4 (u_t - u^*) DUMMY_R + \varepsilon_t \quad (1.08)$$

where *DUMMY* is a dummy variable that gets value of 1 during recessionary periods and zero during other periods; β_2 and $\beta_2 + \beta_4$ indicate Phillips coefficients, and β_1 and $\beta_1 + \beta_3$ show expectations π^e coefficients for tranquil and recessionary economic periods respectively. Note that π_t^e equates to π_{t-1} in backward-looking model, and it equates to expected inflation $E_t(\pi_{t+1})$ in forward-looking model. Also, in order to find out significance of Phillips coefficients during recessionary periods we need to manually calculate standard errors of $\beta_2 + \beta_4$ and $\beta_1 + \beta_3$ with formulas of $\sigma_{\beta_2 + \beta_4} = \sqrt{\sigma_{\beta_2}^2 + \sigma_{\beta_4}^2}$ and $\sigma_{\beta_1 + \beta_3} = \sqrt{\sigma_{\beta_1}^2 + \sigma_{\beta_3}^2}$. This examination will provide significant evidence for behavioural change in dynamics of inflation, and so, in Phillips relationship.

Notably, we estimate these models utilizing HAC-robust Least Squares (LS) technique without including any whitening options as it is a common practice in empirical estimation of traditional and expectation-augmented Phillips curve.

1.4.1.2. Panel estimation of EAPC

For robustness, we also schedule a panel analysis for whole sample in order to control for country-specific effects. It is reasonable to assume that developed, emerging, and frontier markets have different idiosyncratic characteristics by their nature. So, we fix all these country-specific effect in our panel analysis, and we believe it will derive more accurate results rather than generalizing country-based OLS results. Plus, we expect that this panel analysis will provide robustness for our previous findings.

In order to design our panel estimation model, we examine consistency and efficiency of GLS estimators through cross-section fixed (FE) and random effects (RE) as well as pooled estimation. All these specifications have potential advantages and disadvantages (see Kinney and Dunson, 2007; Park, 2009; Bondell et al., 2011; Clark and Linzer, 2015; Bell and Jones, 2015). The pooled model often generates biased estimates as it does not impose any controls for between-effects (unobserved heterogeneity between cross-sections such as culture, religion, gender, race, etc.) among cross-section which leads its residuals to be heteroskedastic. The cross-section fixed-effects model assumes that heterogeneity among all entities is time-invariant and fixed across entities, and it wipes out these between-effects (unobserved heterogeneity among cross-section) by allowing each entity to have their own intercept values. In other words, the fixed dummy variable controls for all time-invariant differences between entities where intercept varies among cross-sections and remains stable over the time horizon. In this respect, FE model specifications for backward- and forward-looking PC models can be formed by panelizing Eq.(1.08) and adding cross-section fixed effects dummy as follows.

$$\pi_{it} = \beta_0 + \beta_1 \pi_{it}^e + \beta_2 U_{GAP\ it} + \beta_3 \pi_{it}^e DUMMY_R + \beta_4 U_{GAP\ it} DUMMY_R + \alpha_i D_i + \varepsilon_{it} \quad (1.09)$$

where $DUMMY$ is a dummy variable that takes value of 1 during recessionary periods and zero if otherwise; β_2 and $\beta_2 + \beta_4$ indicate Phillips coefficients; and β_1 and $\beta_1 + \beta_3$ show fractions of π^e in current inflation during normal and recession economic periods respectively. The D_i is a dummy variable which takes 1 for the country " i " ($i=1, \dots, 41$), and zero for other countries in the sample. Moreover, if our panel data was unbalanced, we also would include a fixed effect for period by considering another dummy variable to proxy years as " D_y ". The $\beta_0 + \alpha_i D_i$ controls time-invariant

between-effect (cross-section) and ε_{it} is an idiosyncratic error term. Also, note that π_t^e equates to π_{t-1} in backward-looking model, and it equates to expected inflation $E_t(\pi_{t+1})$ in forward-looking model. Additionally, in order to find out significance of Phillips ($\beta_2+\beta_4$) and expected inflation ($\beta_1+\beta_3$) coefficients during recession periods we manually calculate their standard errors with formulas of $\sigma_{\beta_2+\beta_4} = \sqrt{\sigma_{\beta_2}^2 + \sigma_{\beta_4}^2}$ and $\sigma_{\beta_1+\beta_3} = \sqrt{\sigma_{\beta_1}^2 + \sigma_{\beta_3}^2}$.

The FE specification is based on two main assumptions: (1) $\varepsilon_t \sim i.i.d.N(0, \sigma_e^2)$, and (2) exogeneity of covariates x_{ij} , i.e. $cov(\varepsilon_{ij}, x_{ij})=0$ for all dependent variables where $Var(\varepsilon_{ij}) = \sigma_e^2$. However, residuals of FE model might not always be the most efficient (although it is consistent) as it completely wipes out between-effects and its residuals account only within-effects (heterogeneity within cross-section, i.e. among variables of same cross-section).

On the other hand, random-effect model is a specific type of pooled estimation that assumes time-varying heterogeneity across entities, thus, it generates estimates closer, on average, to the true value of any particular country. In this respect, we establish our RE specified model by modifying Eq.(1.08) equation as below.

$$\pi_{it} = \beta_{0,i} + \beta_1 \pi_{it}^e + \beta_2 U_{GAP\ it} + \beta_3 \pi_{it}^e DUMMY_R + \beta_4 U_{GAP\ it} DUMMY_R + \varepsilon_{it} \quad (1.10)$$

where $\beta_{0,i} = \beta_0 + \omega_i$ with $\omega_i \sim N(0, \sigma^2)$. And when $\beta_{0,i}$ is plugged into above equation, it becomes as following.

$$\pi_{it} = \beta_0 + \beta_1 \pi_{it}^e + \beta_2 U_{GAP\ it} + \beta_3 \pi_{it}^e DUMMY_R + \beta_4 U_{GAP\ it} DUMMY_R + u_{it} \quad (1.11)$$

where $u_{it} = \omega_i + \varepsilon_{it}$. The ω_i controls between-entity errors, while ε_t controls within-entity errors. The residuals of RE model are often shrunk, and thus homoskedastic, and it also offer possibility of differential between cross-sections. However, the estimators of this RE specification are often biased due to potential correlation between covariates of explanatory variables and ω_i . Unlike FE model, it captures both "within" and "between" deviations, and allows all cross-sections to have a common mean value for intercept. With other words, the dummy variable " D_i " —was a part of intercept in the FE— becomes a part of error " u_i " in the RE model.

A prior to researcher's preference in trade-off between bias and variance, it is more logic to exhibit the dataset and characteristics of the sample. Besides, there are few statistical tests that might be a guideline in selection an appropriate model (see table 1.02). Following one of these guidelines, we initially employ Redundant Fixed Effect and Breush-Pagan LM tests to find out whether our panel data contain respectively a fixed effect and a random effect. In a special case, when both fixed and random effects are observed, we schedule the Hausman (1978) test for final decision-making in model selection as below.

$$H = (\beta_1 - \beta_0)' (Var(\beta_1) - Var(\beta_0))^\rho (\beta_1 - \beta_0) \quad (1.12)$$

where ρ is pseudo-inverse. Hausman test hypothesizes the null hypothesis to alternative where H_0 specifies that both FE (β_0) and RE estimators (β_1) are consistent, but RE is more efficient than FE, while the alternative hypothesis specifies that RE is inconsistent, and only FE (β_0) is consistent.

Table 1.02. Fixed- and Random-Effects Model Selection

Redundant Fixed Effect Test	Breusch-Pagan & Honda LM Tests	Concluded Model
H_0 is not rejected (No fixed effect)	H_0 is not rejected (No random effect)	Data are poolable (Pooled OLS)
H_0 is rejected (Fixed effect)	H_0 is not rejected (No random effect)	Fixed Effect Model (GLS)
H_0 is not rejected (No fixed effect)	H_0 is rejected (Random effect)	Random Effect Model (GLS)
H_0 is rejected (Fixed effect)	H_0 is rejected (Random effect)	(1) Both Fixed and Random Effect Models (2) Hausman Test (recommended)

Notes: The null hypothesis for both Breush-Pagan and Honda LM tests is "No Random Effects". The null hypothesis for Redundant Fixed Effect test is "No Unobserved Heterogeneity (No Fixed Effect)".

Source: The author's design

1.4.2. NKPC version

In case of NKPC, we use the hybrid form of NKPC framework to estimate dynamics of inflation with structural parameters for 41 countries over 1980:Q1-2016:Q1 by following Gali and Gertler's (1999) approach with some setup

modifications that are explained in the Appedix A1 section. This particular model allow to use both backward-looking and forward-looking expectations in a hybrid form simultaneously, unlike to traditional and EPAC versions.

1.4.2.1. Hybrid NKPC with unit labour cost

The NKPC model posits that inflation dynamics are driven by unemployment through labour costs, especially through real marginal costs (labour share of income). Therefore, we use gap real unit labour cost (ulc) as a proxy for real marginal costs. ULC measures average cost of labour per unit output and derived as ratio of total labour cost to real GDP. It links labour productivity and cost of labour used to produce the output. Thus, an increase in ULC indicates a rise in labour's contribution to output; however, if the labour productivity does not rise as much as labour costs, it might harm the economy.

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t \pi_{t+1} + \lambda_{ulc} ulc_t + \varepsilon_t \quad (1.13)$$

where π_t is proxied by first difference of natural logarithm of implicit GDP deflator, and ulc_t is a gap real unit labour cost. Data for real unit labour costs are retrieved from Thomson Reuters Eikon Datastream and transformed into natural logarithmic form. Then, we utilize Hodrick-Prescott filter to calculate trends (μ_t) in series and the cyclical components that deviate around trend. We use a smoothing factor (λ) of 1600 to find out the trend (μ_t) that minimizes the sum as given by:

$$\min_{\{\mu_t\}_{t=0}^T} \left(\sum_{t=0}^T (y_t - \mu_t)^2 + \lambda \sum_{t=1}^{T-1} ((\mu_{t+1} - \mu_t) - (\mu_t - \mu_{t-1}))^2 \right) \quad (1.14)$$

This will strip off trend (μ_t) from series leaving only cyclical component of the data y_t .

Following Gali et al. (2005), we use four lags of π_t , and two lags of ulc_t , output gap (χ_t), import prices (ip_t), unit wage cost (wi_t), policy interest rate (ir_t) as instrumental variables for inflation expectations ($E_t \pi_{t+1}$). Here, χ_t is obtained by detrending natural logarithm of GDP series by Hodrick-Prescott filter with lambda 1600; ir_t is used in percentage form; ip_t and wi_t are proxied by fist differences of their natural logarithms.

On the other hand, the error in estimation of $E_t\pi_{t+1}$ is uncorrelated with information dated t and earlier under the assumption of rational expectations. Thus, it provides the following a, b, and c orthogonality conditions for reduced form equation of hybrid NKPC.

$$E_t\{(\pi_t - \gamma_b\pi_{t-1} - \gamma_f\pi_{t+1} - \lambda_{ulc}ulc_t)z_t\} = 0 \quad (1.13a)$$

$$E_t\{(\phi\pi_t - \omega\pi_{t-1} - \theta\beta\pi_{t+1} - (1-\omega)(1-\theta)(1-\beta\theta)ulc_t)z_t\} = 0 \quad (1.13b)$$

$$E_t\{(\pi_t - \omega\phi^{-1}\pi_{t-1} - \theta\beta\phi^{-1}\pi_{t+1} - (1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1}ulc_t)z_t\} = 0 \quad (1.13c)$$

where Z_t is a vector of instrumental variables; ω is degree of backwardness; θ is price stickiness; and β is subjective discount factor that are explained in section 1.2 as well as in Appendix section A1. The Eq.(1.13a) is orthogonality condition for hybrid NKPC in Eq.(1.13), and we derive Eq.(1.13b) by replacing structural estimates into Eq.(1.13a). Moreover, Gali and Gertler (1999) and Gali et al. (2001) underline that small sample normalization can affect Generalized Method of Moments (GMM) in the estimation. Therefore, we construct eq.(1.13c) as an alternative orthogonality condition for estimation of structural parameters that are specified in Gali and Gertler (1999) as $\lambda_{ulc}=(1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1}$, $\gamma_f=\beta\theta\phi^{-1}$, and $\gamma_b=\omega\phi^{-1}$ where $\phi\equiv\theta+\omega[1-\theta(1-\beta)]$.

1.4.2.2. Hybrid NKPC with unit labour cost and unit non-labour cost

Proxing real marginal costs with unit labour costs which is a widely accepted practice in existing literature. However, we believe that non-labour related costs (capital costs, net interest payments, production taxes, and etc.) also generate inflationary pressure in the economy. In this regard, we show that accounting omitted non-labour costs improves performance and the fit of NKPC. Thus, we alter Gali and Gertler's hybrid NKPC as,

$$\pi_t = \gamma_b\pi_{t-1} + \gamma_f E_t\pi_{t+1} + \lambda_{ulc}ulc_t + \lambda_{unlc}unlc_t + \varepsilon_t \quad (1.14)$$

with structural estimates of $\lambda_{ulc}=\rho(1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1}$, $\lambda_{unlc}=(1-\rho)(1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1}$, $\gamma_f=\beta\theta\phi^{-1}$, and $\gamma_b=\omega\phi^{-1}$ where $\phi\equiv\theta+\omega[1-\theta(1-\beta)]$, and with orthogonality conditions of,

$$E_t\{(\pi_t - \gamma_b\pi_{t-1} - \gamma_f\pi_{t+1} - \lambda_{ulc}ulc_t - \lambda_{unlc}unlc_t)z_t\} = 0 \quad (1.14a)$$

$$E_t\{(\phi\pi_t - \omega\pi_{t-1} - \theta\beta\pi_{t+1} - \rho(1-\omega)(1-\theta)(1-\beta\theta)ulc_t - (1-\rho)(1-\omega)(1-\theta)(1-\beta\theta)unlc_t)z_t\} = 0 \quad (1.14b)$$

$$E_t\{(\pi_t - \omega\phi^{-1}\pi_{t-1} - \theta\beta\phi^{-1}\pi_{t+1} - \rho(1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1}ulc_t - (1-\rho)(1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1}unlc_t)z_t\} = 0 \quad (1.14c)$$

where Z_t is a vector of instrumental variables; and ulc and $unlc$ are unit labour and unit non-labour costs respectively. The ω , θ , β , ϕ , and ρ are structural parameters of NKPC that are explained in section 1.2 as well as in Appendix section A1. The ρ indicates fraction of unit labour costs in the inflation dynamics, while $1-\rho$ shows fraction of unit non-labour costs in the inflation dynamics.

1.4.2.3. Hybrid NKPC with total unit cost

We also test the hybrid NKPC using an alternative proxy of gap total unit costs (tuc) for mc_t . The tuc comprises both gap real unit labour costs (ulc) and gap real unit non-labour costs ($unlc$), therefore we believe it will perform better than only ulc as non-labour costs also influence the price dynamics. In general, non-labour costs include non-labour employee payments, net interest payments, depreciations, rental payments, administrative and operational costs, taxes on production, and all other forms of miscellaneous payments of firms.

Thus, we alter Gali and Gertler's hybrid NKPC as,

$$\pi_t = \gamma_b\pi_{t-1} + \gamma_f E_t\pi_{t+1} + \lambda_{tuc} tuc_t + \varepsilon_t \quad (1.15)$$

with structural parameters of $\lambda_{tuc}=(1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1}$, $\gamma_f=\beta\theta\phi^{-1}$, and $\gamma_b=\omega\phi^{-1}$ where $\phi\equiv\theta+\omega[1-\theta(1-\beta)]$, and with orthogonality conditions of,

$$E_t\{(\pi_t - \gamma_b\pi_{t-1} - \gamma_f\pi_{t+1} - \lambda_{tuc} tuc_t)z_t\} = 0 \quad (1.15a)$$

$$E_t\{(\phi\pi_t - \omega\pi_{t-1} - \theta\beta\pi_{t+1} - (1-\omega)(1-\theta)(1-\beta\theta)tuc_t)z_t\} = 0 \quad (1.15b)$$

$$E_t\{(\pi_t - \omega\phi^{-1}\pi_{t-1} - \theta\beta\phi^{-1}\pi_{t+1} - (1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1}tuc_t)z_t\} = 0 \quad (1.15c)$$

where Z_t is a vector of instrumental variables; and tuc is total unit cost which is sum of unit labour and unit non-labour costs. The ω , θ , β , ϕ , and ρ are structural parameters of NKPC that are explained in section 1.2 as well as in Appendix section A1.

Data for tuc_t , ulc_t and $unlc_t$ are retrieved from Thomson Reuters Eikon Datastream, and transformed into natural logarithmic form, then their cyclical components are derived by using Hodrick-Prescott filter with lambda 1600. The instruments that are utilized in eq.(1.14) are exactly same with eq.(1.13) with addition of two lags of $unlc_t$. However, in case of eq.(1.14) the two lags of tuc_t replaces the two lags of ulc_t as an instrumental variables. The θ , ω , and β are structural parameters of price stickiness, degree of backwardness of firms, and subjective discount factor respectively as in Gali and Gertler (1999), and we introduce a new parameter ρ that accounts fractions of ulc and $unlc$ in real marginal costs.

In estimation of these hybrid NKPC models and their structural parameters, we use HAC-robust GMM technique with "Auto-Schwarz" maximum four lags specification under Bartlett Kernel and Newey-West Fixed bandwidth methodology that iterates to convergence. Moreover, we test $\omega=0$ (thus $\gamma_b=0$) and $\beta=1$ (thus $\gamma_r+\gamma_b=1$) restrictions: First is to determine whether hybrid NKPC converges to the baseline NKPC or not; and second is to confirm validity of Gali and Gertler (1999)'s argument that sum coefficients of backward- and forward-looking variables should hold a unity ($\gamma_r+\gamma_b=1$) under $\beta=1$ rule. Indeed, the β is supposed to be high to justify a low risk-free rate. Estimated values of β confirm that is has a high value, "*less than, but close to, unity*" (Hansen and Singleton, 1983, p. 260). Thus, we expect this value to be close to unity. In our analyses, we also report Sargan-Hansen's (Sargan, 1958; Hansen, 1982) J-statistics -which tests over-identification of restrictions- to confirm validity and relevance of all instruments in GMM analysis, and the duration of price stickiness on quarterly basis utilizing formula $\Omega=1/(1-\theta)$.

Besides, we examine these hybrid models, eqs.(1.13-15), in a panel GMM framework using both static and dynamic instruments to check robustness of country-specific results. Here, we report estimates under cross- and period-fixed effects as well as cross- and period-random effects specifications. We also adjust eqs.(1.13-15) in order to observe how the Phillips trade-off varies across tranquil (normal) and recessionary periods.

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t \pi_{t+1} + \lambda_n ulc_t + \zeta_b R \pi_{t-1} + \zeta_f R E_t \pi_{t+1} + \lambda_r R ulc_t + \varepsilon_t \quad (1.13')$$

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t \pi_{t+1} + \lambda_{1n} ulc_t + \lambda_{2n} unlc_t + \zeta_b R \pi_{t-1} + \zeta_f R E_t \pi_{t+1} + \lambda_{1r} R ulc_t + \lambda_{2r} R unlc_t + \varepsilon_t \quad (1.14')$$

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t \pi_{t+1} + \lambda_n tuc_t + \zeta_b R \pi_{t-1} + \zeta_f R E_t \pi_{t+1} + \lambda_r R tuc_t + \varepsilon_t \quad (1.15')$$

where R is a dummy variable that equates to 1 for negative GDP growth (recessionary) periods, and reverts back to zero for positive GDP growth (tranquil or normal) periods. Thus, γ_b , γ_f , λ_{1n} , λ_{2n} , and λ_n are estimates of hybrid NKPC during normal periods, while $\gamma_b + \zeta_b$, $\gamma_f + \zeta_f$, $\lambda_{1n} + \lambda_{1r}$, $\lambda_{2n} + \lambda_{2r}$, and $\lambda_n + \lambda_r$ are estimates of hybrid NKPC during recessionary periods.

However, prior to these analyses, we examine characteristics of all series with Eq.(1.16) utilizing Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, lest they violate the stationarity assumption of OLS.

$$\Delta \Gamma_t = \theta_0 + \theta_1 T + \rho \Gamma_{t-1} + \varepsilon_t \quad (1.16)$$

where $\Delta \Gamma_t$ is the first difference of a variable Γ ; T is a trend; θ_1 is its multiplier; and ε_t is a residual term. Here, ε_t might show heteroscedastic and serially correlative behaviour, and to fix this problem ADF includes lags of autoregressive terms whereas PP uses Newey-West (1987) standard errors. Thus, robust equation (1.16) for ADF becomes,

$$\Delta \Gamma_t = \theta_0 + \theta_1 T + \rho \Gamma_{t-1} + \sum_{i=1}^k \theta_{i+1} \Delta \Gamma_{t-i} + \varepsilon_t \quad (1.17)$$

where k is an optimal lag length determined with information criterion such as Akaike, Schwarz, or Hannan-Quinn; and ε_t is a White Noise residual term. Here, both ADF and PP hypothesize H_0 ($\rho=0$) against alternative ($\rho<0$), and rejection of null hypothesis confirms stationarity of the variable Γ . We report the results of these unit root tests in Appendix tables A2-4.

Lastly, data range from 1980:Q1 to 2016:Q1 comprises many important economic phases especially 1980's global deflationary era, 1982 LatAm sovereign debt crisis, 1990's low inflationary periods, 1997-1998 Asian financial crisis, 1999-2001 Dotcom bubble, 2008 global financial crisis, 2009 Euro zone (Spain, Ireland, Greece, Portugal, Cyprus) fiscal crisis, and many other country specific recessions. To investigate how traditional PC, NCPC, and hybrid NKPC behave only during

these recession periods we construct a recession-crisis dummy variable that equates to 1 for negative GDP growth periods and to zero for other periods (Appendix table A1).

1.4.2.4. Panel Estimation of Hybrid NKPC

For robustness, we employ panel analysis for hybrid NKPC models by following similar methodology explained at section 1.4.1.2. In this respect, we formulate the cross-section fixed-effect (FE) specified forms of our three NKPC models (1: ulc, 2: ulc-unlc, 3: tuc) as below.

$$\pi_{it} = \gamma_b \pi_{i,t-1} + \gamma_f E_{it} \pi_{i,t+1} + \lambda_{ulc} ulc_{it} + C_0 + \alpha_i D_i + \varepsilon_{it} \quad (1.18)$$

$$\pi_{it} = \gamma_b \pi_{i,t-1} + \gamma_f E_{it} \pi_{i,t+1} + \lambda_{ulc} ulc_{it} + \lambda_{unlc} unlc_{it} + C_0 + \alpha_i D_i + \varepsilon_{it} \quad (1.19)$$

$$\pi_{it} = \gamma_b \pi_{i,t-1} + \gamma_f E_{it} \pi_{i,t+1} + \lambda_{tuc} tuc_{it} + C_0 + \alpha_i D_i + \varepsilon_{it} \quad (1.20)$$

where D_i is a dummy variable which equates 1 for the country “ i ” ($i=1, \dots, 41$), and zero for others in the sample. Moreover, if our panel date was unbalanced, we also would include a fixed effect for period by considering another dummy variable to proxy months as “ D_m ”. The $C_0 + \alpha_i D_i$ is an individual-specific (cross-section) effect and ε_{it} is an idiosyncratic error term.

These FE specifications assume heterogeneity among cross-sections by allowing to have their own intercept values that vary among entities, but time-invariant, i.e. it does not change over time. Thus, FE specifications generate unbiased estimates of regressors. But all omitted variations are captured by the residual terms; therefore, FE specifications might suffer from heteroskedasticity problem (high variance in residuals).

On the other hand, the RE model heals the high variance problem by generating time-varying estimates closer, on average, to the true value of any particular country. On this basis, we formulate the cross-section random-effect (RE) specified forms of our three NKPC models (1: ulc, 2: ulc-unlc, 3: tuc) as below.

$$\pi_{it} = \gamma_b \pi_{i,t-1} + \gamma_f E_{it} \pi_{i,t+1} + \lambda_{ulc} ulc_{it} + C_{0,i} + \varepsilon_{it} \quad (1.21)$$

$$\pi_{it} = \gamma_b \pi_{i,t-1} + \gamma_f E_{it} \pi_{i,t+1} + \lambda_{ulc} ulc_{it} + \lambda_{unlc} unlc_{it} + C_{0,i} + \varepsilon_{it} \quad (1.22)$$

$$\pi_{it} = \gamma_b \pi_{i,t-1} + \gamma_f E_{it} \pi_{i,t+1} + \lambda_{tuc} tuc_{it} + C_{0,i} + \varepsilon_{it} \quad (1.23)$$

where $C_{0,i} = C_0 + \omega_i$ with $\omega_i \sim N(0, \sigma^2)$. And when $C_{0,i}$ is plugged into above equations, they become as followings.

$$\pi_{it} = \gamma_b \pi_{i,t-1} + \gamma_f E_{it} \pi_{i,t+1} + \lambda_{ulc} ulc_{it} + C_0 + u_{it} \quad (1.24)$$

$$\pi_{it} = \gamma_b \pi_{i,t-1} + \gamma_f E_{it} \pi_{i,t+1} + \lambda_{ulc} ulc_{it} + \lambda_{unlc} unlc_{it} + C_0 + u_{it} \quad (1.25)$$

$$\pi_{it} = \gamma_b \pi_{i,t-1} + \gamma_f E_{it} \pi_{i,t+1} + \lambda_{tuc} tuc_{it} + C_0 + u_{it} \quad (1.26)$$

where $u_{it} = \omega_i + \varepsilon_{it}$. However, due to potential correlation between covariates of explanatory variables and ω_i the RE estimators are often biased. Unlike FE model, it captures both "within" and "between" deviations, and allows all cross-sections to have a common time-variant mean value for intercept. With other words, the dummy variable " D_i " —was a part of intercept in the FE— becomes a part of error " u_i " in the RE model.

On the other hand, we explore behavioural changes of hybrid NKPC and its structural parameters during tranquil and recessionary periods by inserting recession dummy variable into FE specification given at eqs.(1.18-1.20) and into RE specification given at eqs.(1.24-1.25) as followings.

$$\begin{aligned} \pi_{it} = & \gamma_{b1} \pi_{i,t-1} + \gamma_{f1} E_{it} \pi_{i,t+1} + \lambda_{mc1} mc_{it} + \gamma_{b2} \pi_{i,t-1} DUMMY_i + \gamma_{f2} E_{it} \pi_{i,t+1} DUMMY_i \\ & + \lambda_{mc2} mc_{it} DUMMY_i + C_0 + \alpha_i D_i + \varepsilon_{it} \end{aligned} \quad (1.27)$$

$$\begin{aligned} \pi_{it} = & \gamma_{b1} \pi_{i,t-1} + \gamma_{f1} E_{it} \pi_{i,t+1} + \lambda_{mc1} mc_{it} + \gamma_{b2} \pi_{i,t-1} DUMMY_i + \gamma_{f2} E_{it} \pi_{i,t+1} DUMMY_i \\ & + \lambda_{mc2} mc_{it} DUMMY_i + C_0 + u_{it} \end{aligned} \quad (1.28)$$

where eq.(1.27) and eq.(1.28) represent FE and RE specification of hybrid NKPC respectively. The D_i is a dummy variable which equates 1 for the country " i " ($i=1, \dots, 41$), and zero for others in the sample. The $C_0 + \alpha_i D_i$ is an individual-specific (cross-section) fixed-effect and ε_{it} is an idiosyncratic error term. The mc is real marginal cost that is proxied by unit labor costs (ulc) in the model 1, unit labor costs and unit non-labour costs in the model 2, and total unit costs in the model 3. The $DUMMY_i$ is a dummy variable that takes value of 1 during recessionary periods, and zero during other periods. Thus, coefficients of backward-looking, forward-looking, and real marginal cost factor during recessionary periods are $(\gamma_{b1} + \gamma_{b2})$, $(\gamma_{f1} + \gamma_{f2})$, and $(\lambda_{mc1} + \lambda_{mc2})$ respectively. Their standard errors are calculated with formula of

$\sigma_{1+2} = \sqrt{\sigma_1^2 + \sigma_2^2}$. In selection of appropriate specification for our three NKPC model, we follow guidelines mentioned in section 1.4.1.2 at table 1.02.

Further, we examine structural parameters of panel hybrid NKPC models (1, 2, and 3) during tranquil and recessionary periods. For this, we recall orthogonality conditions (eq.1.13c for model 1; eq.1.14c for model 2; eq.1.15c for model 3) and extend them with dummy structural parameters. For an illustration, the orthogonality condition for model 2 is shaped as below.

$$\begin{aligned}
E_t\{ & (\pi_t - \omega_1\phi_1^{-1}\pi_{t-1} - \theta_1\beta_1\phi_1^{-1}\pi_{t+1} - \rho_1(1 - \omega_1)(1 - \theta_1)(1 - \beta_1\theta_1)\phi_1^{-1}ulc_t \\
& - (1 - \rho_1)(1 - \omega_1)(1 - \theta_1)(1 - \beta_1\theta_1)\phi_1^{-1}unlc_t \\
& - \omega_2\phi_2^{-1}\pi_{t-1}DUMMY - \theta_2\beta_2\phi_2^{-1}\pi_{t+1}DUMMY \\
& - \rho_2(1 - \omega_2)(1 - \theta_2)(1 - \beta_2\theta_2)\phi_2^{-1}ulc_tDUMMY - (1 - \rho_2)(1 \\
& - \omega_2)(1 - \theta_2)(1 - \beta_2\theta_2)\phi_2^{-1}unlc_tDUMMY)z_t\} \\
& = 0
\end{aligned} \tag{1.29}$$

where Z_t is a vector of instrumental variables and $\phi \equiv \theta + \omega[1 - \theta(1 - \beta)]$. The subscript “1” and “2” indicate structural parameters during tranquil (normal) and recessionary periods respectively. *DUMMY* is a dummy variable that takes value of 1 during recessionary periods, and zero during other periods. The model 1 is a special case of eq.(1.29) where $\rho=1$, indicating that all fraction of real marginal cost is attributable by only unit labour cost. Moreover, the eq.(1.29) gives following relationships during normal (tranquil) periods:

$$\begin{aligned}
{}^N\lambda_{ulc} &= \rho_1(1 - \omega_1)(1 - \theta_1)(1 - \beta_1\theta_1)\phi_1^{-1} \\
{}^N\lambda_{unlc} &= (1 - \rho_1)(1 - \omega_1)(1 - \theta_1)(1 - \beta_1\theta_1)\phi_1^{-1} \\
{}^N\gamma_f &= \beta_1\theta_1\phi_1^{-1} \\
{}^N\gamma_b &= \omega_1\phi_1^{-1}
\end{aligned}$$

And it gives following relationships during recessionary periods.

$$\begin{aligned}
{}^R\lambda_{ulc} &= \rho_2(1 - \omega_2)(1 - \theta_2)(1 - \beta_2\theta_2)\phi_2^{-1} \\
{}^R\lambda_{unlc} &= (1 - \rho_2)(1 - \omega_2)(1 - \theta_2)(1 - \beta_2\theta_2)\phi_2^{-1} \\
{}^R\gamma_f &= \beta_2\theta_2\phi_2^{-1}
\end{aligned}$$

$${}^R\gamma_b = \omega_2\phi_2^{-1}$$

1.5. Results and discussion

The paper empirically tests validity and stability of backward-looking EAPC (traditional PC), pure forward-looking EAPC (NCPC), and hybrid NKPC over Q1:1980-Q1:2016 across 41 countries (Appendix table A1) during stable and unstable economic periods to find out whether they behave notionally. The following sub-sections address data and methodology of these three versions of the Phillips Curve.

1.5.1. Results for EAPC - traditional and NCPC versions

1.5.1.1. Observations for how Phillips curve changes over time periods

Tables 1.03-1.04 present results of OLS estimation of traditional PC (backward-looking EAPC) and New Classical (forward-looking EAPC) PC for 41 countries individually in different time horizons. We categorize countries according to their S&P market classification, and examine PC estimations after 1980's, 1990's, and 2000's separately in order to observe whether Phillips relationship varies across countries as well as different time periods. We particularly paid focus on these mentioned time periods due to the observations of Ball and Mazumder (2019) who found strong evidence of regime shift in the early 1990s where backward-looking component of inflation starts to lose weight and in the late 1990s where it drops weight remarkable. Our results shed light on an overall validity of the traditional backward-looking (BL) PC during early 1980's where afterwards it loses its significance in majority of the sampled countries. Especially, we detect that the PC was valid for all developed countries except Belgium and Singapore during 1980-1990, whereas its behaviour was ambiguous for emerging and frontier markets. More specifically, we notice that PC fails to work in all Latin American countries - *Chile and Mexico in emerging market, and Argentina and Venezuela in frontier market classification*- which might be due to LatAm sovereign debt crisis during 1980's. Equally, we detect that traditional PC also fails in Greece and Turkey due to

the same reason, i.e. unstable economic environment. These two countries have experienced about 20 quarters of recessions just during 1980-1990 (Appendix table A1).

On the other hand, forward-looking (FL) PC performs better comparing to traditional one for almost all developed countries during 1980-2016, except Singapore who also had failed in the previous (traditional PC) analysis as well. Among emerging and frontier markets, the only improvement occurs in Thailand in which PC becomes valid with pure forward-looking specification. Moreover, notice that the model continues its functionality in developed markets, even, when we restrict the analysis period to 1990-2016 where Thai EAPC gains its validity, but Austrian EAPC loses it. Although, we fail to detect substantial changes for emerging and frontier markets, it is clearly visible that the PC with pure forward-looking specification tend to perform better than the one with backward-looking specification during 1990-2016 comparing to unrestricted period. Apparently, few Latin American countries like Argentina, Chile, and Venezuela generate plausible results regarding solidness of EAPC after overcoming sovereign debt crisis hurricane in mid 1980's.

Interestingly, tables 1.03-1.04 show that coefficients of backward-looking specification decrease as we get closer to the present time, while coefficients of forward-looking specification get dominance. It seems to be valid for almost all countries, especially for developed ones, and indicates that backward-looking specification was a fundamental factor in dynamics of inflation in early 80's which, by the time, is replaced by forward-looking specification. It also explains why inflation today is more prone to market speculations than it was before 1980's.

Moreover, when the analysis period is restricted to 2000-2016, we observe that the backward-looking model has weakened further in terms of overall significance almost in all sampled countries. During this period we account massive failures, especially in developed markets of the EU which can be addressed to the number of economic crises -*Dotcom crisis (1999-2001)*, *Great Recession (2007-2009)*, and *Euro zone sovereign debt crisis (2009-2014)*- comprised by the analysis time interval. Thus, we conclude that PC with pure forward-looking specification performs better than that with backward-looking one -*which loses significance after 1990's- until 2000's where afterwards it also collapses.*

Table 1.03. BL and FL EAPC over Time Horizons in Developed Countries

Periods	After 80's 1980:Q1-2016:Q1				After 90's 1990:Q1-2016:Q1				After 00's 2000:Q1-2016:Q1			
	BACKWARD-LOOKING		FORWARD-LOOKING		BACKWARD-LOOKING		FORWARD-LOOKING		BACKWARD-LOOKING		FORWARD-LOOKING	
Variables	π_{t-1}	U_{GAP}	π_{t+1}^e	U_{GAP}	π_{t-1}	U_{GAP}	π_{t+1}^e	U_{GAP}	π_{t-1}	U_{GAP}	π_{t+1}^e	U_{GAP}
Australia	0.5334*** (0.1134)	-0.1255** (0.0522)	0.5646*** (0.1053)	-0.0754** (0.0312)	0.3549** (0.1455)	-0.1565** (0.0644)	0.5810** (0.2500)	-0.1009** (0.0501)	0.3073** (0.1481)	-0.2259* (0.1352)	0.6724*** (0.1777)	-0.0559* (0.0304)
Austria	0.4862*** (0.0802)	-0.1337*** (0.0416)	0.5979*** (0.0914)	-0.1064*** (0.0385)	0.4940*** (0.0953)	-0.0552 (0.0375)	0.7481*** (0.1648)	-0.0342 (0.0383)	0.5695*** (0.1371)	0.0119 (0.0642)	1.2965*** (0.1991)	-0.0084 (0.0687)
Belgium	0.5199*** (0.0805)	-0.0414 (0.0346)	0.8557*** (0.0631)	-0.0144** (0.0075)	0.3869*** (0.1184)	-0.0286 (0.0438)	0.5775*** (0.1242)	-0.0531** (0.0247)	0.2257* (0.1327)	-0.3054*** (0.1015)	0.5581*** (0.1952)	-0.2605*** (0.1043)
Canada	0.5225*** (0.1100)	-0.1082** (0.0434)	0.5547*** (0.0708)	-0.0630** (0.0251)	0.1358* (0.0755)	-0.1703*** (0.0592)	0.5752*** (0.1165)	-0.1592*** (0.0528)	0.0193 (0.0705)	-0.1435** (0.0633)	-0.9886 (0.6668)	-0.2331** (0.1001)
Denmark	0.5968*** (0.1038)	-0.0239 (0.0238)	0.4660*** (0.1076)	-0.0387** (0.0166)	-0.0066 (0.0904)	-0.0063 (0.0205)	0.5225*** (0.1327)	-0.0378** (0.0152)	0.0660 (0.0887)	-0.0529 (0.0644)	0.6444*** (0.2059)	-0.0488* (0.0259)
Finland	0.5877*** (0.0761)	-0.0343* (0.0213)	0.5026*** (0.0685)	-0.0646*** (0.0165)	0.3110*** (0.0830)	-0.0758** (0.0306)	0.5308*** (0.1423)	-0.0770*** (0.0187)	0.2182* (0.1308)	-0.2448*** (0.0837)	0.6087*** (0.1919)	-0.1796** (0.0805)
France	0.5059*** (0.0486)	-0.0472* (0.0272)	0.5843*** (0.0329)	-0.0631** (0.0319)	0.4326*** (0.1401)	-0.0714 (0.0601)	0.5621*** (0.1255)	-0.0615** (0.0302)	0.3312* (0.1815)	-0.0811 (0.0837)	0.5987** (0.2553)	-0.0524* (0.0312)
Germany	0.4059*** (0.1052)	-0.1024** (0.0510)	0.5651*** (0.0980)	-0.0884** (0.0427)	0.1482 (0.1024)	-0.1074** (0.0513)	0.5988*** (0.1665)	-0.0469** (0.0195)	0.1146 (0.1301)	-0.0171 (0.0704)	0.6890** (0.2918)	-0.0239* (0.0128)
Ireland	0.4963*** (0.0694)	-0.0539** (0.0250)	0.5054*** (0.0831)	-0.0570* (0.0302)	0.3609*** (0.1317)	-0.0613*** (0.0231)	0.5623*** (0.1184)	-0.0318** (0.0150)	0.4078*** (0.1276)	-0.0712 (0.0609)	0.9864*** (0.2020)	-0.0300 (0.0202)
Italy	0.8812*** (0.0428)	-0.0353*** (0.0115)	0.9194*** (0.0412)	-0.0498*** (0.0138)	0.6800*** (0.0812)	-0.0384*** (0.0143)	0.8459*** (0.0751)	-0.0456*** (0.0144)	0.8259*** (0.1441)	-0.0405 (0.0381)	0.8955*** (0.3164)	-0.0437 (0.0354)
Japan	0.3674*** (0.1391)	-0.3150** (0.1372)	0.5398*** (0.1479)	-0.2361** (0.1127)	0.3115** (0.1507)	-0.3167** (0.1441)	0.7525*** (0.2688)	-0.1601* (0.0939)	0.4739*** (0.1682)	-0.1065 (0.1139)	0.7222* (0.4503)	-0.1026 (0.1233)
Netherlands	0.3765*** (0.1165)	-0.0419* (0.0234)	0.5774*** (0.1778)	-0.0289* (0.0153)	0.2675** (0.1216)	-0.0404** (0.0208)	0.5482*** (0.1075)	-0.0252*** (0.0052)	0.2809* (0.1547)	-0.0320 (0.0285)	0.9985*** (0.3602)	0.0106 (0.0420)
Norway	0.4784*** (0.0952)	-0.2049** (0.0883)	0.4938*** (0.0738)	-0.1091* (0.0645)	-0.1165 (0.0733)	-0.0194 (0.0895)	0.5166*** (0.1580)	-0.0544** (0.0241)	-0.1538 (0.1411)	-0.0987 (0.1422)	0.6824 (0.6495)	-0.0776 (0.1493)
Portugal	0.4846*** (0.0685)	-0.0558* (0.0303)	0.5852*** (0.0662)	-0.0398* (0.0227)	0.4657*** (0.1064)	-0.0974*** (0.0341)	0.6213*** (0.1256)	-0.0325* (0.0187)	0.0341 (0.1741)	-0.0697 (0.0515)	0.9466*** (0.2009)	0.0016 (0.0291)
Singapore	0.5019*** (0.1018)	-0.0177 (0.0156)	0.6295*** (0.1052)	-0.0117 (0.0237)	0.3864*** (0.1240)	-0.1305* (0.0783)	0.6556*** (0.1958)	-0.2202*** (0.0910)	0.3156** (0.1444)	-0.2107* (0.1147)	0.7046** (0.3228)	-0.2850** (0.1270)
South Korea	0.4731*** (0.1297)	-0.1272** (0.0649)	0.5254*** (0.1642)	-0.0954* (0.0552)	0.4269*** (0.1333)	-0.2877* (0.1537)	0.6705*** (0.1367)	-0.2808* (0.1584)	0.2929** (0.1232)	0.0954 (0.1624)	0.6214** (0.3102)	0.2029 (0.1728)
Spain	0.5165*** (0.0912)	-0.0519*** (0.0178)	0.6279*** (0.0663)	-0.0475* (0.0263)	0.3069*** (0.1136)	-0.0393* (0.0234)	0.4838*** (0.1487)	-0.0403* (0.0232)	0.2533* (0.1415)	-0.0559 (0.0345)	-0.1284 (0.6760)	-0.0708 (0.0542)
Sweden	0.5188*** (0.0828)	-0.0812** (0.0388)	0.7693*** (0.0747)	-0.0606* (0.0322)	0.2679*** (0.1042)	-0.0994* (0.05222)	0.8862*** (0.1248)	-0.0691* (0.0402)	0.3090** (0.1511)	-0.1409* (0.0846)	0.7011* (0.4157)	-0.1151 (0.1113)
Switzerland	0.7105*** (0.0532)	-0.0897* (0.0455)	0.6547*** (0.0759)	-0.1393* (0.0779)	0.7462*** (0.0699)	-0.0449 (0.0414)	0.9258*** (0.0763)	-0.0556* (0.0329)	0.5026*** (0.1007)	-0.0027 (0.0657)	0.5851* (0.03536)	-0.0154 (0.1020)
United Kingdom	0.4518*** (0.0732)	-0.0498** (0.0254)	0.6460*** (0.0622)	-0.1464** (0.0705)	0.3655*** (0.1109)	-0.0758* (0.0445)	0.6492*** (0.1206)	-0.1533** (0.0782)	0.4828*** (0.1098)	0.1011 (0.0807)	0.1350 (0.1523)	0.0981 (0.0725)
United States	0.4065*** (0.1269)	-0.0944*** (0.0302)	0.7313*** (0.1243)	-0.0919*** (0.0344)	0.1695*** (0.0708)	-0.0826*** (0.0292)	0.7489** (0.3622)	-0.0772** (0.0360)	0.1195* (0.0707)	-0.0779** (0.0315)	0.1043 (0.8176)	-0.0540 (0.0459)

Notes: Numbers in the table are coefficient estimates with HAC standard errors in parentheses. The *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The inflation is denoted as π and proxied by CPI. And $U_{GAP}=U-U^*$.

Table 1.04. BL and FL EAPC over Time Horizons in Emerging & Frontier Markets

Periods	After 80's 1980:Q1-2016:Q1				After 90's 1990:Q1-2016:Q1				After 00's 2000:Q1-2016:Q1			
	BACKWARD-LOOKING		FORWARD-LOOKING		BACKWARD-LOOKING		FORWARD-LOOKING		BACKWARD-LOOKING		FORWARD-LOOKING	
Variables	π_{t-1}	U_{GAP}	π_{t+1}^e	U_{GAP}	π_{t-1}	U_{GAP}	π_{t+1}^e	U_{GAP}	π_{t-1}	U_{GAP}	π_{t+1}^e	U_{GAP}
Brazil	-	-	-	-	0.9041*** (0.0874)	0.2974 (0.4276)	0.5077*** (0.0401)	0.8294 (0.5782)	0.5023*** (0.1597)	-0.0132 (0.0431)	1.2063*** (0.4122)	-0.0356 (0.0462)
Chile	0.7355*** (0.0798)	-0.0664 (0.0429)	0.9106*** (0.0451)	-0.0523 (0.0533)	0.6565*** (0.0858)	-0.0577 (0.0395)	0.9049*** (0.0465)	-0.0803* (0.0492)	0.3150*** (0.1135)	-0.1243** (0.0670)	1.1182*** (0.3034)	-0.1299* (0.0738)
China	0.5746*** (0.0654)	-0.0277* (0.0143)	0.5367*** (0.1106)	-0.0364* (0.0203)	0.5183*** (0.0688)	-0.0481* (0.0264)	0.5221*** (0.1527)	-0.0467* (0.0262)	0.5651*** (0.0862)	-0.0013 (0.0282)	0.5594* (0.3184)	-0.0273* (0.0160)
Czech	-	-	-	-	0.5396*** (0.1171)	-0.0522 (0.0739)	0.4289*** (0.1159)	-0.0738* (0.0391)	0.3115** (0.1384)	-0.0982 (0.0707)	0.2125 (0.3554)	-0.1444* (0.0853)
Greece	0.9058*** (0.0286)	-0.0123 (0.0159)	0.5613*** (0.0834)	-0.0163 (0.0549)	0.8898*** (0.0427)	-0.0119 (0.0133)	0.8442*** (0.0901)	-0.0101 (0.0281)	0.5389*** (0.1069)	-0.0187 (0.0192)	1.1177*** (0.2270)	-0.0155 (0.0235)
Hungary	-	-	-	-	0.5463** (0.2335)	-0.1366 (0.1958)	0.4612*** (0.0988)	-0.2238 (0.1920)	0.0872 (0.1086)	-0.2410 (0.2527)	-0.0661 (0.9728)	-0.2595 (0.3038)
India	0.4686*** (0.0765)	-0.0620** (0.0277)	0.4190*** (0.0838)	-0.1562*** (0.0378)	0.4215*** (0.0822)	-0.1506*** (0.0442)	0.5258*** (0.2096)	-0.1326** (0.0576)	0.4204*** (0.1107)	-0.1175** (0.0576)	0.6434 (0.5338)	-0.1399* (0.0837)
Indonesia	0.6439*** (0.1485)	-0.0712 (0.1155)	0.6189*** (0.1462)	-0.0591 (0.1317)	0.6728*** (0.1507)	-0.0564 (0.1275)	0.6685*** (0.1548)	-0.0282 (0.1470)	0.1517 (0.1797)	0.3154 (0.3712)	0.7554*** (0.3056)	0.2431 (0.3622)
Malaysia	0.5434*** (0.1589)	-0.0426* (0.0226)	0.4253*** (0.1244)	-0.0571*** (0.0220)	0.4674*** (0.1233)	-0.0480* (0.0271)	0.4179*** (0.1679)	-0.0692** (0.0348)	0.1183 (0.1812)	-0.0675* (0.03811)	0.5377 (0.6037)	-0.0803* (0.0437)
Mexico	0.8778*** (0.0841)	0.2121 (0.2052)	0.9072*** (0.0300)	0.0404 (0.1741)	0.7153*** (0.0665)	0.0551 (0.2056)	0.9184*** (0.0918)	-0.0451 (0.1438)	0.1107 (0.0851)	-0.1895*** (0.0675)	0.6571*** (0.1062)	-0.0751* (0.0414)
Philippines	0.6027*** (0.0928)	-0.1999*** (0.0591)	0.5921*** (0.0784)	-0.0752** (0.0387)	0.5421*** (0.1510)	-0.1175** (0.0567)	0.6216*** (0.0581)	-0.0289** (0.0139)	0.3249*** (0.1375)	-0.0167 (0.0471)	0.5652*** (0.2885)	0.0026 (0.0411)
Poland	-	-	-	-	0.6058*** (0.1015)	0.0156 (0.0911)	0.7878*** (0.1041)	-0.4411 (0.4678)	0.4155*** (0.1325)	-0.0417** (0.0212)	0.8524*** (0.1750)	-0.0422* (0.0241)
Russia	-	-	-	-	0.6375*** (0.1403)	-1.1854 (1.2084)	0.4140*** (0.0537)	-1.4802 (1.6148)	0.5430*** (0.1337)	-0.1281*** (0.0500)	0.5714*** (0.1829)	-0.2154*** (0.0863)
South Africa	0.7289*** (0.0505)	-0.0008 (0.0290)	0.8722*** (0.0699)	0.0111 (0.0309)	0.6614*** (0.0864)	0.0002 (0.0280)	0.8970*** (0.0991)	0.0103 (0.0318)	0.5934*** (0.1149)	-0.0141 (0.0319)	0.9257*** (0.3588)	-0.0192 (0.0336)
Taiwan	0.4072** (0.2127)	-0.2695*** (0.0572)	0.5379*** (0.1741)	-0.2232*** (0.0713)	-0.1479* (0.0886)	-0.3292*** (0.0585)	0.0354 (0.2476)	-0.2636*** (0.0978)	0.0149 (0.0754)	-0.1834* (0.0968)	0.4622 (0.5004)	-0.0877 (0.1058)
Thailand	0.5648*** (0.0701)	-0.0496 (0.0315)	0.5958*** (0.1171)	-0.0909** (0.0465)	0.5249*** (0.0843)	-0.0778** (0.0385)	0.4950*** (0.1802)	-0.1309** (0.0573)	0.4337*** (0.0942)	-0.0282 (0.0556)	0.2918 (0.4648)	-0.0860 (0.0839)
Turkey	0.7795*** (0.0670)	0.0119 (0.1490)	0.7698*** (0.0414)	-0.0148 (0.0868)	0.8442*** (0.0713)	-0.0115 (0.1217)	0.8123*** (0.0369)	-0.0269 (0.0766)	0.7450*** (0.0602)	-0.0748 (0.0950)	0.8669*** (0.0884)	-0.0886 (0.0718)
Argentina	0.6792*** (0.1233)	-0.3090 (0.6578)	0.7832*** (0.0207)	0.0697 (0.1914)	0.6264*** (0.0981)	-0.1693 (0.1579)	0.7998*** (0.0068)	-0.1627* (0.0964)	0.7913*** (0.1041)	-0.40631* (0.2317)	0.5625*** (0.0797)	-0.2628** (0.1333)
Romania	-	-	-	-	0.3838* (0.2234)	-0.5001 (0.4835)	0.7679*** (0.1476)	0.4389 (0.3580)	0.8666*** (0.0469)	-0.0335 (0.0410)	0.9103*** (0.0621)	0.0077 (0.0520)
Venezuela	0.8261*** (0.1007)	-0.1267 (0.0797)	0.4273*** (0.1640)	0.0918 (0.2183)	0.8708*** (0.1027)	-0.1408* (0.0814)	0.8371*** (0.0860)	-0.3243*** (0.0821)	0.9075*** (0.1568)	-0.1538 (0.1055)	0.8859*** (0.1251)	-0.2921*** (0.0809)

Notes: Numbers in the table are coefficient estimates with HAC standard errors in parentheses. The *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The last three countries (Argentina, Romania, and Venezuela) are classified as frontier economies according to SP market classification, while other countries are emerging economies. The inflation is denoted as π and proxied by CPI. And $U_{GAP}=U-U^*$.

1.5.1.2. Observations for how Phillips curve behaves during tranquil and recessionary periods

The tables 1.05-1.06 present estimation results of Eq.(1.08) model where superscripts "N" and "R" indicate estimates for normal and recessionary periods respectively. In the left hand side of tables 1.05-1.06, results of backward-looking model show that the Phillips relation (${}^N U_{GAP}$) works in majority of developed countries during normal (tranquil) economic periods, but its significance remains limited at 10% level. Apparently, the coefficient gains statistically more significance in Canada, South Korea, Sweden, United Kingdom, and United States in individual cases, while it totally fails in few developed countries such as Belgium, Denmark, Finland, Italy, Singapore, and most of emerging and frontier countries. To generalize, when we exclude outliers, the average Phillips coefficient (${}^N U_{GAP}$) appears around -0.07 for developed market sample during normal (tranquil) periods.

Moreover, backward-looking fraction of inflation (${}^N \pi_{t-1}$) appears statistically significant at 1% level in majority of the sample during normal economic periods with exception of Romania where lagged inflation fails to be significant ambiguously. Its average magnitude in developed, emerging, and frontier markets is about 50.73%, 60.63%, and 67.78% respectively. This once again shows that most developed countries are less backward-looking comparing to emerging and frontier ones.

On the other hand, tables 1.05-1.06 blatantly show that the Phillips relation (${}^R U_{GAP}$) collapses and backward-looking fraction of inflation (${}^R \pi_{t-1}$) remarkably increases in magnitude within whole sample countries without any loss in significance during recessionary periods. The average coefficient of past inflation scales up from 50.73% to 56.34% in developed markets, from 60.63% to 67.10% in emerging markets, and from 67.78% to 90.91% in frontier markets. This indicates that markets become more inflation-sensitive during recessionary periods as backward-looking coefficient gains weight and significance.

On the right hand side of the tables 1.05-1.06, results of forward-looking model show that the Phillips relation (${}^N U_{GAP}$) works in majority of developed countries during normal economic periods with better significance levels comparing to backward-looking case. It is clear that Phillips coefficient (${}^N U_{GAP}$) gains a remarkable significance especially in Austria, Belgium, Denmark, Finland, France,

Germany, Japan, Switzerland, and United States. When we exclude insignificant results, the average Phillips coefficient (${}^N U_{GAP}$) appears as same as it was in backward-looking case, -0.07, for developed market sample during normal (tranquil) periods. In cases of emerging and frontier countries, forward-looking model generates alike results as backward-looking one, and in majority of these countries the Phillips relation does not work during both growing and non-growing periods.

Moreover, forward-looking fraction of inflation [${}^N E_t(\pi_{t+1})$] appears statistically significant at 1% level in majority of the sample during normal economic periods without any exceptions. Its average magnitude in developed, emerging, and frontier markets is about 62.05%, 58.53%, and 48.96% respectively. This indicates that developed countries are more forward-looking than emerging and frontier ones. Besides, Phillip relation (${}^R U_{GAP}$) fails to be valid throughout whole sample during recessionary periods, and forward-looking fraction of inflation [${}^R E_t(\pi_{t+1})$] considerably increases in magnitude within all sample countries without any loss in significance even in emerging and frontier markets. The average coefficient of expected inflation rises from 62.05% to 80.09% in developed markets; from 58.53% to 74.13% in emerging markets; and from 48.96% to 60.37% in frontier markets. This indicates that the dominance of expected inflation in forward-looking model increases in recessionary periods comparing to tranquil (normal) periods in all sampled countries disregarding their market classification. In other words, countries become more inflation-sensitive during recessionary periods as forward-looking coefficient gains weight and significance.

Notice that both backward- and forward-looking models estimate overall increase in weight and significance of inflation factor (past inflation in backward-looking case and expected future inflation in forward-looking case) during recessionary periods. We believe this picks up due to two issues. First, the Phillips coefficient loses its significance during recession, thus current inflation becomes more sensitive to past or expected future inflation. Second, both models do not incorporate past inflation and expected future inflation variables simultaneously in a hybrid form. Thus, we cannot clearly conclude whether markets become more backward- or forward-looking during recessionary periods or not. The findings only show us that inflation becomes more sensitive to its past or expected future values during recessionary periods and the Phillips relation demises.

In addition, our emerging and frontier markets pre-dominantly comprised by inflation-prone fragile countries those have experienced many non-growing periods since beginning of our analysis period (1980), however, developed markets have relatively lesser recession periods. This also might have some impact on limited increase in past inflation coefficient of backward-looking model in developed markets during recessionary periods, while the coefficient increases remarkably in emerging and frontier markets.

Table 1.05. BL and FL EAPC during Normal/Recession Periods in Develop Markets

Countries	Backward-Looking PC Model					Forward-Looking PC Model					Obs
	$N_{\pi_{t-1}}$	$N_{U_{GAP}}$	$R_{\pi_{t-1}}$	$R_{U_{GAP}}$	C	$N_{E_t(\pi_{t+1})}$	$N_{U_{GAP}}$	$R_{E_t(\pi_{t+1})}$	$R_{U_{GAP}}$	C	
Australia	0.5645*** (0.0739)	-0.0874* (0.0486)	0.4435*** (0.1757)	-0.1620 (0.1819)	0.0017*** (0.0004)	0.6755*** (0.1147)	-0.0900* (0.0476)	0.7845*** (0.2233)	-0.0344 (0.1456)	0.0015*** (0.0006)	145
Austria	0.4559*** (0.0942)	-0.0829* (0.0427)	0.4582*** (0.1388)	-0.3037** (0.1341)	0.0012*** (0.0002)	0.5608*** (0.0845)	-0.0607** (0.0285)	0.6664*** (0.1323)	-0.2564*** (0.0982)	0.0009*** (0.0002)	145
Belgium	0.5603*** (0.0927)	0.0184 (0.0363)	0.5982*** (0.1790)	0.1200 (0.0793)	0.0011*** (0.0002)	0.7012*** (0.0808)	-0.0363* (0.0197)	0.7783*** (0.0926)	-0.0134 (0.0697)	0.0005** (0.0002)	145
Canada	0.5248*** (0.1034)	-0.0883** (0.0389)	0.5856*** (0.1758)	-0.1611 (0.1082)	0.0013*** (0.0003)	0.7120*** (0.0660)	-0.0672** (0.0328)	0.8435*** (0.1354)	-0.0490 (0.1521)	0.0002 (0.0003)	145
Denmark	0.5514*** (0.0811)	-0.0342 (0.0247)	0.6855*** (0.1688)	0.0196 (0.0472)	0.0014*** (0.0003)	0.5598*** (0.1166)	-0.0219* (0.0113)	0.7644*** (0.1783)	-0.0324 (0.0416)	0.0004 (0.0004)	145
Finland	0.6161*** (0.0678)	-0.0154 (0.0341)	0.7213*** (0.1417)	-0.0588 (0.0574)	0.0010*** (0.0003)	0.5473*** (0.0620)	-0.0641*** (0.0207)	0.7787*** (0.1770)	-0.0648 (0.0427)	0.0003 (0.0003)	145
France	0.5113*** (0.0488)	-0.0614* (0.0366)	0.5886*** (0.0913)	0.0760 (0.1682)	0.0003* (0.0001)	0.5955*** (0.0355)	-0.0444** (0.0214)	0.8046*** (0.1194)	0.0331 (0.2915)	-0.0001 (0.0002)	145
Germany	0.4294** (0.1832)	-0.0921* (0.0516)	0.4958** (0.2037)	-0.1189 (0.0768)	0.0026*** (0.0006)	0.5853*** (0.1047)	-0.0341** (0.0178)	0.7944*** (0.1535)	-0.0308 (0.0409)	0.0006* (0.0004)	145
Ireland	0.4929*** (0.1368)	-0.0455* (0.0261)	0.5540** (0.2225)	-0.0276 (0.0556)	0.0007** (0.0004)	0.5154*** (0.1150)	-0.0479* (0.0246)	0.6461** (0.2170)	-0.0642 (0.0638)	0.0008 (0.0006)	145
Italy	0.5896*** (0.0496)	0.0283* (0.0145)	0.7061*** (0.0599)	-0.0476** (0.0220)	0.0004** (0.0002)	0.9769*** (0.0606)	-0.0069 (0.0256)	0.9924*** (0.0913)	-0.0657* (0.0369)	0.0004 (0.0003)	145
Japan	0.2183** (0.1053)	-0.2154* (0.1274)	0.3865** (0.1671)	-0.5047** (0.2302)	0.0009** (0.0004)	0.5259*** (0.1433)	-0.2260** (0.1161)	1.0723*** (0.4230)	-0.4751** (0.2375)	0.0006* (0.0003)	145
Netherlands	0.5081*** (0.1009)	-0.0349* (0.0206)	0.5503*** (0.1319)	-0.0533 (0.0382)	0.0010*** (0.0002)	0.5107*** (0.1738)	-0.0253* (0.0149)	0.6894*** (0.2071)	-0.0033 (0.0482)	0.0011*** (0.0004)	145
Norway	0.4815*** (0.0802)	-0.0993* (0.0570)	0.5603*** (0.1569)	-0.4354* (0.2500)	0.0022*** (0.0004)	0.5182*** (0.0733)	-0.0264* (0.0155)	0.7156*** (0.1940)	-0.3042* (0.1782)	0.0010** (0.0005)	145
Portugal	0.5397*** (0.0723)	-0.0549* (0.0324)	0.6637*** (0.1525)	-0.0748 (0.0667)	0.0026*** (0.0006)	0.5512*** (0.0757)	-0.0388* (0.0208)	0.6513*** (0.1967)	-0.0377 (0.0647)	0.0020*** (0.0008)	144
Singapore	0.5658*** (0.1048)	0.0212 (0.0252)	0.2786 (0.1860)	-0.0504 (0.0540)	0.0010*** (0.0003)	0.6629*** (0.1117)	-0.0033 (0.0234)	0.1974 (0.2682)	-0.0194 (0.0434)	0.0006 (0.0004)	145
South Korea	0.4615*** (0.0597)	-0.0689** (0.0314)	0.5193*** (0.0886)	0.5234 (0.6053)	0.0017*** (0.0004)	0.5371*** (0.1305)	-0.1028** (0.0529)	0.9613*** (0.2141)	0.1518 (0.381)	0.0025*** (0.0007)	145
Spain	0.5410*** (0.1072)	-0.0345* (0.0193)	0.6498*** (0.1734)	-0.0125 (0.0419)	0.0021*** (0.0007)	0.6508*** (0.1097)	-0.0434* (0.0257)	0.7359*** (0.1794)	-0.0096 (0.0493)	0.0023*** (0.0007)	145
Sweden	0.5611*** (0.0776)	-0.0563** (0.0275)	0.6200*** (0.1299)	-0.0179 (0.1120)	0.0010*** (0.0003)	0.6756*** (0.1138)	-0.0610** (0.0291)	0.9789*** (0.2319)	-0.0515 (0.1242)	0.0006 (0.0004)	145
Switzerland	0.6162*** (0.0639)	-0.0753* (0.0447)	0.5732*** (0.1268)	-0.0472 (0.2333)	0.0006*** (0.0002)	0.5943*** (0.0913)	-0.1453** (0.0698)	0.7924*** (0.1576)	0.0151 (0.2776)	0.0005 (0.0003)	145
United Kingdom	0.4635*** (0.0490)	-0.0470** (0.0235)	0.5018*** (0.1514)	-0.1163 (0.1295)	0.0004 (0.0003)	0.6308*** (0.0680)	-0.1885** (0.0822)	0.7848*** (0.1744)	-0.0204 (0.1275)	0.0016*** (0.0005)	145
United States	0.4019*** (0.1174)	-0.0921*** (0.0291)	0.4078*** (0.1253)	-0.0770 (0.0637)	0.0018*** (0.0004)	0.7431*** (0.1378)	-0.0746** (0.0297)	0.8020*** (0.1989)	-0.0952 (0.0731)	0.0007 (0.0005)	145

Notes: Numbers in the table are coefficient estimates with HAC-robust standard errors in parentheses. The *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The superscripts "N" and "R" indicate estimations for normal (growing) and recessionary periods respective.

Table 1.06. BL and FL PC Model during Normal/Recession Periods in Emerging and Frontier Markets

Countries	Backward-Looking PC Model					Forward-Looking PC Model					Obs
	$N_{\pi_{t-1}}$	$N_{U_{GAP}}$	$R_{\pi_{t-1}}$	$R_{U_{GAP}}$	C	$N_{E_t(\pi_{t+1})}$	$N_{U_{GAP}}$	$R_{E_t(\pi_{t+1})}$	$R_{U_{GAP}}$	C	
Brazil	0.6328*** (0.1395)	0.2578 (0.3374)	0.7273*** (0.2099)	-0.2465 (0.6209)	0.0052*** (0.0019)	0.4545*** (0.0938)	0.6443 (0.5081)	0.5691*** (0.1420)	0.0413 (1.1816)	0.0130** (0.0052)	106
Chile	0.7207*** (0.0955)	-0.0889** (0.0391)	0.7888*** (0.1630)	-0.0273 (0.1157)	0.0020*** (0.0006)	0.9057*** (0.0484)	-0.0396 (0.0280)	0.9235*** (0.1086)	-0.0797 (0.1388)	0.0005 (0.0005)	121
China	0.6191*** (0.0624)	-0.0248* (0.0144)	0.6318*** (0.1178)	-0.0110 (0.0607)	0.0011*** (0.0003)	0.5816*** (0.1094)	-0.0452* (0.0260)	0.7683*** (0.1497)	0.0189 (0.0958)	0.0004 (0.0005)	145
Czech	0.5375*** (0.2952)	0.0503 (0.1047)	0.6318** (0.3166)	-0.2434 (0.2155)	0.0015** (0.0007)	0.5118*** (0.2952)	-0.0404 (0.0839)	0.7479** (0.3762)	-0.1972 (0.1752)	-0.0004 (0.0009)	93
Greece	0.9730*** (0.0301)	0.0002 (0.0259)	0.8208*** (0.0721)	-0.0186 (0.0424)	0.0008*** (0.0003)	0.9324*** (0.1401)	-0.0104 (0.0526)	0.2145 (0.1760)	-0.0226 (0.1198)	0.0036*** (0.0013)	145
Hungary	0.4646* (0.2752)	-0.2417 (0.2759)	0.6549** (0.3236)	0.0656 (0.4856)	0.0052* (0.0028)	0.5314*** (0.1082)	-0.4268 (0.3061)	0.6037*** (0.1207)	0.1812 (0.4789)	0.0018 (0.0019)	101
India	0.5483*** (0.1116)	-0.0390 (0.0249)	0.5807*** (0.1350)	-0.0797 (0.0488)	0.0055*** (0.0008)	0.4984*** (0.1071)	-0.0896** (0.0444)	0.6857*** (0.1477)	-0.0136 (0.1004)	0.0068*** (0.0008)	145
Indonesia	0.5892*** (0.0474)	-0.0284 (0.0732)	0.6152*** (0.0932)	0.1966 (0.7892)	0.0060*** (0.0007)	0.5592*** (0.0551)	-0.0013 (0.0631)	0.6401*** (0.1434)	-0.0192 (0.9998)	0.0063*** (0.0009)	145
Malaysia	0.5217*** (0.1521)	-0.0391** (0.0182)	-0.0311 (0.4490)	-0.0479 (0.0815)	0.0011* (0.0006)	0.5452*** (0.1602)	-0.0626** (0.0263)	0.0743 (0.3487)	-0.0495 (0.0835)	0.0007 (0.0005)	125
Mexico	0.6102*** (0.0894)	0.2117 (0.2023)	0.7227*** (0.1217)	0.7032 (0.5722)	0.0064*** (0.0021)	0.7361*** (0.0852)	0.1043 (0.1543)	0.9072*** (0.1192)	0.3224 (0.6259)	0.0043** (0.0018)	145
Philippines	0.6119*** (0.0392)	-0.0570** (0.0257)	0.6645*** (0.2410)	-0.2853** (0.1173)	0.0030*** (0.0005)	0.4902*** (0.0750)	-0.0516** (0.0256)	0.7646*** (0.1833)	-0.2211** (0.1025)	0.0043*** (0.0008)	145
Poland	0.6309** (0.2698)	-0.2459 (0.2949)	0.7186** (0.3555)	0.1151 (0.4710)	0.0065* (0.0035)	0.4408*** (0.0967)	-0.1187 (0.1273)	0.6725*** (0.1188)	-1.5115 (1.3253)	0.0023 (0.0028)	109
Russia	0.5994** (0.2596)	0.2381 (0.4535)	0.6143** (0.2697)	-2.2745 (2.8064)	0.0246* (0.0145)	0.4576** (0.2128)	0.1887 (0.4116)	0.6822** (0.3338)	-2.7840 (3.5023)	0.0225** (0.0106)	100
South Africa	0.5832*** (0.0549)	-0.0270 (0.0254)	0.6988*** (0.0869)	0.0934 (0.0625)	0.0027*** (0.0005)	0.5118*** (0.0942)	-0.0350 (0.0251)	0.9690*** (0.1094)	0.0988* (0.0538)	0.0017* (0.0009)	145
Taiwan	0.5311** (0.2633)	-0.2679*** (0.0649)	0.5895** (0.2446)	-0.2745 (0.1709)	0.0020*** (0.0004)	0.5265** (0.1946)	-0.2569*** (0.0858)	0.6322*** (0.2383)	-0.1971 (0.2506)	0.0015*** (0.0005)	145
Thailand	0.4898*** (0.1302)	-0.0464 (0.0358)	0.5730*** (0.1682)	-0.0638 (0.0809)	0.0017*** (0.0004)	0.5716*** (0.1475)	-0.0837 (0.0525)	0.7290*** (0.1950)	-0.0924 (0.0938)	0.0014** (0.0005)	144
Turkey	0.6434*** (0.0915)	0.0346 (0.1650)	0.7029*** (0.1482)	-0.0884 (0.3256)	0.0077*** (0.0024)	0.6954*** (0.0368)	-0.0712 (0.0882)	0.8248*** (0.0571)	-0.0219 (0.2039)	0.0056*** (0.0018)	145
Argentina	0.6617*** (0.1031)	-0.3075 (0.2209)	1.0092*** (0.2871)	0.4933 (1.2137)	0.0187** (0.0088)	0.6110*** (0.0461)	0.0104 (0.1737)	0.6912*** (0.0590)	0.0944 (0.2598)	-0.0011 (0.0015)	129
Romania	0.1873 (0.2207)	0.0304 (0.2335)	0.4118 (0.2714)	-1.0172 (0.9186)	0.0250** (0.0107)	0.4559*** (0.1008)	0.0402 (0.1106)	0.5862** (0.2366)	0.8197 (0.6136)	0.0027 (0.0039)	102
Venezuela	0.6938*** (0.1100)	0.0253 (0.0541)	0.8090*** (0.1287)	-0.3190* (0.1713)	0.0109*** (0.0029)	0.4020*** (0.1053)	0.0740 (0.0819)	0.5337*** (0.1249)	0.0695 (0.2545)	0.0221*** (0.0047)	112

Notes: Numbers in the table are coefficient estimates with HAC standard errors in parentheses. The *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The superscripts "N" and "R" indicate estimations for normal (tranquil) and recessionary periods respective. The last three countries (Argentina, Romania, Venezuela) are classified as Frontier markets according to S&P market classification.

1.5.1.3. Panel OLS estimation of classical PC

For robustness, we employ Panel OLS analysis in order to get generalized conclusion for observation that we have already explored on country-specific

examination above. Following guidelines in table 1.02, we run Redundant Fixed Effect and Breush-Pagan LM tests for both backward- and forward-looking EAPC. As an aftermath, we find out that both tests signalize of existence of fixed- and random-effects at 1% significance level. Therefore, we conduct Hausman test for final decision making in model selection. We report results of the Hausman test given at Eq.(1.12) in table 1.07 where the outcome recommends using FE specification for both backward- and forward-looking PC models by rejecting the null hypothesis with probability close to zero.

Table 1.07. Results for Correlated Random Effects - Hausman Test

Model	Redundant Fixed Effect	Breush-Pagan LM	Hausman Test
BL	187.8254 (0.0000)	182.0554 (0.0000)	209.3493 (0.0000)
FL	215.0347 (0.0000)	178.9009 (0.0000)	87.7315 (0.0000)

Notes: BL and FL represent Backward-Looking and Forward-Looking models respectively. The Chi-square statistics are given in the columns with probabilities of rejecting null hypothesis in parentheses. The null hypothesis of the Redundant Fixed Effect test is "no fixed effects"; whereas the null hypothesis of Breush-Pagan LM test is "no random effects". The null hypothesis of the Hausman test is H_0 : Both FE and RE estimators are consistent, but RE estimators are more efficient than FE. The alternative hypothesis of the Hausman test is H_1 : RE estimators are inconsistent, FE estimators are consistent. The Hausman degree of freedom of chi-square for both models is 4.

Even though Hausman test suggests to use FE specification, we report results of pooled, RE, and FE panel OLS estimations of EAPC for whole sample (41 countries) in order to make a broad comparison in Table 1.08. Notice that all panel models (pooled, RE, and FE) generate close estimates for inflation dynamics, but the appropriate one is FE specification in both backward- and forward-looking cases. The R-square value of FE backward-looking specification indicates that explanatory factors account nearly 68% variations in current inflation, and Phillips coefficient is estimated as -0.07 during growing economic periods at 5% significance level. It indicates that a percentage increase in unemployment gap decreases inflation by 0.07%. The Phillips coefficient, however, sharply changes to -0.14 and loses its significance totally during recessionary periods. The coefficient of π_t^e during non-recessionary period stakes value of 0.4759 at 1% significance level which indicates that 47.59% of current inflation (π_t) is formed by past period's inflation (π_{t-1}). And it increases to 0.8441 during recessionary periods preserving its significance at 1% level. This implies that share of past inflation (π_{t-1}) in current inflation (π_t)

jumps from 47.59% to 84.41%. The pooled and RE specifications also derive similar results due to Swamy-Arora (1972) estimator of the variance components of RE where σ_u (cross-section random) gets rho number of zero and σ_e (idiosyncratic random) gets 1. This means the variance of RE is entirely comprised of idiosyncratic random, and the weight of cross-section random is zero. Thus, both pooled and RE models generate similar results.

Table 1.08. OLS Panel Estimation of EAPC during Normal/Recession Periods

Variables	Backward-looking			Forward-looking		
	<i>Pooled</i>	<i>Fixed</i>	<i>Random</i>	<i>Pooled</i>	<i>Fixed</i>	<i>Random</i>
Intercept	0.0032*** (0.0007)	0.0037*** (0.0007)	0.0032*** (0.0007)	0.0030*** (0.0002)	0.0033*** (0.0005)	0.0031*** (0.0005)
$N\pi_t^e$	0.5369*** (0.0750)	0.4759*** (0.0679)	0.5369*** (0.0750)	0.5503*** (0.0110)	0.5097*** (0.0778)	0.5373*** (0.0777)
NU_{GAP}	-0.0899*** (0.0372)	-0.0714** (0.0327)	-0.0899*** (0.0372)	-0.0532** (0.0236)	-0.0380** (0.0191)	-0.0487** (0.0211)
$R\pi_t^e$	0.8848*** (0.1326)	0.8441*** (0.1227)	0.8848*** (0.1326)	0.6281*** (0.0162)	0.6142*** (0.1129)	0.6239*** (0.1149)
RU_{GAP}	-0.1507 (0.1150)	-0.1411 (0.1148)	-0.1507 (0.1150)	-0.0929 (0.0554)	-0.0829 (0.0927)	-0.0902 (0.0930)
Weighted R ²	-	-	0.6676	-	-	0.7433
Unweighted R ²	0.6676	0.6802	0.6676	0.7560	0.7641	0.7559
Panel Obs.	5587	5587	5587	5591	5591	5591
σ_u	-	-	0.0000	-	-	0.0043
σ_e	-	-	1.0000	-	-	0.9957

Notes: The Panel OLS estimation methodology is used to determine dynamics of inflation, π_t , with 41 cross-sections and 144 periods (1980Q2-2016Q1). The π_t^e equates to past inflation (π_{t-1}) in backward-looking model, while it takes value of $E_t(\pi_{t+1})$ in forward-looking case. The superscripts "N" and "R" indicate estimations for normal (growing) and recessionary periods respective. The numbers in the table are estimated coefficients with white standard errors and covariances in the parenthesis, and *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The σ_u and σ_e represent Swamy and Arora estimator of variance components of random effect (cross-section and idiosyncratic respectively) with rho numbers.

On the right hand side of table 1.08, the R-square value of FE forward-looking specification account relatively higher (76%) variations of current inflation comparing to backward-looking model. The Phillips coefficient shrinks to nearly half; it is about -0.038 significant at 5% level. Similar to backward-looking case, the coefficient gets twofold in absolute magnitude (-0.0829) and loses its statistical significance during recessionary periods. The Phillips coefficient indicates that a percentage increase in unemployment gap decreases inflation by 0.04%.

The coefficient of π_t^e during growing period stakes value of 0.5097 at 1% significance level which indicates that 51% of current inflation (π_t) is formed by expected future inflation ($E_t(\pi_{t+1})$). This coefficient increases to 0.6142 during non-growing periods preserving its significance at 1% level. The similar scenario is observed in backward-looking case. This indicates that share of expected future inflation ($E_t(\pi_{t+1})$) in current inflation (π_t) jumps from 50.97% to 61.42%. It sheds a light on that inflation becomes more sensitive to expected inflation (to lagged inflation in backward-looking case) and Phillips relation collapses during recessionary periods. The pooled and RE specifications also derive alike results as σ_u (cross-section random) gets rho number of zero and σ_e (idiosyncratic random) gets rho number of 1.

The panel results reveal that the Phillips relation collapses during recessionary periods, and inflation becomes more sensitive to its lagged (in case of backward-looking) and expected future values (in case of forward-looking) as the same scenario was observed in country-based time-series OLS analyses. Although absolute magnitudes of π_{t-1} and $E_t(\pi_{t+1})$ increase about 0.36 and 0.11 respectively during recessionary periods, it won't show that inflation becomes more backward-looking during these periods as models do not incorporate these two variables in a hybrid framework. In order to clearly observe this behaviour of inflation, we schedule a hybrid specification of NKPC where both backward- and forward-looking coefficients are integrated into single model.

1.5.2. Results for NKPC versions

1.5.2.1. Country-based GMM estimations of hybrid NKPC

Table 1.09 present results of GMM estimation of three different hybrid NKPC models with their restricted and unrestricted structural parameters for sampled 41 countries over 1980Q1-2016Q1. This table also reports Sargan-Hansen's J-statistics for instrumental variables that are used in the model to avoid endogeneity problem caused by autoregressive term and expected inflation. The null hypothesis of the test is that $J=0$, included instruments are makes sense and valid, i.e. uncorrelated with the error term, and the dropped ones are correctly left out the model. Notice that all reported J-statistics are far from the rejection of the null, giving us the confidence that our overidentification restrictions are appropriate.

Table 1.09. Results for Hybrid NKPC

Market	Country	Model	HYBRID NKPC						
			γ_b	γ_r	λ_{ulc}	λ_{unlc}	λ_{tuc}	J-Stat.	Obs.
D	Australia	1	0.2001*** (0.0531)	0.7677*** (0.0571)	0.0290*** (0.0100)	-	-	11.7745 [0.8136]	137
		2	0.1850*** (0.0503)	0.7698*** (0.0509)	0.0377*** (0.0135)	0.0109** (0.0047)	-	12.6453 [0.8122]	137
		3	0.2098*** (0.0734)	0.7993*** (0.0769)	-	-	0.0220** (0.0108)	8.0747 [0.9466]	137
D	Austria	1	0.4166*** (0.0573)	0.5837*** (0.0624)	0.0269** (0.0136)	-	-	8.0313 [0.8877]	138
		2	0.3859*** (0.0536)	0.6131*** (0.0558)	0.0341** (0.0152)	0.0084* (0.0049)	-	8.3018 [0.9394]	138
		3	0.3832*** (0.0587)	0.6038*** (0.0593)	-	-	0.0231** (0.0101)	7.3691 [0.9466]	138
D	Belgium	1	0.2949*** (0.0394)	0.6702*** (0.0590)	0.0337** (0.0167)	-	-	14.2075 [0.5833]	138
		2	0.2836*** (0.0407)	0.6558*** (0.0557)	0.0386** (0.0169)	0.0083** (0.0037)	-	15.7189 [0.6122]	138
		3	0.3041*** (0.0432)	0.6823*** (0.0507)	-	-	0.0185*** (0.0072)	12.2286 [0.7281]	138
D	Canada	1	0.2876*** (0.0695)	0.7226*** (0.0710)	0.0334** (0.0169)	-	-	12.5793 [0.4808]	137
		2	0.2664*** (0.0744)	0.7301*** (0.0728)	0.1093*** (0.0237)	0.0313*** (0.0091)	-	11.9742 [0.6084]	137
		3	0.3121*** (0.0741)	0.7322*** (0.0773)	-	-	0.0402** (0.0202)	11.5936 [0.4788]	137
D	Denmark	1	0.4953*** (0.0593)	0.5305*** (0.0604)	0.0413* (0.0226)	-	-	9.6584 [0.9173]	138
		2	0.5066*** (0.0592)	0.5387*** (0.0633)	0.0526** (0.0257)	0.0117** (0.0059)	-	11.8380 [0.8924]	138
		3	0.4727*** (0.0687)	0.5552*** (0.0797)	-	-	0.0276* (0.0161)	9.7600 [0.6370]	138
D	Finland	1	0.4236*** (0.0188)	0.5057*** (0.0180)	0.0386*** (0.0082)	-	-	21.4938 [0.1603]	138
		2	0.3517*** (0.0177)	0.5396*** (0.0186)	0.0837*** (0.0097)	0.0210*** (0.0037)	-	21.7897 [0.2415]	138
		3	0.4194*** (0.021)	0.5501*** (0.0245)	-	-	0.0255*** (0.0065)	19.6791 [0.1846]	138
D	France	1	0.3058*** (0.0263)	0.6710*** (0.0272)	0.0335*** (0.0083)	-	-	20.8148 [0.2347]	138
		2	0.2907*** (0.0249)	0.6852*** (0.0264)	0.0292*** (0.0076)	0.0024*** (0.0010)	-	19.9627 [0.3349]	138
		3	0.2854*** (0.0266)	0.6888*** (0.0287)	-	-	0.0065*** (0.0020)	14.6779 [0.6187]	138
D	Germany	1	0.2741*** (0.0747)	0.7273*** (0.0799)	0.0273*** (0.0104)	-	-	16.1016 [0.5166]	137
		2	0.2975*** (0.0697)	0.6752*** (0.0720)	0.0264*** (0.0099)	0.0067* (0.0035)	-	16.8825 [0.5978]	137
		3	0.2251*** (0.0797)	0.7607*** (0.0857)	-	-	0.0252*** (0.0094)	16.5517 [0.4851]	137
D	Ireland	1	0.4224*** (0.0718)	0.5803*** (0.0824)	0.0289*** (0.0107)	-	-	13.0153 [0.7352]	135
		2	0.4360*** (0.0818)	0.5410*** (0.0891)	0.0264** (0.0126)	0.0168* (0.0088)	-	13.0992 [0.5946]	135
		3	0.4461*** (0.0721)	0.5364*** (0.0765)	-	-	0.0339** (0.0166)	14.4936 [0.6319]	135
D	Italy	1	0.4481*** (0.0261)	0.5638*** (0.0285)	0.0198** (0.0096)	-	-	13.3891 [0.7098]	138
		2	0.4654*** (0.0255)	0.5440*** (0.0290)	0.0312*** (0.0099)	0.0075* (0.0041)	-	16.2741 [0.5734]	138
		3	0.5206*** (0.0317)	0.4854*** (0.0331)	-	-	0.0024 (0.0077)	13.9613 [0.6698]	138

Notes: Numbers in the table are coefficient estimates of HAC-robust GMM technique with "Auto-Schwarz" maximum four lags specification under Bartlett Kernel and Newey-West fixed bandwidth methodology that iterates to convergence. The HAC standard errors are presented in parentheses, and *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The J-Statistics indicates over-identification with probability in brackets, and the market classification is in S&P standards.

Table 1.09. (continues)

Market	Country	Model	HYBRID NKPC					J-Stat.	Obs.
			γ_b	γ_f	λ_{ulc}	λ_{unlc}	λ_{tuc}		
D	Japan	1	0.1332** (0.0613)	0.8134*** (0.0697)	0.0367** (0.0161)	-	-	14.6713 [0.6191]	137
		2	0.0849* (0.0496)	0.8687*** (0.0600)	0.0175* (0.0103)	0.0071*** (0.0027)	-	14.9201 [0.6012]	137
		3	0.1041** (0.0491)	0.8554*** (0.0560)	-	-	0.0145*** (0.0055)	14.1461 [0.5878]	137
D	Netherlands	1	0.3252*** (0.0200)	0.5743*** (0.0306)	0.0212*** (0.0028)	-	-	16.8413 [0.3959]	138
		2	0.4028*** (0.0465)	0.5134*** (0.0459)	0.0272*** (0.0066)	0.0131*** (0.0052)	-	21.2076 [0.2171]	106
		3	0.3445*** (0.0272)	0.5637*** (0.0304)	-	-	0.0302*** (0.0084)	21.3054 [0.3202]	103
D	Norway	1	0.5095*** (0.0809)	0.5096*** (0.1026)	0.0921*** (0.0353)	-	-	14.3448 [0.4996]	137
		2	0.4682*** (0.1042)	0.5556*** (0.1305)	0.1181*** (0.0405)	0.0517** (0.0214)	-	14.6671 [0.5491]	137
		3	0.4678*** (0.1111)	0.5721*** (0.1281)	-	-	0.0950** (0.0403)	12.4481 [0.3309]	138
D	Portugal	1	0.3513*** (0.0396)	0.5262*** (0.0523)	0.1009*** (0.0215)	-	-	11.4438 [0.8326]	115
		2	0.3961*** (0.0240)	0.5030*** (0.0390)	0.0772*** (0.0146)	0.0087** (0.0042)	-	24.2091 [0.1139]	115
		3	0.4063*** (0.0250)	0.5535*** (0.0266)	-	-	0.0163** (0.0085)	21.4370 [0.1234]	115
D	Singapore	1	0.2432*** (0.0632)	0.6905*** (0.1513)	0.0598** (0.0244)	-	-	13.6773 [0.4740]	136
		2	0.2457*** (0.0634)	0.5717*** (0.1105)	0.0553** (0.0260)	0.0961*** (0.0293)	-	14.1336 [0.5888]	136
		3	0.2820*** (0.0670)	0.5878*** (0.1279)	-	-	0.1281*** (0.0372)	12.9846 [0.5277]	136
D	South Korea	1	0.1871** (0.0781)	0.7649*** (0.0905)	0.0608** (0.0288)	-	-	10.9859 [0.7536]	138
		2	0.2998*** (0.1055)	0.7208*** (0.1088)	0.0637** (0.0298)	0.0209** (0.0109)	-	10.3386 [0.6660]	138
		3	0.3230*** (0.0995)	0.7075*** (0.1084)	-	-	0.0438** (0.0194)	10.9284 [0.7577]	138
D	Spain	1	0.4188*** (0.0489)	0.5272*** (0.0504)	0.0443*** (0.0137)	-	-	15.4293 [0.5646]	137
		2	0.3901*** (0.0475)	0.5717*** (0.0485)	0.0232** (0.0117)	0.0091** (0.0043)	-	15.9168 [0.6628]	137
		3	0.4418*** (0.0529)	0.5345*** (0.0523)	-	-	0.0158* (0.0085)	13.9899 [0.6678]	137
D	Sweden	1	0.3474*** (0.0624)	0.5889*** (0.0574)	0.0483** (0.0245)	-	-	17.9176 [0.3941]	138
		2	0.3029*** (0.0535)	0.5627*** (0.0540)	0.0854*** (0.0273)	0.0417*** (0.0129)	-	20.102 [0.3885]	138
		3	0.2882*** (0.0553)	0.6465*** (0.0571)	-	-	0.0675*** (0.0258)	19.0385 [0.3263]	138
D	Switzerland	1	0.4754*** (0.0208)	0.5852*** (0.0304)	0.0535*** (0.0038)	-	-	15.3584 [0.4986]	137
		2	0.3884*** (0.019)	0.5467*** (0.0137)	0.0386*** (0.0013)	0.0110*** (0.0011)	-	22.8789 [0.1953]	137
		3	0.3519*** (0.0268)	0.5935*** (0.0213)	-	-	0.0062* (0.0035)	16.0174 [0.5913]	137
D	United Kingdom	1	0.1585** (0.0705)	0.8094*** (0.0777)	0.0923*** (0.0228)	-	-	13.9618 [0.5284]	137
		2	0.1450** (0.0698)	0.7902*** (0.0786)	0.0779*** (0.0222)	0.0271** (0.0128)	-	17.2070 [0.4404]	137
		3	0.2062*** (0.0729)	0.7214*** (0.0791)	-	-	0.0735*** (0.0224)	18.2123 [0.2517]	137
D	United States	1	0.1731*** (0.0443)	0.8259*** (0.0502)	0.0203** (0.0089)	-	-	10.7636 [0.8686]	137
		2	0.2031*** (0.0479)	0.7903*** (0.0553)	0.0189** (0.0091)	0.0041* (0.0024)	-	10.4643 [0.9157]	137
		3	0.2138*** (0.0387)	0.7770*** (0.0440)	-	-	0.0094** (0.0047)	10.9867 [0.8573]	137

Table 1.09. (continues)

Market	Country	Model	HYBRID NKPC					J-Stat.	Obs.
			γ_b	γ_r	λ_{ulc}	λ_{unlc}	λ_{tuc}		
E	Brazil	1	0.5327*** (0.0045)	0.4411*** (0.0403)	0.0610*** (0.0205)	-	-	17.1314 [0.2492]	85
		2	0.5400*** (0.0189)	0.4894*** (0.0369)	0.0638* (0.0373)	-0.0054 (0.0085)	-	17.5098 [0.4884]	84
		3	0.5151*** (0.0034)	0.3782*** (0.0348)	-	-	0.0101* (0.0060)	18.6200 [0.1800]	85
E	Chile	1	0.6533*** (0.0372)	0.3235*** (0.0369)	-0.0281 (0.0189)	-	-	15.3696 [0.5689]	116
		2	0.6926*** (0.0416)	0.2499*** (0.0411)	-0.0235 (0.0191)	0.0174* (0.0095)	-	15.0304 [0.7207]	116
		3	0.6885*** (0.0419)	0.2628*** (0.0409)	-	-	0.0226 (0.0175)	14.4687 [0.6337]	116
E	China	1	0.3811*** (0.0502)	0.6155*** (0.0521)	0.0867* (0.0479)	-	-	10.6637 [0.8735]	138
		2	0.4241*** (0.0449)	0.5406*** (0.0484)	0.0874* (0.0497)	0.0384** (0.0190)	-	12.6101 [0.8579]	138
		3	0.2665*** (0.0633)	0.7339*** (0.0721)	-	-	0.1189*** (0.0436)	8.2636 [0.8751]	138
E	Czech Republic	1	0.5223*** (0.0378)	0.4689*** (0.0601)	0.0738** (0.0315)	-	-	11.7655 [0.8141]	80
		2	0.5700*** (0.0375)	0.3009*** (0.0667)	0.1512*** (0.0352)	0.0235** (0.0098)	-	13.0874 [0.8341]	80
		3	0.5740*** (0.0393)	0.4056*** (0.0586)	-	-	0.0409* (0.0225)	12.1574 [0.7905]	80
E	Greece	1	0.3997*** (0.0493)	0.5851*** (0.0526)	-0.0076 (0.0214)	-	-	11.5086 [0.6457]	137
		2	0.3876*** (0.0501)	0.6206*** (0.0548)	-0.0060 (0.0218)	0.0036 (0.0070)	-	12.5570 [0.6365]	137
		3	0.3436*** (0.0516)	0.6515*** (0.0541)	-	-	0.0034 (0.0150)	9.2858 [0.7510]	137
E	Hungary	1	0.5471*** (0.0282)	0.4305*** (0.0396)	0.0433*** (0.0141)	-	-	10.7756 [0.5482]	94
		2	0.4999*** (0.0344)	0.4641*** (0.0536)	0.0460* (0.0241)	0.0267** (0.0118)	-	10.3308 [0.5009]	94
		3	0.5481*** (0.0546)	0.4016*** (0.0828)	-	-	0.0775*** (0.0294)	6.6715 [0.3523]	94
E	India	1	0.5471*** (0.0448)	0.3910*** (0.0539)	0.0789*** (0.0289)	-	-	20.6854 [0.2407]	138
		2	0.4915*** (0.0465)	0.4459*** (0.0516)	0.0595** (0.0255)	0.1127*** (0.0308)	-	19.9319 [0.3987]	138
		3	0.4873*** (0.0465)	0.4388*** (0.0512)	-	-	0.1389*** (0.0389)	19.7114 [0.1833]	138
E	Indonesia	1	0.5025*** (0.0536)	0.3751*** (0.0711)	0.0189* (0.0113)	-	-	15.4270 [0.4211]	128
		2	0.4737*** (0.0455)	0.4321*** (0.0589)	0.0195* (0.0113)	0.0311** (0.0126)	-	15.4199 [0.8013]	128
		3	0.5114*** (0.0553)	0.3902*** (0.0707)	-	-	0.0420** (0.0177)	15.1864 [0.5821]	128
E	Malaysia	1	0.4307*** (0.0463)	0.5103*** (0.0681)	0.0265** (0.0133)	-	-	16.4223 [0.5631]	115
		2	0.3801*** (0.0536)	0.5140*** (0.0614)	0.0535*** (0.0128)	0.1086*** (0.0288)	-	16.3884 [0.4262]	117
		3	0.4044*** (0.0455)	0.5090*** (0.0533)	-	-	0.0344** (0.0175)	17.2395 [0.6965]	115
E	Mexico	1	0.5817*** (0.0374)	0.4068*** (0.0389)	0.0162** (0.0080)	-	-	9.8304 [0.6308]	76
		2	0.5924*** (0.0365)	0.4400*** (0.0345)	0.0239*** (0.0059)	0.0375*** (0.0063)	-	12.6005 [0.8147]	76
		3	0.6597*** (0.0539)	0.3519*** (0.0550)	-	-	0.0299*** (0.0111)	10.7831 [0.6290]	76

Table 1.09. (continues)

Market	Country	Model	HYBRID NKPC					Obs.	
			γ_b	γ_r	λ_{ulc}	λ_{unlc}	λ_{tuc}		J-Stat.
E	Philippines	1	0.4654*** (0.0379)	0.4425*** (0.0342)	0.0393*** (0.0151)	-	-	16.4499 [0.6271]	115
		2	0.4595*** (0.0115)	0.4467*** (0.0255)	0.0435*** (0.0097)	0.1121*** (0.0114)	-	14.8825 [0.6700]	117
		3	0.5001*** (0.0272)	0.3980*** (0.0347)	-	-	0.0288** (0.0148)	15.6299 [0.4791]	115
E	Poland	1	0.4713*** (0.0315)	0.4597*** (0.0415)	0.0186*** (0.0073)	-	-	9.5483 [0.8891]	102
		2	0.4622*** (0.0280)	0.4470*** (0.0372)	0.0211*** (0.0078)	0.0345*** (0.0053)	-	10.4831 [0.9150]	102
		3	0.4731*** (0.0304)	0.4574*** (0.0351)	-	-	0.0321*** (0.0084)	9.9359 [0.9340]	102
E	Russia	1	0.4818*** (0.0254)	0.4589*** (0.0402)	0.0976*** (0.0351)	-	-	12.3918 [0.7166]	98
		2	0.4368*** (0.0222)	0.4704*** (0.0422)	0.1173*** (0.0339)	0.0350*** (0.0062)	-	14.3252 [0.7077]	98
		3	0.4671*** (0.0288)	0.5376*** (0.0253)	-	-	0.0628*** (0.0202)	12.4031 [0.6483]	98
E	South Africa	1	0.3681*** (0.0424)	0.5899*** (0.0485)	0.0546*** (0.0213)	-	-	11.5534 [0.7741]	136
		2	0.3612*** (0.0417)	0.5452*** (0.0450)	0.1034*** (0.0288)	0.0221*** (0.0074)	-	15.3409 [0.7007]	136
		3	0.4442*** (0.0734)	0.5374*** (0.0755)	-	-	0.0154* (0.0090)	12.3341 [0.5005]	136
E	Taiwan	1	0.5140*** (0.0172)	0.4511*** (0.0493)	0.1276*** (0.0127)	-	-	9.5159 [0.8907]	106
		2	0.4807*** (0.0460)	0.4687*** (0.0548)	0.0955*** (0.0194)	0.0187*** (0.0054)	-	10.1505 [0.8587]	106
		3	0.4588*** (0.0208)	0.4672*** (0.0428)	-	-	0.0803*** (0.0149)	15.2972 [0.4302]	106
E	Thailand	1	0.5368*** (0.0879)	0.4047*** (0.1085)	0.0405*** (0.0132)	-	-	8.7879 [0.8883]	109
		2	0.4969*** (0.0763)	0.4774*** (0.0892)	0.0301** (0.0125)	0.0273* (0.0149)	-	11.1083 [0.8509]	109
		3	0.5130*** (0.0881)	0.4748*** (0.0897)	-	-	0.0580*** (0.0192)	10.8540 [0.6975]	109
E	Turkey	1	0.5292*** (0.0677)	0.4476*** (0.0658)	0.0754*** (0.0226)	-	-	8.5562 [0.8996]	102
		2	0.4924*** (0.0750)	0.4527*** (0.0630)	0.0459* (0.0257)	0.0610** (0.0302)	-	9.1077 [0.8441]	101
		3	0.5472*** (0.0626)	0.4361*** (0.0572)	-	-	0.0684** (0.0279)	8.9362 [0.8808]	102
F	Argentina	1	0.6240*** (0.0441)	0.3426*** (0.0251)	-0.0098 (0.0069)	-	-	7.9563 [0.9502]	101
		2	0.6300*** (0.0496)	0.3132*** (0.0319)	-0.0024 (0.0059)	-0.0183** (0.0080)	-	11.6288 [0.8658]	101
		3	0.5612*** (0.0324)	0.4000*** (0.0264)	-	-	-0.0814*** (0.0115)	9.1609 [0.9066]	101
F	Romania	1	0.6162*** (0.0654)	0.3849*** (0.0595)	0.0386*** (0.0124)	-	-	9.6653 [0.8835]	99
		2	0.5394*** (0.0157)	0.4241*** (0.0195)	0.0135** (0.0068)	0.0098*** (0.0036)	-	14.0213 [0.7277]	99
		3	0.5319*** (0.0149)	0.4695*** (0.0218)	-	-	0.0240*** (0.0082)	13.1379 [0.6627]	99
F	Venezuela	1	0.6288*** (0.0633)	0.3644*** (0.0715)	0.1378*** (0.0229)	-	-	14.7118 [0.6162]	109
		2	0.6058*** (0.0567)	0.4073*** (0.0634)	0.1001*** (0.0255)	0.0735* (0.0372)	-	15.0570 [0.5914]	109
		3	0.6489*** (0.0597)	0.3675*** (0.0652)	-	-	0.1338*** (0.0271)	14.8338 [0.6074]	109

Notes: Numbers in the table are coefficient estimates of HAC-robust GMM technique with "Auto-Schwarz" maximum four lags specification under Bartlett Kernel and Newey-West fixed bandwidth methodology that iterates to convergence. The HAC standard errors are presented in parentheses, and *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The J-Statistics indicates over-identification with probability in brackets, and the market classification is in S&P standards.

Table 1.09 reveals that the models (1, 2, and 3) perfectly work in almost all countries except Greece, Chile, and Argentina where λ (marginal labour cost gap) appears to be statistically insignificant. Moreover, notice that forward-looking specification is dominant among all developed markets while dominance of the backward-looking specification is clearly seen among frontier markets. Especially, the most advanced economies like Australia, Japan, United States, and United Kingdom have the greatest coefficients of forward-looking specification, while few Latin American countries like Venezuela, Chile, Argentina, and Mexico have the greatest backward-looking coefficients in the sample. However, the characteristics of inflation in emerging markets are quite ambiguous. Although the backward-looking specification appears to be dominant in majority of emerging markets, a number of countries like China, Greece, Malaysia, Russia, and South Africa have quasi-forward-looking dominance.

Although all of three models (1, 2, and 3) generate similar results for 41 countries, the significance of $unlc$ in model 2 recommends us to not exclude it from NKPC model. In table 1.09, model 1 shows how dynamics of inflation is structured when we omit $unlc$ and consider solely ulc as a proxy for mc in hybrid NKPC framework. This specification estimates that 55% of average inflation of whole sample is determined by expected inflation (γ_f), while 42% is determined by past inflation (γ_b), and remaining is attributable to the real marginal cost factor (λ). More specifically, table 1.10 shows that average subjective discount factor (β) of whole sample takes values of 0.90, close to unity, when we do not impose any restriction into it. Subsequently, average degree of backwardness (ω) of whole sample is about 0.47 indicating 47% of firms in countries sets price following backward-looking rule of thumb, while remaining 53% updates prices considering expectations as well as demand and cost dynamics. Average of price stickiness (Θ) of whole sample is roughly 0.70 which implies that the price duration is averagely 3.33 quarters. In case when we restrict β to a unity, the average ω of whole sample is escalates up to 0.52, while Θ drops to 0.66, thus price duration decreases to 2.94 quarters.

On the other hand, when we integrate $unlc$ into the model, average of the "trio" of γ_f - γ_b - λ remain almost unchanged. The model 2 estimates that 54% and 41% of average inflation of whole sample is determined by γ_f and γ_b respectively, while remaining share is attributable to λ_{ulc} and λ_{unlc} factors. Interestingly, table 1.10

reveals that average decomposition factor (ρ) of real marginal cost gap is about 0.67 in unrestricted β case, which indicates that λ is comprised of 67% of ulc and 33% of $unlc$. Moreover, average ω and Θ of the sample are accounted as 0.41 and 0.65 respectively, indicating 41% of firms follow backward-looking rule of thumb, while 59% takes into account forward-looking dynamics in resetting prices, where new prices remain roughly 2.87 quarters. When β is restricted to a unity, average ω rise to 0.44, while average Θ falls to 0.62, thus the price duration decreases to 2.66 quarters. Interestingly, when we impose $\beta=1$ restriction, average ρ drops from 0.67 to 0.63, increasing significance of $unlc$ in λ .

Alternatively, when we incorporate ulc and $unlc$ in model 3 as tuc , we again derive almost similar *trio* where the shares of γ_f , γ_b , and λ_{tuc} in current inflation accounted as 55%, 41% and 4% respectively. In case of their structural parameters, table 1.10 displays that average ω and Θ of the sample are derived as 0.48 and 0.71 respectively when we allow β to be estimated within the model 3 (average estimated β is 0.92). The value of degree of backwardness is very close to a half which means the other half of price setters behave in forward-looking characteristics in updating prices. Besides, the value of Θ estimates that these newly updated prices persist only for 3.48 quarters under unrestricted β , however, when β is restricted to a unity, Θ drops to 0.66, thus the price duration decreases to 2.98 quarters.

Indeed, there might be country-specific effects on the results; therefore, we focus results of countries akin to each other, i.e. countries with same market classification. In this respect, model 1 estimates that nearly 64% of current inflation in developed markets is driven by γ_f , while 32% and remaining 4% is determined by γ_b and λ_{ulc} respectively in unrestricted β case. Thus, average structural parameters of ω , Θ , and β for developed markets are recorded as 0.37, 0.74, and 0.96 respectively. In accordance with our expectations, the value ω is smaller in developed markets indicating lesser fraction (37%) of firms behave in backward-looking characteristics, while remaining 63% has forward-looking characteristics. On contrary, the value of Θ is higher in developed markets indicating that nominal rigidities are greater (price persistence is 3.81 quarters) in advanced economies. Besides, when β is restricted to a unity, average ω rise to 0.41, while average Θ falls to 0.70, thus the price persistence reduces to 3.39 quarters.

Table 1.10. Results for NKPC Structural Parameters

Mrkt	Country	Model	Unrestricted Beta Case					Restricted Beta ($\beta=1$) Case			
			ω	Θ	β	P	Ω	ω	Θ	ρ	Ω
D	Australia	1	0.2046*** (0.0000)	0.8264*** (0.0000)	0.9498*** (0.0000)	-	5.76	0.2153*** (0.0073)	0.8560*** (0.0065)	-	6.94
		2	0.1766*** (0.0000)	0.7873*** (0.0000)	0.9334*** (0.0000)	0.7760*** (0.0000)	4.70	0.1932*** (0.0075)	0.8096*** (0.0064)	0.6018*** (0.0273)	5.25
		3	0.2191*** (0.0000)	0.8222*** (0.0000)	1.0148*** (0.0000)	-	5.62	0.2203*** (0.0019)	0.8359*** (0.0016)	-	6.09
D	Austria	1	0.5239*** (0.0000)	0.7332*** (0.0000)	1.0010*** (0.0000)	-	3.75	0.5238*** (0.0001)	0.7334*** (0.0001)	-	3.75
		2	0.4427*** (0.0000)	0.7055*** (0.0000)	0.9971*** (0.0000)	0.8028*** (0.0000)	3.40	0.4433*** (0.0002)	0.7051*** (0.0002)	0.8027*** (0.0004)	3.39
		3	0.4759*** (0.0000)	0.7807*** (0.0000)	0.9606*** (0.0000)	-	4.56	0.4819*** (0.0027)	0.7769*** (0.0022)	-	4.48
D	Belgium	1	0.3239*** (0.0000)	0.7928*** (0.0000)	0.9285*** (0.0000)	-	4.83	0.3394*** (0.0047)	0.8083*** (0.0041)	-	5.22
		2	0.2969*** (0.0000)	0.7770*** (0.0000)	0.8838*** (0.0000)	0.8234*** (0.0000)	4.48	0.298*** (0.0071)	0.7904*** (0.0060)	0.7115*** (0.0235)	4.77
		3	0.3578*** (0.0000)	0.8279*** (0.0000)	0.9699*** (0.0000)	-	5.81	0.3649*** (0.0030)	0.8265*** (0.0015)	-	5.76
D	Canada	1	0.3103*** (0.0000)	0.7635*** (0.0000)	1.0209*** (0.0000)	-	4.23	0.7627*** (0.0012)	0.3019*** (0.0015)	-	1.43
		2	0.2224*** (0.0000)	0.6133*** (0.0000)	0.9938*** (0.0000)	0.7772*** (0.0000)	2.59	0.2241*** (0.0004)	0.6123*** (0.0002)	0.7754*** (0.0004)	2.58
		3	0.3322*** (0.0000)	0.7090*** (0.0000)	1.0996*** (0.0000)	-	3.44	0.3195*** (0.0073)	0.7948*** (0.0085)	-	4.87
D	Denmark	1	0.6243*** (0.0000)	0.5822*** (0.0000)	1.1486*** (0.0000)	-	2.39	0.5882*** (0.0038)	0.6123*** (0.0037)	-	2.58
		2	0.5928*** (0.0000)	0.6002*** (0.0000)	1.2602*** (0.0000)	0.8174*** (0.0000)	2.00	0.5894*** (0.0090)	0.6038*** (0.0086)	0.9098*** (0.0221)	2.52
		3	0.6243*** (0.0000)	0.6353*** (0.0000)	1.1544*** (0.0000)	-	2.74	0.5995*** (0.0021)	0.6667*** (0.0014)	-	3.00
D	Finland	1	0.5029*** (0.0000)	0.7695*** (0.0000)	0.7804*** (0.0000)	-	4.34	0.7214*** (0.0107)	0.5139*** (0.0139)	-	2.06
		2	0.3397*** (0.0000)	0.6801*** (0.0000)	0.7664*** (0.0000)	0.7992*** (0.0000)	3.13	0.3806*** (0.0099)	0.6252*** (0.0059)	0.8683*** (0.0164)	2.67
		3	0.5294*** (0.0000)	0.7762*** (0.0000)	0.8946*** (0.0000)	-	4.47	0.7512*** (0.0036)	0.5676*** (0.0043)	-	2.31
D	France	1	0.3385*** (0.0000)	0.7817*** (0.0000)	0.9503*** (0.0000)	-	4.58	0.3677*** (0.0087)	0.7916*** (0.0081)	-	4.80
		2	0.3197*** (0.0000)	0.7923*** (0.0000)	0.9510*** (0.0000)	0.9232*** (0.0000)	4.81	0.3410*** (0.0086)	0.8259*** (0.0074)	0.8832*** (0.0209)	5.74
		3	0.3562*** (0.0000)	0.9098*** (0.0000)	0.9450*** (0.0000)	-	11.09	0.9290*** (0.0085)	0.3683*** (0.0122)	-	1.58
D	Germany	1	0.2995*** (0.0000)	0.7924*** (0.0000)	1.0029*** (0.0000)	-	4.82	0.2994*** (0.0002)	0.7934*** (0.0002)	-	4.84
		2	0.3277*** (0.0000)	0.7886*** (0.0000)	0.9432*** (0.0000)	0.7985*** (0.0000)	4.73	0.3332*** (0.0043)	0.7639*** (0.0030)	0.8569*** (0.0078)	4.24
		3	0.2377*** (0.0000)	0.8228*** (0.0000)	0.9761*** (0.0000)	-	5.64	0.2393*** (0.0022)	0.8210*** (0.0010)	-	5.59
D	Ireland	1	0.5289*** (0.0000)	0.7193*** (0.0000)	1.0100*** (0.0000)	-	3.56	0.5295*** (0.0006)	0.7218*** (0.0005)	-	3.59
		2	0.5186*** (0.0000)	0.7005*** (0.0000)	0.9188*** (0.0000)	0.6113*** (0.0000)	3.34	0.5187*** (0.0040)	0.6730*** (0.0039)	0.6135*** (0.0124)	3.06
		3	0.5547*** (0.0000)	0.7158*** (0.0000)	0.9317*** (0.0000)	-	3.52	0.6320*** (0.0125)	0.7776*** (0.0115)	-	4.50
D	Italy	1	0.6039*** (0.0000)	0.7193*** (0.0000)	1.0562*** (0.0000)	-	3.56	0.5861*** (0.0026)	0.7053*** (0.0038)	-	3.39
		2	0.5784*** (0.0000)	0.6484*** (0.0000)	1.0426*** (0.0000)	0.8069*** (0.0000)	2.84	0.5642*** (0.0014)	0.6507*** (0.0017)	0.7414*** (0.0085)	2.86
		3	-	-	-	-	-	-	-	-	-

Notes: Numbers in the table are coefficient estimates of HAC-robust GMM technique with "Auto-Schwarz" maximum four lags specification under Bartlett Kernel and Newey-West fixed bandwidth methodology that iterates to convergence. The HAC standard errors are presented in parentheses, and *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The restricted specification impose $\beta=1$ into the model; ω is degree of backwardness; Θ degree of price stickiness; ρ shows fraction of unit labour cost (u/c) in real marginal cost; Ω is duration of prices in quarterly basis periods calculated as $1/(1-\Theta)$; and D, E, and F indicates the market classification in S&P standards as Developed, Emerging, and Frontier markets.

Table 1.10. (continues)

Mrkt	Country	Model	Unrestricted Beta Case					Restricted Beta ($\beta=1$) Case			
			ω	Θ	β	P	Ω	ω	Θ	ρ	Ω
D	Japan	1	0.1260*** (0.0000)	0.8274*** (0.0000)	0.9301*** (0.0000)	-	5.79	0.1196*** (0.0037)	0.7905*** (0.0026)	-	4.77
		2	0.0798*** (0.0000)	0.8637*** (0.0000)	0.9451*** (0.0000)	0.7122*** (0.0000)	7.34	0.0966*** (0.0025)	0.8676*** (0.0057)	0.7679*** (0.0195)	7.55
		3	0.1032*** (0.0000)	0.8936*** (0.0000)	0.9498*** (0.0000)	-	9.40	0.1033*** (0.0027)	0.8872*** (0.0038)	-	8.87
D	Netherlands	1	0.3847*** (0.0000)	0.8728*** (0.0000)	0.7785*** (0.0000)	-	7.86	0.4323*** (0.0080)	0.7868*** (0.0031)	-	4.69
		2	0.4686*** (0.0000)	0.7806*** (0.0000)	0.7651*** (0.0000)	0.6745*** (0.0000)	4.56	0.4834*** (0.0102)	0.7117*** (0.0084)	0.8709*** (0.0289)	3.47
		3	0.3997*** (0.0000)	0.8312*** (0.0000)	0.7868*** (0.0000)	-	5.92	0.3841*** (0.0091)	0.6750*** (0.0051)	-	3.08
D	Norway	1	0.5512*** (0.0000)	0.5553*** (0.0000)	1.0910*** (0.0000)	-	2.02	0.5559*** (0.0022)	0.5463*** (0.0022)	-	2.20
		2	0.4234*** (0.0000)	0.5651*** (0.0000)	1.0803*** (0.0000)	0.6956*** (0.0000)	1.87	0.4277*** (0.0040)	0.4903*** (0.0035)	0.6848*** (0.0057)	1.96
		3	0.4890*** (0.0000)	0.5564*** (0.0000)	1.0581*** (0.0000)	-	2.07	0.4870*** (0.0077)	0.5721*** (0.0073)	-	2.34
D	Portugal	1	0.3421*** (0.0000)	0.6936*** (0.0000)	0.7387*** (0.0000)	-	3.26	0.3312*** (0.0214)	0.7733*** (0.0172)	-	4.41
		2	0.4071*** (0.0000)	0.6919*** (0.0000)	0.7472*** (0.0000)	0.8990*** (0.0000)	3.25	0.4269*** (0.0205)	0.7574*** (0.0170)	0.6294*** (0.0755)	4.12
		3	0.5313*** (0.0000)	0.8358*** (0.0000)	0.8660*** (0.0000)	-	6.09	0.5111*** (0.0060)	0.7623*** (0.0053)	-	4.21
D	Singapore	1	0.2383*** (0.0000)	0.7621*** (0.0000)	0.8880*** (0.0000)	-	4.20	0.2465*** (0.0030)	0.7102*** (0.0041)	-	3.45
		2	0.2091*** (0.0000)	0.6828*** (0.0000)	0.7123*** (0.0000)	0.3652*** (0.0000)	3.15	0.2355*** (0.0070)	0.5890*** (0.0071)	0.3945*** (0.0196)	2.43
		3	0.2098*** (0.0061)	0.7651*** (0.0100)	0.8129*** (0.0199)	-	4.26	0.2592*** (0.0080)	0.7326*** (0.0104)	-	3.74
D	South Korea	1	0.1738*** (0.0000)	0.7642*** (0.0000)	0.9295*** (0.0000)	-	4.24	0.1716*** (0.0061)	0.7682*** (0.0052)	-	4.31
		2	0.2561*** (0.0000)	0.6765*** (0.0000)	1.0242*** (0.0000)	0.7794*** (0.0000)	3.09	0.2443*** (0.0028)	0.6761*** (0.0016)	0.7963*** (0.0039)	3.09
		3	0.2558*** (0.0110)	0.6708*** (0.0070)	1.0197*** (0.0148)	-	3.04	0.2612*** (0.0119)	0.6694*** (0.0070)	-	3.02
D	Spain	1	0.4885*** (0.0000)	0.7380*** (0.0000)	0.8333*** (0.0000)	-	3.82	0.5302*** (0.0127)	0.7033*** (0.0159)	-	3.37
		2	0.4669*** (0.0000)	0.7700*** (0.0000)	0.8887*** (0.0000)	0.7174*** (0.0000)	4.35	0.4891*** (0.0084)	0.7761*** (0.0126)	0.7724*** (0.0574)	4.47
		3	0.5994*** (0.0000)	0.8056*** (0.0000)	0.9002*** (0.0000)	-	5.14	0.6325*** (0.0085)	0.8179*** (0.0134)	-	5.49
D	Sweden	1	0.3809*** (0.0000)	0.7585*** (0.0000)	0.8514*** (0.0000)	-	4.14	0.4158*** (0.0053)	0.7329*** (0.0052)	-	3.74
		2	0.2741*** (0.0000)	0.6769*** (0.0000)	0.7524*** (0.0000)	0.6717*** (0.0000)	3.10	0.3194*** (0.0070)	0.6174*** (0.0044)	0.5689*** (0.0244)	2.61
		3	0.2870*** (0.0000)	0.7352*** (0.0000)	0.8758*** (0.0000)	-	3.78	0.3174*** (0.0050)	0.7088*** (0.0067)	-	3.43
D	Switzerland	1	0.5629*** (0.0000)	0.6286*** (0.0000)	1.3106*** (0.0000)	-	2.12	0.6622*** (0.0181)	0.6001*** (0.0102)	-	2.50
		2	0.4364*** (0.0000)	0.7436*** (0.0000)	0.8260*** (0.0000)	0.7785*** (0.0000)	3.90	0.3774*** (0.0153)	0.6873*** (0.0045)	0.8382*** (0.0091)	3.20
		3	0.4682*** (0.0000)	0.9264*** (0.0000)	0.8524*** (0.0000)	-	13.59	0.4876*** (0.0252)	0.9274*** (0.0210)	-	13.77
D	United Kingdom	1	0.1339*** (0.0000)	0.7152*** (0.0000)	0.9562*** (0.0000)	-	3.51	0.1464*** (0.0019)	0.7123*** (0.0015)	-	3.48
		2	0.1721*** (0.0000)	0.7009*** (0.0000)	0.9133*** (0.0000)	0.7857*** (0.0000)	3.34	0.1811*** (0.0037)	0.6833*** (0.0030)	0.7499*** (0.0177)	3.16
		3	0.1904*** (0.0000)	0.7488*** (0.0000)	0.8897*** (0.0000)	-	3.98	0.2199*** (0.0063)	0.7524*** (0.0060)	-	4.04
D	United States	1	0.1763*** (0.0000)	0.8422*** (0.0000)	0.9986*** (0.0000)	-	6.34	0.1753*** (0.0003)	0.8419*** (0.0002)	-	6.33
		2	0.2111*** (0.0000)	0.8301*** (0.0000)	0.9895*** (0.0000)	0.8209*** (0.0000)	5.89	0.2128*** (0.0018)	0.8295*** (0.0012)	0.7781*** (0.0068)	5.87
		3	0.2408*** (0.0000)	0.8889*** (0.0000)	0.9846*** (0.0000)	-	9.00	0.2479*** (0.0031)	0.8951*** (0.0030)	-	9.53

Table 1.10. (continues)

Mrkt	Country	Model	Unrestricted Beta Case					Restricted Beta ($\beta=1$) Case			
			ω	θ	β	P	Ω	ω	θ	ρ	Ω
E	Brazil	1	0.6264*** (0.0000)	0.6012*** (0.0000)	0.8627*** (0.0000)	-	2.51	0.6367*** (0.0017)	0.5604*** (0.0019)	-	2.27
		2	-	-	-	-	-	-	-	-	-
		3	0.7098*** (0.0070)	0.7888*** (0.0075)	0.8074*** (0.0193)	-	4.73	0.7496*** (0.0021)	0.7164*** (0.0015)	-	3.53
E	Chile	1	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-
E	China	1	0.3842*** (0.0000)	0.6260*** (0.0000)	0.9912*** (0.0000)	-	2.67	0.3836*** (0.0007)	0.6220*** (0.0007)	-	2.65
		2	0.4073*** (0.0000)	0.5763*** (0.0000)	0.9008*** (0.0000)	0.6951*** (0.0000)	2.36	0.4582*** (0.0052)	0.5512*** (0.0041)	0.7202*** (0.0128)	2.23
		3	0.2305*** (0.0000)	0.6341*** (0.0000)	1.0009*** (0.0000)	-	2.73	0.2305*** (0.0001)	0.6342*** (0.0000)	-	2.73
E	Czech Republic	1	0.5938*** (0.0000)	0.5576*** (0.0000)	0.9559*** (0.0000)	-	2.26	0.6102*** (0.0010)	0.5456*** (0.0007)	-	2.20
		2	0.5260*** (0.0000)	0.5291*** (0.0000)	0.5249*** (0.0000)	0.8657*** (0.0000)	2.12	0.6720*** (0.0112)	0.3644*** (0.0101)	0.7680*** (0.0118)	1.57
		3	0.7272*** (0.0000)	0.6088*** (0.0000)	0.8441*** (0.0000)	-	2.56	0.7432*** (0.0043)	0.5794*** (0.0035)	-	2.38
E	Greece	1	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-
E	Hungary	1	0.6846*** (0.0000)	0.6274*** (0.0000)	0.8586*** (0.0000)	-	2.68	0.7029*** (0.0013)	0.5679*** (0.0016)	-	2.31
		2	0.5609*** (0.0000)	0.6127*** (0.0000)	0.8499*** (0.0000)	0.6328*** (0.0000)	2.58	0.5889*** (0.0014)	0.5532*** (0.0018)	0.6883*** (0.0054)	2.24
		3	0.6127*** (0.0000)	0.5942*** (0.0000)	0.7556*** (0.0000)	-	2.46	0.6608*** (0.0041)	0.5158*** (0.0018)	-	2.07
E	India	1	0.6064*** (0.0000)	0.6078*** (0.0000)	0.7131*** (0.0000)	-	2.55	0.6949*** (0.0090)	0.5233*** (0.0065)	-	2.10
		2	0.4508*** (0.0000)	0.5135*** (0.0000)	0.7964*** (0.0000)	0.3456*** (0.0000)	2.06	0.5034*** (0.0047)	0.4681*** (0.0031)	0.3268*** (0.0144)	1.88
		3	0.4710*** (0.0000)	0.5591*** (0.0000)	0.7587*** (0.0000)	-	2.27	0.5419*** (0.0071)	0.5039*** (0.0052)	-	2.02
E	Indonesia	1	0.6283*** (0.0000)	0.8804*** (0.0000)	0.5327*** (0.0000)	-	8.36	0.9628*** (0.0402)	0.6409*** (0.0346)	-	2.78
		2	0.5480*** (0.0000)	0.7409*** (0.0000)	0.6747*** (0.0000)	0.3855*** (0.0000)	3.86	0.6775*** (0.0116)	0.5715*** (0.0087)	0.1064*** (0.0444)	2.33
		3	0.6079*** (0.0000)	0.7623*** (0.0000)	0.6085*** (0.0000)	-	4.21	0.8053*** (0.0100)	0.5488*** (0.0122)	-	2.22
E	Malaysia	1	0.5396*** (0.0000)	0.8001*** (0.0000)	0.7991*** (0.0000)	-	5.00	0.6312*** (0.0066)	0.7331*** (0.0041)	-	3.75
		2	0.3379*** (0.0000)	0.5993*** (0.0000)	0.7625*** (0.0000)	0.3300*** (0.0000)	2.50	0.3902*** (0.0036)	0.5170*** (0.0020)	0.2645*** (0.0078)	2.07
		3	0.4800*** (0.0000)	0.8017*** (0.0000)	0.7534*** (0.0000)	-	5.04	0.5994*** (0.0097)	0.7365*** (0.0063)	-	3.80
E	Mexico	1	0.8299*** (0.0000)	0.6765*** (0.0000)	0.8580*** (0.0000)	-	3.09	0.8105*** (0.0131)	0.6546*** (0.0078)	-	2.90
		2	0.7283*** (0.0000)	0.3943*** (0.0000)	1.0920*** (0.0000)	0.3892*** (0.0000)	1.65	0.6854*** (0.0035)	0.4856*** (0.0029)	0.4114*** (0.0096)	1.94
		3	0.8855*** (0.0000)	0.3956*** (0.0000)	1.1074*** (0.0000)	-	1.65	0.8669*** (0.0025)	0.4303*** (0.0063)	-	1.76
E	Philippines	1	0.5558*** (0.0000)	0.7759*** (0.0000)	0.6811*** (0.0000)	-	4.46	0.7268*** (0.0138)	0.6911*** (0.0100)	-	3.24
		2	0.4273*** (0.0000)	0.5676*** (0.0000)	0.7318*** (0.0000)	0.2797*** (0.0000)	2.31	0.5018*** (0.0073)	0.4812*** (0.0041)	0.1580*** (0.0180)	1.93
		3	0.6166*** (0.0000)	0.8183*** (0.0000)	0.5996*** (0.0000)	-	5.50	0.6856*** (0.0218)	0.4664*** (0.0187)	-	1.87
E	Poland	1	0.6179*** (0.0000)	0.8395*** (0.0000)	0.7179*** (0.0000)	-	6.23	0.7054*** (0.0068)	0.7888*** (0.0059)	-	4.73
		2	0.5265*** (0.0000)	0.7276*** (0.0000)	0.6997*** (0.0000)	0.3789*** (0.0000)	3.67	0.5693*** (0.0064)	0.6557*** (0.0020)	0.2062*** (0.0201)	2.90
		3	0.5872*** (0.0000)	0.7766*** (0.0000)	0.7309*** (0.0000)	-	4.48	0.7223*** (0.0098)	0.7398*** (0.0055)	-	3.84

Table 1.10. (continues)

Mrkt	Country	Model	Unrestricted Beta Case					Restricted Beta ($\beta=1$) Case			
			ω	Θ	β	P	Ω	ω	Θ	ρ	Ω
E	Russia	1	0.5038*** (0.0000)	0.6047*** (0.0000)	0.7935*** (0.0000)	-	2.53	0.6378*** (0.0055)	0.6163*** (0.0029)	-	2.61
		2	0.4046*** (0.0000)	0.5801*** (0.0000)	0.7512*** (0.0000)	0.7704*** (0.0000)	2.38	0.5588*** (0.0120)	0.6033*** (0.0025)	0.8150*** (0.0378)	2.52
		3	0.5332*** (0.0000)	0.6023*** (0.0000)	1.0188*** (0.0000)	-	2.51	0.5291*** (0.0009)	0.6029*** (0.0003)	-	2.52
E	South Africa	1	0.4017*** (0.0000)	0.7204*** (0.0000)	0.8936*** (0.0000)	-	3.58	0.4263*** (0.0077)	0.7578*** (0.0076)	-	4.13
		2	0.3371*** (0.0000)	0.6405*** (0.0000)	0.7944*** (0.0000)	0.8238*** (0.0000)	2.78	0.3356*** (0.0121)	0.5411*** (0.0099)	0.7148*** (0.0196)	2.18
		3	0.6072*** (0.0000)	0.7984*** (0.0000)	0.9200*** (0.0000)	-	4.96	0.5885*** (0.0051)	0.7312*** (0.0052)	-	3.72
E	Taiwan	1	0.5137*** (0.0000)	0.5225*** (0.0000)	0.8628*** (0.0000)	-	2.09	0.5473*** (0.0029)	0.4697*** (0.0020)	-	1.89
		2	0.4860*** (0.0000)	0.5733*** (0.0000)	0.8265*** (0.0000)	0.8361*** (0.0000)	2.34	0.5026*** (0.0052)	0.4971*** (0.0029)	0.8415*** (0.0035)	1.99
		3	0.4929*** (0.0000)	0.6585*** (0.0000)	0.7621*** (0.0000)	-	2.93	0.5838*** (0.0074)	0.5482*** (0.0037)	-	2.21
E	Thailand	1	0.5737*** (0.0128)	0.7350*** (0.0128)	0.7373*** (0.0341)	-	3.77	0.6428*** (0.0254)	0.6452*** (0.0155)	-	2.82
		2	0.5831*** (0.0000)	0.6327*** (0.0000)	0.8855*** (0.0000)	0.5248*** (0.0000)	2.72	0.6087*** (0.0023)	0.5901*** (0.0018)	0.5005*** (0.0075)	2.44
		3	0.6078*** (0.0000)	0.5993*** (0.0000)	0.9385*** (0.0000)	-	2.50	0.6216*** (0.0013)	0.5789*** (0.0008)	-	2.37
E	Turkey	1	0.5980*** (0.0000)	0.5710*** (0.0000)	0.8856*** (0.0000)	-	2.33	0.6414*** (0.0046)	0.5578*** (0.0032)	-	2.26
		2	0.5073*** (0.0000)	0.5812*** (0.0000)	0.8025*** (0.0000)	0.4296*** (0.0000)	2.39	0.5811*** (0.0088)	0.5656*** (0.0036)	0.1656*** (0.0428)	2.30
		3	0.6350*** (0.0000)	0.5593*** (0.0000)	0.9049*** (0.0000)	-	2.27	0.6741*** (0.0036)	0.5344*** (0.0017)	-	2.15
F	Argentina	1	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-
F	Romania	1	0.8017*** (0.0000)	0.4932*** (0.0000)	1.0155*** (0.0000)	-	1.97	0.7992*** (0.0001)	0.4990*** (0.0001)	-	2.00
		2	0.7210*** (0.0000)	0.7417*** (0.0000)	0.7644*** (0.0000)	0.5798*** (0.0000)	3.87	0.7935*** (0.0094)	0.6178*** (0.0038)	0.3869*** (0.0217)	2.62
		3	0.8017*** (0.0000)	0.4932*** (0.0000)	1.0155*** (0.0000)	-	1.97	0.7993*** (0.0002)	0.4990*** (0.0001)	-	2.00
F	Venezuela	1	0.6288*** (0.0006)	0.3897*** (0.0017)	0.9524*** (0.0061)	-	1.64	0.6298*** (0.0009)	0.3748*** (0.0011)	-	1.60
		2	0.5777*** (0.0000)	0.3588*** (0.0000)	1.0826*** (0.0000)	0.5764*** (0.0000)	1.56	0.5751*** (0.0013)	0.3787*** (0.0012)	0.5413*** (0.0067)	1.61
		3	0.6694*** (0.0000)	0.3276*** (0.0000)	1.1575*** (0.0000)	-	1.49	0.6499*** (0.0013)	0.3700*** (0.0008)	-	1.59

On the other hand, model 2 predicts that current inflation in developed markets is structured as follows: 63% by γ_f , 32% by γ_b , 4% by λ_{ulc} , and 1% by λ_{unlc} , which is quite similar as in model 1. Here, average structural parameters of ω , Θ , and ρ are estimated as 0.35, 0.70, and 0.74 respectively under $\beta=1$ case, and when we relax β , they become as 0.34, 0.71, and 0.75 respectively with average estimated β of 0.92. Notice that ω , Θ , and β stay in line with the model 1 estimation, so they deserve similar comments as in model 1. Interestingly, the value of ρ varies around 0.77 for almost all developed countries except Singapore with ρ value of

0.36, denoting that nearly 77% of real marginal cost is determined by ulc , while only 0.23% is attributable to $unlc$. The low ρ in Singapore might be related with country's regulations and wage structure, because its neighbours like Malaysia, Indonesia, and India (in emerging market classification) also derive similar coefficient of ρ .

Lastly, model 3 also provides robustness for estimations in models 1 and 2. It predicts that 64% of inflation is structured by inflation expectations in developed markets, while only 33% is formed by the past inflation, leaving a share of 3% for real marginal cost factor (tuc). It also yields a higher estimate of Θ for almost all developed countries in table 1.10, where average Θ appears as 0.78 under unrestricted β case. It indicates that price duration is about 4.56 quarters in these markets, and we believe that this estimation is much closer the "true" value as tuc incorporates both ulc and $unlc$.

Interestingly, most advanced countries like Japan, United States, United Kingdom, Australia, South Korea, Canada, Germany, France, and Belgium are distinguished with greater forward-looking/smaller backward-looking specifications comparing to the average of developed markets. For instance, 86% of inflation in Japan is determined by γ_f , while 10% is attributable to γ_b . Similarly, around 80% of inflation in United States, United Kingdom, and Australia is attributable to the γ_f , while the share of γ_b is only around 20%. In cases of South Korea, Germany, Canada, France, and Belgium inflation seems to have similar structure where around 70% of the current inflation is formed by the γ_f , while only 28% is attributable to γ_b .

Coming to structural parameters in table 1.10, model 3 estimates that average price stickiness in these nine "distinguished" countries is about 7 quarters with average β of 0.98, while models 1 and 2 derive it as 5 quarters with average β 's of 0.97 and 0.95 respectively. When we restrict β to a unity, model 3 accounts the price duration as 6 quarters, while models 1 and 2 stick with 5 quarters as in relaxed β case. More interestingly, ρ is estimated as 0.80 by model 2 with relaxed β , while it drops to 0.77 with restricted β . This implies that 80% of real marginal cost is attributable to labour-related costs while only 20% is formed non-labour-related costs.

In table 1.09, notice that remaining developed countries have similar inflation structure, i.e. backward-looking coefficient varies around 0.40-0.50 and forward-looking specification ranges between 0.50-0.60. The structural estimates derived by model 3, in table 1.10, show that average duration of prices in these markets are about 5 quarters under relaxed β case, while models 1 and 2 account it as 4 and 3.5 quarters respectively. Plus, restricting β to a unity leads slight decreases in price duration in all three models. The average ρ in developed markets, net of distinguished countries, is accounted as 0.72 under both restricted and unrestricted β . Comparing ρ value of "distinguished" countries, *unlc* picks up a weight indicating that non-labour/labour costs have relative greater/smaller share in real marginal cost factor in these countries. It is worth to note that the Singaporean ρ appears remarkably low among developed sample countries as it derives a value of 0.36. We observe that Singapore's neighbour countries such as Malaysia (0.33), Indonesia (0.38), and India (0.34) also generate quite similar ρ value. Thus, we believe that non-labour costs have greater significance comparing to labour costs in this region.

In case of emerging markets, all of three models yield similar estimates of averages of forward- ($\frac{\sum \gamma_f}{N}$) and backward-looking ($\frac{\sum \gamma_b}{N}$) coefficients, around 46% and 49% respectively. As well as the sample average value of λ factor appears to be around 5%. Although these results indicate that inflation structure in emerging markets is very close to 50%-50% formation, the sample can easily be separated as forward- and backward-looking countries in accordance with dominance of these coefficients one to another. The forward-lookers are China, Greece, Malaysia, Russia, and South Africa, while remaining markets are backward-lookers. Particularly, notice that $\gamma_f\gamma_b$ trade-off in China and Greece is more alike to developed countries, contrarily; the trade-off in Chile and Mexico is more alike to frontier markets rather than the emerging sample.

In table 1.10, model 1 and 3 derive alike structural parameter estimations for emerging countries, where averages of ω and Θ are 0.58 and 0.67 respectively with average β value of 0.83. It indicates that 58% of price setters account only past inflation in updating prices, and these newly updated prices persist for 3 quarters. When β is restricted to a unity, we observe increase in average value of ω , and decrease in average value of Θ which implies shorter price duration, about 2.5 quarters. Alternatively, the model 2 yields smaller values for average ω , Θ , and β .

Especially, average degree of backwardness and price stickiness drop by 10 base points, thus duration of new prices come to equilibrium at 2.5 quarters under relaxed β . In case of restriction of β to a unity, the price duration falls further to 2.2 quarters.

Interestingly, average decomposition factor (ρ) of λ is recorded as 0.55 for emerging markets' sample. It indicates that 55% of λ is formed by *ulc*, while only 45% is attributable to *unlc*. This *ulc-unlc* trade-off was around 77%-23% for developed markets' sample, so it means that inflation in emerging markets are more sensitive to *unlc* than inflation in developed markets. Importantly, notice that estimated ρ in India, Indonesia, Malaysia, Mexico, Philippines, and Poland varies around 0.28-0.39. We believe that a cheap labour alongside with local regulations (high taxation, high loan rates, high import prices, energy dependence) that might cause non-labour costs to be expensive have significant contribution in low ρ in these countries except Poland which remains ambiguous.

Finally, even though inflation structure in our sampled frontier markets seems to be highly backward-looking, it is worth to note that the sample is comprised of only 3 countries, and to be more concrete the analysis should be tested only few more frontier countries. Nevertheless, all three models in table 1.09 yield a 60%-40% ($\gamma_f\gamma_b$) structure of inflation in frontier markets, meaning that around 60% of current inflation in Argentina, Romania, and Venezuela is determined by past inflation, while only 40% is determined by expected future inflation. Moreover, all the models derive negative value for *ulc* and *unlc* for Argentinean case, where the first is statistically insignificant, thus showing that the model does not work, while the second is ambiguously seems to be statistically significant, showing that the model does not work in context of NKPC theory. Therefore, we do not report structural parameter for Argentina.

Furthermore, notice that $\gamma_f\gamma_b$ trade-off in Romania is more alike to emerging countries rather than the frontier sample. Its estimate of λ is significantly different than the Venezuelan one. It shows that inflation in Venezuela is more sensitive to cycles in real marginal costs factor. Interestingly, table 1.10 reveals that Romanian firms have a higher degree of backwardness ($\omega=0.80$) comparing to Venezuelan firms with $\omega=0.63$. Equally, price stickiness is also higher in Romania than Venezuela. The models 1 and 3 estimates that price duration in Romania is about 2 quarters, while the model 2 yields a higher price duration, around 3.87 quarters

under relaxed β case. The similar scenario repeats in $\beta=1$ case, where the models 1 and 3 accounts the duration of prices as 2 quarters, while the model 2 yields a higher nominal rigidity, about 2.6 quarters. In case of Venezuela, all three models generate similar estimations for price duration about 1.6 quarters in both restricted an unrestricted β . Besides, the value of ρ is almost equal in both countries under relaxed β case, around 0.58, which simply implies a 58%-42% *ulc-unlc* trade-off. However, restriction of β to a unity causes a significant reduction in Romanian ρ (drops to 0.39), while it yields a slighter change in Venezuelan ρ (drops to 0.54). It might be addressed to underestimation of Romanian β by the model 2, around 0.76, while other models estimate it as 1.01.

1.5.2.2. Panel GMM estimation of hybrid NKPC

After reviewing how hybrid NKPC works across different countries, we schedule a panel analysis for whole sample believing that it will provide robustness for our previous findings. Initially, we employ Hausman test and find out that random-effect (RE) estimators are consistent and efficient for all three NKPC models (see table 1.11) as chi-statistics fails to reject H_0 with probabilities higher than 0.05.

Table 1.11. Results for Hausman Test

Model	Chi-Sq. (Prob.)
1 - NKPC model with <i>ulc</i> only as proxy for <i>mc</i>	0.4845 (0.9223)
2 - NKPC model with <i>ulc</i> and <i>unlc</i> as proxies for <i>mc</i>	0.4641 (0.9769)
3 - NKPC model with <i>tuc</i> as proxy for <i>mc</i>	0.3648 (0.9474)

Notes: The Chi-square statistics are given in the last column with probabilities of rejecting null hypothesis in parenthesis. The null hypothesis of the test is H_0 : Both FE and RE estimators are consistent, but RE estimators are more efficient than FE. The alternative is H_1 : RE estimators are inconsistent, FE estimators are consistent. The degree of freedom of chi-square for model 1 and 3 is three; while for model 2 is four.

Although Hausman test suggests to dear RE specification, we report all panel results in table 1.12 to make a comprehensive comparison. We already know that estimates of FE are inefficient. Plus, J-statistics imply that FE models also have overidentification problem that brings bias to their estimates. RE derives more efficient estimates, however, we need to check whether RE model is poolable or not.

For this, we hypothesize intercept of RE ($H_0: c+U_i=0$) using Wald tests. As a result, we find that the null hypothesis is rejected at 1% significance level, thus we conclude that RE is an appropriate model. Nevertheless, σ_u (cross-section random) and σ_e (idiosyncratic random) which represent Swamy-Arora (1972) estimator of the variance components of RE, imply that the RE specified panel data, actually, generates very similar results with pooled panel data. Because notice that σ_e gets rho number of close to 1, while σ_u gets rho number close to zero. This means almost entire the variance of RE is comprised of idiosyncratic random, and the weight of cross-section random very close to zero. Thus, the pooled model results also deserve a focus.

The pooled model 1 estimates 56%-40% trade-off between forward- and backward-looking components respectively with λ_{ulc} of 0.034 by accounting 61% of variations in current inflation. We believe that a blatant dominance of γ_f occurs due to less number of frontier markets in whole sample, i.e. just 3 frontier countries in a 41-sized sample. The model 2 and 3 also estimate 56%-40% trade-off between γ_f and γ_b in pooled specification where Phillips coefficient is about 0.02. The significance of λ_{unlc} indicates that unit non-labour cost factor matters in determining current inflation. Thus, it should be integrated into model when we proxy real marginal costs.

On the other hand, the dominance of γ_f preserves with 54%-57% range when a RE specification is assigned to models 1, 2, and 3. The weight of γ_b slightly increases up to 41%, while real marginal cost (λ) gets value between 0.02-0.03 at 1% significance level. Due to Hausman tests RE specification derives efficient estimates, therefore, we conclude that 55% of current inflation is formed by expected future inflation, while remaining share is attributable to past inflation and real marginal cost factor. In model 1 predicts the Phillips coefficient as 0.0212, while models 2 and 3 pick up slightly higher estimates, i.e. around 0.0328. Moreover, the model 2 in RE specification appear as the best set up as it derives higher R-squared (0.6126) value where all explanatory variables seem to be statistically significant at 1% level. This also indicates that proxy of real marginal costs should account compound of unit labour and unit non-labour costs.

Table 1.12. Results for Panel GMM Estimation of Hybrid NKPC

Panel Model	POOLED			RANDOM			FIXED		
	1	2	3	1	2	3	1	2	3
γ_b	0.4026*** (0.0117)	0.3941*** (0.0117)	0.4039*** (0.0046)	0.3964*** (0.0024)	0.4111*** (0.0019)	0.4109*** (0.0017)	0.3756*** (0.0644)	0.36054*** (0.0675)	0.3965*** (0.0597)
γ_f	0.5512*** (0.0179)	0.5590*** (0.0182)	0.5586*** (0.0073)	0.5749*** (0.0028)	0.5450*** (0.0025)	0.5587*** (0.0023)	0.5499*** (0.0927)	0.5304*** (0.0934)	0.5412*** (0.0808)
λ_{ulc}	0.0337*** (0.0080)	0.0202*** (0.0033)	-	0.0212*** (0.0005)	0.0329*** (0.0004)	-	0.0498*** (0.0152)	0.0339** (0.0168)	-
λ_{unlc}	-	0.0056** (0.0027)	-	-	0.0058*** (0.0004)	-	-	0.0265*** (0.0097)	-
λ_{tuc}	-	-	0.0166*** (0.0066)	-	-	0.0328*** (0.0006)	-	-	0.0182*** (0.0068)
intercept	-	-	-	0.0002*** (0.0000)	0.0002*** (0.0000)	0.0002*** (0.0000)	0.0006 (0.0008)	0.0012 (0.0008)	0.0008 (0.0006)
Effect	-	-	-	Random Cross- sections $\sigma_u=0.0001$ $\sigma_e=0.9999$	Random Cross- sections $\sigma_u=0.0001$ $\sigma_e=0.9999$	Random Cross- sections $\sigma_u=0.0001$ $\sigma_e=0.9999$	Cross- section fixed dummies	Cross- section fixed dummies	Cross- section fixed dummies
R-sq.	0.6121	0.6133	0.6096	0.5926' 0.5926"	0.6126' 0.6126"	0.6099' 0.6099"	0.6168	0.625	0.6154
J-Stat.	9.4339 (0.3982)	14.8694 (0.2487)	11.8996 (0.3715)	13.7453 (0.2474)	16.3556 (0.1755)	12.8788 (0.3779)	50.5295 (0.0037)	50.8695 (0.0114)	22.0324 (0.0241)
Obs.	4919	4891	4900	4919	4891	4900	4919	4891	4900

Notes: The Panel GMM estimation methodology is used to determine dynamics of inflation, π_t , with 41 cross-sections and 138 periods (1981Q1-2016Q1) utilizing fixed instruments of four lags of inflation, and two lags of import prices, interest rates, change in wages, and output gap. The model 1 is hybrid NKPC that uses *ulc* as a proxy for *mc* with mentioned fixed instruments plus two lags of *ulc*; the 2 is *unlc* augmented version of 1 with fixed instruments plus two lags of *ulc* and *unlc*; the 3 uses *tuc* as a proxy for *mc* with fixed instruments plus two lags of *tuc*. All models use white cross-section instrument weighting matrix, and white cross-section standard errors and covariance that are given in parenthesis. The asterisk denotes significance in following order: *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The single quotation mark in the R-squared column indicates weighted R^2 , while double quotation indicates unweighed R^2 . The J-statistics presented with probabilities in the parenthesis. The σ_u and σ_e represent Swamy and Arora estimator of variance components of random effect (cross-section and idiosyncratic respectively) with rho numbers.

Further, we present results of structural parameters of our three models in both cases: relaxing β and restricting it to a unity, in table 1.13. The unrestricted β case of model 1 estimates subjective discount factor (β) and degree of backwardness (ω) of the sample as 0.9145 and 0.5027 respectively where both are statistically significant at 1% level. The fraction of ω indicates that nearly half of the firms in countries sets price following backward-looking rule of thumb, while other half updates prices following forward-looking expectations. In the same specification, the price stickiness (Θ) of the sample appears around 0.80 with 1%

significance power implying that the price duration is about 5 quarters in the sample. When we impose $\beta=1$ restriction, we observe very slight changes in structural parameters, i.e. degree of backwardness increases to 51%, while price duration decreases to 4.935 quarters.

On the other hand, our augmented NKPC model 2 derives more accurate estimations for structural parameters of our sample. In restricted $\beta=1$ case, it finds higher degree backwardness (0.51) and lower nominal rigidity (0.74) comparing to model 1. It implies if β would equate 1, nearly 51% of firms exhibit backward-looking characteristics in setting prices where new prices would remain for 3.8 quarters. On the other hand, when we let the model estimate the β it finds subjective discount factor as 0.8746. This specification predicts ω and Θ values as 0.48 and 0.74 respectively where first indicates only 48% of firms in our sampled countries follows backward-looking rule of thumb characteristics, while 52% takes forward-looking dynamics into account in resetting prices, and second implies that these new prices remain roughly 3.9 quarters. Plus, unit labour cost fraction ρ appears as 0.85 indicating that nearly 85% of real marginal cost in the sample is comprised by *ulc*, while only 0.15% is attributable by *unlc*.

The model 3, which incorporates both *ulc* and *unlc* in one factor (*tuc*), derives similar result for degree of backwardness and price stickiness comparing to model 2. Its unrelaxed β specification estimates ω as 0.50 which indicates that half of price setters follows backward-looking rule of thumb in updating prices, while other half follows forward-looking expectations. These newly set prices will remain nearly for 4 quarters as price stickiness parameter (Θ) equates to 0.75. When we relax subjective discount factor, the model estimates it (β) as 0.9121 much closer to a unity comparing value of estimated β in model 2. The degree of backwardness (0.50) remains unchanged while price stickiness drops a little weight (0.74). It indicates that nearly half of the firms set prices following backward-looking rule of thumb, while remaining 53% updates prices following forward-looking expectations and newly updated prices last for 3.85 quarters.

Additionally, we gauge performance of our three hybrid NKPC models and their structural parameters during tranquil and recessionary periods separately. It gives us significant evidence about how structural parameters of inflation changes across these two states of economy. We report estimated results in table 1.14

where "N" and "R" capped variables represent their behaviour during growing and recessionary periods respectively.

Table 1.13. Panel GMM Estimation of Structural Parameters of Hybrid NKPC

β type	Model	ω	Θ	β	ρ	Ω	J-stat.	Obs.
Restricted	1	0.5145*** (0.0057)	0.7970*** (0.0056)	1	-	4.93	0.0035 (1.0000)	4910
Unrestricted	1	0.5027*** (0.0004)	0.8002*** (0.0008)	0.9145*** (0.0016)	-	5.01	0.0000 (1.0000)	4910
Restricted	2	0.5138*** (0.0072)	0.7364*** (0.0067)	1	0.8679*** (0.0291)	3.79	0.0077 (1.0000)	4886
Unrestricted	2	0.4876*** (0.0007)	0.7451*** (0.0005)	0.8746*** (0.0011)	0.8492*** (0.0019)	3.92	0.0002 (1.0000)	4886
Restricted	3	0.5027*** (0.0059)	0.7403*** (0.0044)	1	-	3.85	0.0043 (1.0000)	4885
Unrestricted	3	0.5002*** (0.0005)	0.7499*** (0.0005)	0.9121*** (0.0010)	-	4.00	0.0002 (1.0000)	4885

Notes: The Panel GMM estimation methodology is used to estimate structural parameters of NKPC with 41 cross-sections and 138 periods (1980Q1-2016Q1). The model 1 is hybrid NKPC that uses *ulc* as a proxy for *mc* with mentioned fixed instruments plus two lags of *ulc*; the 2 is *unlc* augmented version of 1 with fixed instruments plus two lags of *ulc* and *unlc*; the 3 uses *tuc* as a proxy for *mc* with fixed instruments plus two lags of *tuc*. All models use white cross-section instrument weighting matrix, and white cross-section standard errors and covariance that are given in parenthesis. The asterisk denotes significance in following order: *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. J-statistics hypothesizes overidentification problem with probability in parenthesis; ω is degree of backwardness; Θ degree of price stickiness; ρ shows fraction of unit labour cost (*ulc*) in real marginal cost; and Ω is duration of prices in quarterly basis periods calculated as $1/(1-\theta)$.

The Hausman test suggests that estimates of RE specification are more efficient than FE in all three models. Plus, J-statistics also imply that FE specified models comprise overidentification problem. Hypothesizing if intercepts of RE models ($H_0: c+U_i=0$) equal zero or not, we find that the models are not poolable. Therefore, our primary focus is estimates of RE models, although we report other specification results. The table 1.14 shows that pooled and RE models derive quite similar results. This happens due to Swamy-Arora estimators of variance components of random-effect σ_u (cross-section random) and σ_e (idiosyncratic random) that get rho numbers very close to zero and one respectively. The RE specified model 1 estimates 35%-53% backward- and forward-looking trade-off and a 0.07 coefficient for *ulc* factor during pure growing periods at 1% significance level. Whereas it indicate that sensitivity of current inflation to its past and expected future values increases during recessionary periods. However, majority of this increase occurs in backward-looking coefficient, while forward-looking coefficient picks remarkably low weight. The backward- and forward-looking trade-off turns to 47%-

54% preserving its 1% significance level while *ulc* shrinks to 0.03 and totally loses its significance.

Table 1.14.Panel GMM Estimation of Hybrid NKPC during Normal/Recession Periods

	POOLED			FIXED			RANDOM		
	1	2	3	1	2	3	1	2	3
N_{Y_b}	0.3674*** (0.0236)	0.3753*** (0.0261)	0.3634*** (0.0234)	0.3512*** (0.0237)	0.3278*** (0.0265)	0.3432*** (0.0236)	0.3527*** (0.0214)	0.3615*** (0.0229)	0.3566*** (0.0273)
N_{Y_f}	0.5288*** (0.0231)	0.5240*** (0.0245)	0.5444*** (0.0231)	0.4837*** (0.0239)	0.4756*** (0.0246)	0.4840*** (0.0242)	0.5368*** (0.0206)	0.5473*** (0.0202)	0.5414*** (0.0240)
$N_{\lambda_{ulc}}$	0.0530*** (0.0069)	0.0782*** (0.0086)	-	0.0529*** (0.0071)	0.0825*** (0.0093)	-	0.0664*** (0.0103)	0.0715*** (0.0101)	-
$N_{\lambda_{unlc}}$	-	0.0126*** (0.0037)	-	-	0.0135*** (0.0034)	-	-	0.0130*** (0.0032)	-
$N_{\lambda_{tuc}}$	-	-	0.0426*** (0.0068)	-	-	0.0432*** (0.0067)	-	-	0.0530*** (0.0081)
R_{Y_b}	0.4608*** (0.0534)	0.4651*** (0.0580)	0.4655*** (0.0526)	0.4546*** (0.0546)	0.4294*** (0.0600)	0.4259*** (0.0536)	0.4680*** (0.0532)	0.4636*** (0.0528)	0.4595*** (0.0573)
R_{Y_f}	0.5463*** (0.0450)	0.5530*** (0.0481)	0.5559*** (0.0458)	0.5145*** (0.0457)	0.5225*** (0.0487)	0.5238*** (0.0470)	0.5416*** (0.0457)	0.5493*** (0.0474)	0.5508*** (0.0452)
$R_{\lambda_{ulc}}$	0.0252* (0.0146)	0.0500* (0.0261)	-	0.0213 (0.0142)	0.0421 (0.0271)	-	0.0292 (0.0201)	0.0513 (0.0337)	-
$R_{\lambda_{unlc}}$	-	0.0316*** (0.0090)	-	-	0.0338*** (0.0091)	-	-	0.0369** (0.0174)	-
$R_{\lambda_{tuc}}$	-	-	0.0567*** (0.0162)	-	-	0.0573*** (0.0160)	-	-	0.0581** (0.0265)
intercept	-	-	-	0.0041*** (0.0004)	0.0043*** (0.0005)	0.0044*** (0.0004)	0.0049*** (0.0013)	0.0053*** (0.0012)	0.0051*** (0.0015)
Effects	-	-	-	Cross- sections Fixed Dummies	Cross- sections Fixed Dummies	Cross- sections Fixed Dummies	Random Cross- sections $\sigma_u=0.0168$ $\sigma_e=0.9832$	Random Cross- sections $\sigma_u=0.0235$ $\sigma_e=0.9765$	Random Cross- sections $\sigma_u=0.0196$ $\sigma_e=0.9804$
R-sq.	0.6043' 0.6271"	0.6062' 0.6346"	0.6026' 0.6282"	0.6129' 0.6401"	0.6148' 0.6490"	0.6141' 0.6426"	0.6832' 0.6832"	0.7008' 0.7008"	0.6812' 0.6812"
J-stat.	18.2876 (0.1209)	18.5662 (0.1187)	18.3648 (0.1194)	24.0428 (0.0527)	24.3105 (0.0437)	24.1809 (0.0488)	14.1608 (0.2422)	13.9547 (0.2571)	14.0895 (0.2490)
Obs.	4919	4886	4886	4919	4886	4886	4919	4886	4886

Notes: The Panel GMM estimation methodology is used to determine dynamics of inflation, π_t , with 41 cross-sections and 138 periods (1980Q1-2016Q1) utilizing fixed instruments of four lags of inflation, and two lags of import prices, interest rates, change in wages, and output gap. The model 1 is hybrid NKPC that uses *ulc* as a proxy for *mc* with mentioned fixed instruments plus two lags of *ulc*; the 2 is *unlc* augmented version of 1 with fixed instruments plus two lags of *ulc* and *unlc*; the 3 uses *tuc* as a proxy for *mc* with fixed instruments plus two lags of *tuc*. The superscripts "N" and "R" indicate estimations for normal (growing) and recessionary periods respective. The numbers in the table are estimated coefficients with white standard errors and covariances in the parenthesis, and *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The single quotation mark in the R-squared column indicates weighted R^2 , while double quotation indicates unweighted R^2 . The J-statistics presented with probabilities in the parenthesis. The σ_u and σ_e represent Swamy and Arora estimator of variance components of random effect (cross-section and idiosyncratic respectively) with rho numbers. The Hausman test suggest RE specification as appropriate model.

Similar scenario repeats in RE specified model 2 and model 3 cases. Augmented model 2 derives better results in terms of R-squared value that account nearly 70% of variations in current inflation. The model estimates backward- and forward-looking trade-off as 36%-54% and ulc and $unlc$ factors as 0.07 and 0.01 respectively during tranquil (normal) periods at 1% significance level. Whereas, the trade-off becomes 46%-55% preserving its significance; ulc drops to 0.05 losing its significance totally, and $unlc$ scales up to 0.04 preserving significance at 5% level during recessionary periods. On the other hand, the model 3 predicts tranquil (normal) period trade-off as 36%-54% and tranquil (normal) period tuc as 0.05 at 1% significance level, and recessionary period trade-off as 46%-55% at 1% significance level and recessionary period tuc as 0.06 at 5% significance level. These findings indicate that inflation has mainly backward-looking characteristics during recessionary periods, and unit labour cost fails to explain inflation in non-growing economic environment. Whereas, unit-non labour cost factor preserve its significance, thus it deserves a focus in proxying real marginal costs effectively. We address it to the fact that firms often respond to shocks by adjusting costs, mostly reducing non-labour costs as labour costs are rigid due to wage-setting institutions (collective wage agreement and labour contracts). Therefore, labour costs remain stock-still, while non-labour costs behave sensitive to recessionary shocks (Dhyne and Druant, 2010).

Lastly, we report structural parameters of hybrid NKPC models during normal (tranquil) and recessionary periods at table 1.15 where " N " and " R " capped variables represent their attitudes during growing and recessionary periods respectively. The coefficients of degree of backwardness, price stickiness, subjective discount factor, and real marginal cost fraction factor during recessionary periods are $(\omega_1+\omega_2)$, $(\theta_1+\theta_2)$, $(\beta_1+\beta_2)$, and $(\rho_1+\rho_2)$ respectively. Their standard errors are calculated with formula of $\sigma_{1+2} = \sqrt{\sigma_1^2 + \sigma_2^2}$.

Table 1.15 provides plausible results that unveil several facts. First, all three models behave more or less the same shedding a light on that degree of backwardness ranges between 0.44-0.46 during growing (normal) economic periods with 0.73-0.80 price stickiness in the markets. This indicates that nearly 45% of firms set the prices with backward-looking rule of thumb while these new prices last for 4-5 quarters.

Table 1.15.Structural Parameters of Hybrid NKPC during Normal/Recession periods

Model	1		2		3	
β type	Restricted	Unrestricted	Restricted	Unrestricted	Restricted	Unrestricted
$^N\omega$	0.4677*** (0.0108)	0.4539*** (0.0007)	0.4521*** (0.0265)	0.4486*** (0.0004)	0.4638*** (0.0116)	0.4515*** (0.0005)
$^N\Theta$	0.7935*** (0.0576)	0.8041*** (0.0009)	0.7328*** (0.0592)	0.7525*** (0.0013)	0.7625*** (0.0578)	0.7794*** (0.0011)
$^N\beta$	1	0.9026*** (0.0000)	1	0.8722*** (0.0000)	1	0.8979*** (0.0000)
$^N\rho$	-	-	0.7707*** (0.0849)	0.7521*** (0.0002)	-	-
$^N\Omega$	4.84	5.10	3.74	4.04	4.21	4.53
$^R\omega$	0.6028*** (0.0373)	0.5919*** (0.0014)	0.6073*** (0.0482)	0.5905*** (0.0015)	0.5961*** (0.0394)	0.5922*** (0.0014)
$^R\Theta$	0.7717*** (0.0724)	0.7892*** (0.0016)	0.7251*** (0.0827)	0.7449*** (0.0026)	0.7498*** (0.0762)	0.7703*** (0.0019)
$^R\beta$	1	0.7854*** (0.0003)	1	0.7993*** (0.0007)	1	0.7917*** (0.0005)
$^R\rho$	-	-	0.8756*** (0.1383)	0.8649*** (0.0009)	-	-
$^R\Omega$	4.52	4.74	3.64	3.92	3.97	4.35
J-stat.	0.1046 (1.0000)	0.1151 (1.0000)	0.1462 (1.0000)	0.1570 (1.0000)	0.1288 (1.0000)	0.1301 (1.0000)
Obs.	4919	4919	4886	4886	4886	4886

Notes: The Panel GMM estimation methodology is used to estimate structural parameters of NKPC with 41 cross-sections and 138 periods (1980Q1-2016Q1). The model 1 is hybrid NKPC that uses *ulc* as a proxy for *mc* with mentioned fixed instruments plus two lags of *ulc*; the 2 is *unlc* augmented version of 1 with fixed instruments plus two lags of *ulc* and *unlc*; the 3 uses *tuc* as a proxy for *mc* with fixed instruments plus two lags of *tuc*. All models use white cross-section instrument weighting matrix, and white cross-section standard errors and covariance that are given in parenthesis. The superscripts "N" and "R" indicate estimations for normal (growing) and recessionary periods respective. The asterisk denotes significance in following order: *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. J-statistics hypothesizes overidentification problem with probability in parenthesis; ω is degree of backwardness; Θ degree of price stickiness; ρ shows fraction of unit labour cost (*ulc*) in real marginal cost; and Ω is duration of prices in quarterly basis periods calculated as $1/(1-\Theta)$.

However, degree of backwardness remarkably increases to 0.59-0.60 (almost 15 bps) during recessionary periods while price stickiness appears quite stock-still as we observe very limited decrease in Θ . This indicates that nominal prices are fairly rigid as Keynesian economists argue. This rigidity is more blatant in the model 2 where nominal prices remain for 4.04 (unrestricted β case) / 3.74 (restricted β case) quarters during normal periods and this duration decreases to 3.92 (restricted β case) / 3.64 (restricted β case) quarters during recessionary periods.

Additionally, the model 2 shows that fraction of unit labour costs in real marginal cost is about 0.75 and 0.77 under relaxed β (which is estimated as 0.8522) and unrelaxed $\beta=1$ conditions respectively. This implies that remaining 0.33-0.35 percentage fraction is attributable by unit non-labour costs. However, the decomposition factor ρ jumps up to 0.86 and 0.87 during recessionary periods in unrestricted and restricted β cases respectively during pure recessionary periods. This indicates that fraction of unit labour costs in real marginal costs increases, while non-labour cost fraction decreases as firms adjust their costs (mostly reducing non-labour costs as labour costs are protected by wage agreement and labour contracts) in response to shocks (Dhyne and Druant, 2010).

1.6. Concluding remarks

This chapter examines dynamics of inflation during tranquil and recessionary periods under Phillips Curve (PC) framework and reports several findings. First, we find that forward-looking characteristic of inflation picks up weight after 1990's which indicates that inflation became more sensitive to expected prices. We also observe that inflation in developed markets (with nearly 40%-60% backward- and forward-looking trade-off) is more forward-looking comparing to emerging (50%-50% BF trade-off) and frontier (60%-40% BF trade-off) markets. This indicates that developed markets dear forward-looking price expectations more than others. Plus, we believe that frontier and some of emerging economies do not seem to be working so smoothly, in practice, in terms of macroeconomic systems as developed markets do.

Second, we reveal that NKPC describes the dynamics of inflation the best. However, the hybrid version of NKPC need better proxy for real marginal costs. For this, we augment hybrid NKPC model with omitted fraction of real marginal costs, unit non-labour costs. And the augmented NKPC model seems to be working better capturing more variations in current inflation. For robustness, we also incorporate unit labour and non-labour costs into one total unit cost factor, and we show that this variable is a better proxy for real marginal costs than using accounting only unit labour costs. In best specification, NKPC model shows that the Phillips relation (λ) varies across countries and markets. The model predicts that development markets have average *ulc* and *unlc* coefficients of 0.05 and 0.02 respectively, whereas

emerging and frontier markets have average coefficients of 0.07-0.04 (*ulc- unlc*) and 0.09-0.03 (*ulc- unlc*).

Third, we observe that all versions of Phillips curve collapses during pure recessionary periods, except our unit non-labour cost augmented NKPC hybrid model. In this specification, unit labour cost factor loses its statistical significance, while unit non-labour costs factor preserve its significance at 5% level. Moreover, NKPC structural parameters analysis indicates that fraction decomposition factor of real marginal cost (ρ) is about 0.75 during growing periods and it increases to 0.86 during pure recessionary periods. This indicates that weight of unit labour costs in real marginal costs increases, while non-labour cost fraction shrinks as firms adjust their costs (mostly reducing non-labour costs as labour costs are rigid due to wage agreement and labour contracts) in response to shocks. Thus, unit labour costs remain irresponsive while unit non-labour cost picks up more sensitivity during recessionary periods. On the other hand, the decomposition factor ρ varies across countries. We observe that development markets tend to have higher ρ (the average is about 0.75) comparing to emerging and frontier markets ($\rho=0.60$). Majority of developed markets has modernized labour markets where rights of employees protected by collective labour agreements and contracts that regulate the working conditions of unionized and non-unionized workers. Thus, nominal prices can be really persistent in these markets. However, the influence of labour unions and collective labour agreements is notably scant in developing (emerging and frontier) countries. In most cases employers directly cut wages in a response to negative shocks in these markets. Therefore, fraction of unit labour costs in real marginal costs often decreases concordantly ρ decrease further during recessionary periods.

Fourth, we find out that degree of backwardness (ω) ranges between 0.44-0.46 during growing (normal) periods, whereas it remarkably increases to 0.59-0.60 (almost 15 bps) during recessionary periods. This implies that firms tend to follow backward-looking rule of thumb in setting prices during recessionary periods. We believe that expectations on future prices flow smoothly and bidirectional between agents and market during growing economic periods, so agents benefit from all information available (past and expected) in the market. However, economic depression causes an uncertainty raising cloud of dust in the market, thus the

smooth flow will be disrupted. Until the dust settles, agents mainly benefit from backward-looking information.

Fifth, although we observe very limited decrease in price stickiness (θ), we believe that it is quite stock-still during both normal and recessionary period. Newly set prices seem to remain for 4-5 quarters during growing economic periods, whereas it slightly decreases to 3.5-4.5 quarters during recessionary periods. On contrary, our country-based NKPC structural parameter analysis report that nominal rigidity varies across cross-section countries remarkably. Particularly, it is relatively higher in development markets than emerging and frontier ones. The average price duration in developed markets is about 5 quarters, while it is nearly 4 quarters in emerging and frontier markets.

To conclude, we believe that inflation is very effective tool that has a role in economic and financial stability. We examine its dynamics and explore how its parameters behave normal and recessionary periods. Our findings reveal that degree of backwardness increases, while subjective discount factor decreases and Phillips relation (where real marginal costs only proxied by unit labour costs) totally lose its significance during economic depression. Thus, we conclude that there are significant structural and behavioural changes in dynamics of the inflation (Phillips Curve) during recessionary periods. In this respect, we conclude that it yields valuable information that signalizes upcoming crisis event, therefore, it can be used in our main chapter where we set up an early crisis signalling framework for 41 sampled countries over 1980-2016.

CHAPTER TWO

DYNAMICS OF UNEMPLOYMENT – OKUN’S LAW DURING TRANQUIL AND RECESSIONARY PERIODS

2.1. Introduction

The fundamental relationship between unemployment and real output has an important role in designing an early crisis warning system (EWS). It also reflects real aspects of macroeconomics that is a matter of interest for every individual agent in the economy, starting from consumers up to policy-makers. However, majority of related EWS literature omits its role in EWS due to two factors: (1) They mainly focus on financial (nominal) aspects of economy by attempting to gauge imbalances and crashes in currencies; (2) They argue that the unemployment rate is a lagging variable for crisis.

In this chapter, we show that unemployment and output are linked bi-directionally, thus, unemployment also can be used as a leading variable for crisis. In order to satisfy main aim of this thesis which is to establish better and more generalized EWS, we attempt to incorporate unemployment as a signalling variable into our EWS model. For this reason, we also examine structural and behavioural changes in unemployment-output relationship during recessionary periods. The common practice for such investigation is Okun's (1962) law framework which states empirical negative relationship between unemployment and real output⁵.

This empirical relationship significantly reflects real aspects of economy; therefore, it is crucial for a generalized EWS model which aims to account both real and nominal aspects of economy. In this respect, we study validity and stability of Okun's law in this chapter believing that it might yield valuable indications to be used in our EWS model. Due to its importance for economic policy, Okun's law has quite sizeable literature, especially for the U.S. However, a recent stream of literature points out that validity and stability of the relationship varies across countries and time periods which might be due to country-specific or economic environment-specific factors.

⁵ Artur Okun explored that each additional percentage point above 4% unemployment rate -the rate that considered as full employment condition- causes roughly 3% decrease in real output.

In this chapter, we examine Okun's relationship with a broader country-time sample using up-to-date data and primarily aiming to check whether dynamics and notional behaviour of the unemployment-output relationships vary across two states of economy: Tranquil periods, when economic fundamentals are largely sound and sustainable; and Recessionary periods, when economic variables go through an adjustment process before reaching a more sustainable level or growth path. We examine validity and stability of the relationship across 55 countries individually over 1980-2016 time periods. Besides, we also measure the magnitude of the Okun's coefficient during tranquil (normal) and recessionary periods separately. This will give us opportunity to measure whether the coefficient remains stable or turns undulant and whether it can be used as deterministic factor in the crisis signalling frameworks.

The remaining of the chapter is structured in following order. The next section briefly reviews empirical literature of Okun's law. Section 2.3 introduces the methodology and data used to test validity and stability of the Okun's law during tranquil and recessionary periods over 1980-2016. Section 2.4 discusses key findings of the study and the final section concludes.

2.2. Literature review

Due to its importance for economic policy, Okun's Law has always been used in empirical analyses and considerable body of related literature covers the US, the UK and the European countries. The central focus of this literature is whether Okun's relationship is stable and valid or not. A recent stream of papers points out that validity and stability of Okun's Law varies across countries and time periods. Although many researchers fix country-specific effects, time variation of Okun's law still remains arguable. Knotek (2007) claims that the instability in Okun's coefficients is related to the business cycle, reflecting the fact that unemployment reacts to output very differently during expansions than it does in recessions (i.e. in expansions, Okun's coefficient is smaller than during recessions). This is a central motivation of this chapter in relation to core aim of the thesis which is establishing better EWS model. Gordon (2010) calls attention to a structural shift in triangle of output, hours, and productivity during the last three recessions (1990-1991, 2001, and 2007-2009) that often labeled as "*jobless recoveries*" which refer to the periods when the Okun's law is arguably failed as a result of slow growth of real output

accompanied by continuing decline in employment. By examining the Okun's law in two different episodes (pre and post 1986), he finds that cyclical responses of aggregate hours and of output productivity remarkably differ from what Okun (1962) estimates. His results show that aggregate hours became more sensitive, while output productivity has almost lost significance. Thus, he concludes that this structural shift occurred due to the rise of some factors such as immigration, imports, and healthcare costs, jointly with the reduction in real minimum wage, have contributed to a rise of inequality and of flexibility of labor markets. Alongside with new technological development, firms easily scale the productivity up during economic recoveries even they continue to cut labor costs.

Few other studies (Reich, 2010; Meyer and Tasci, 2012; Owyang and Sepkhposyan, 2012; McCarthy et al., 2012; Chinn et al., 2014; Valadkhani and Smyth, 2015; Cazes and Verick, 2011; Pereira, 2014) also boldly assert that the Okun's law is unstable over time addressing to a great time variation in Okun's parameters and it's overly sensitivity to the cyclical fluctuations. Chinn et al. (2014) believe this sensitivity is one of the two motives behind instability of Okun's law. The second motive is elimination of the long-term effects between real output and unemployment after first differencing or filtration methodologies which remove low frequency information. Chinn et al. (2014) argues that any loss of information might bring serious bias to the estimates if the long-run interactions generate a strong impact on short-run changes in unemployment and GDP.

Meyer and Tasci (2012) argue that Okun's law has been unstable during recessionary periods due to its failure to account shifts in labor force participation and due to the static aspects of the original Okun's model. They highlight that, even though, the coefficient substantially varies over time, its sign remains negative. Alternatively, they urge allowing regression to reflect a dynamics (changing) relationship between output and unemployment fluctuations based on the fact that these measures follow longer-run or structural trends, which change over time. Fundamentally, the Okun's law involves deviations of real output and unemployment rates from their full employment levels that, however, are not observable. Therefore, determining these values using appropriate statistical methods appears to be a key step in the estimation of Okun's coefficient. There are several methods available to isolate cyclical component from a time series and

derive its smoothed series. Alongside univariate techniques of removing linear deterministic and quadratic trends, the differencing methodology is also an applicable tool. On the other hand, more advanced approaches such as Boschan-Ebanks (1978) Phase-Average Trend method (PAT), Beveridge-Nelson (1981) filter (BE), Hodrick-Prescott (1997) filter (HP), Baxter-King (1995) Bandpass filter (BK), and Christiano-Fitzgerald (1999) Bandpass filter (CF) are also capable of removing irregular stochastic and deterministic frequencies from the series.

Gordon (2010) criticizes the frequently used HP filter as well as bandpass filters (BK and CF) arguing that they are overly sensitive to the cyclical fluctuations, especially during recession periods. Instead, he prefers to use Kalman filter that allows manual controls for outside information (aspects of inflation and supply shocks) and timing of business cycle, as a result isolates trend which is unresponsive to these cyclical fluctuations.

On the other hand, Beyer and Tasci (2012) argue that smoothing techniques and filtrations can produce different results, but it cannot be reason of substantial variations in the output-unemployment relationship. Lee (2000) studies robustness of Okun's law across 16 OECD countries over 1955-1996, presenting both first-difference and gap model specifications using comparatively HP, BN, and Kalman filters. He states that the coefficient considerably varies across countries; however, the disparity across filtration methods is negligibly low. As a main motive for variation he points out differences in labor market slacks, i.e. Japan has high institutional rigidity (lifetime job security), while European labor markets have less rigidities.

Owyang and Sepkhposyan (2012) consider various specifications of the law to assess the degree of time variation in the unemployment and output fluctuations over the business cycle. They pay particular attention to the three most recent the US recessions and document a great degree of instability in the historical performance of Okun's law during recessionary periods. They observe that the coefficient shrinks in absolute magnitude during recessions and document that Okun's law is highly correlated with the business cycle. They concluded that the largest changes in the coefficients tend to appear around recessions periods. Similar finding was observed by Grant (2017) who studied Okun's relationship in the US during the Great Recession. He finds that widely accepted -2.0 Okun's

coefficient shrank remarkable to -0.5 during recession periods. These findings indicate that behavioural changes in the coefficient (unemployment-output relationship) might yield signaling information of upcoming crisis; thus, it can be used in the EWS models.

Contrarily, Ball et al. (2012) document quite strong and stable trade-off between unemployment and real output across different countries, which, even, has not substantially weakened during the Great Recession. They conclude that Okun's coefficient remained fairly stable over time periods and the arguments about "*jobless recoveries*" or demise of the Law during the Great recession periods are futile. They opine that misunderstanding has arisen due to slow growth in output which, in turn, led high unemployment to linger. Although they detect that impact of a percentage change in output on unemployment rate substantially varies from one country to another, they address it to the country's idiosyncratic characteristics of labor markets such as Japanese "*lifetime employment*" tradition which makes employers reluctant to dismiss employees and flexible European labor markets due to extremely high frequency of temporary employee contracts.

To our knowledge, the literature lacks of a broad investigation on behavioural changes of the Okun's relationship during recessionary periods. Many of recent literature mainly studies the Okun's law at a sub-country, regional levels (Adanu, 2005; Villaverde and Maza, 2009; Binet and Facchini, 2013; Durech et al., 2014) using the original framework, and document heterogeneity regarding overall stability and validity of the law. Also, empirical literature that covers Okun's law examination in large international sample is notably scant as well.

In this respect, our study attempts to fill this gap by studying Okun's Law relationship internationally over 55 countries between periods of 1980 and 2016. We report comparative results of the Okun's coefficients during pure growing (tranquil) and non-growing periods in order to explore whether the coefficients remain stable or turn undulant and can be used as deterministic factor for recession signalling system. To address Chinn et al. (2014), we schedule an ARDL analysis and run error correction model to account both short and long-term relationship between unemployment gap and real output gap. Further, we cement our findings with dynamic panel estimations fixing country-specific effects.

2.3. Data and methodology

The paper empirically tests the validity and stability of the Okun's Law in many dimensions over 1980-2016 across 55 countries (Appendix table B1) using quarterly data capturing tranquil (normal) and recessionary periods.

2.3.1. Empirical model set-up

To set up econometric model for Okun's Law, we start with a simple Cobb-Douglas production function:

$$Y = Af(K, L) \quad (2.01)$$

where the output Y is a function of fixed capital (K) and total employment (L) under condition of $\alpha+\beta=1$; and A is technological changes that may shift Y . We can define unemployment (U) as $U=N-L$ where N is total labor force. Thus, equation (2.01) becomes:

$$Y = A + \eta K + \varphi N - \varphi U \quad (2.02)$$

We assume that shifts in aggregate demand and changes in employment cause output to fluctuate around potential and A , K , and N grow at constant rate. To account cyclical fluctuations, we integrate long-run levels of series and stochastic terms for other shocks on output as following.

$$Y_t - Y_t^* = (A_t - A_t^*) + \eta(K_t - K_t^*) + \varphi(N_t - N_t^*) - \varphi(U_t - U_t^*) + \varepsilon_t \quad (2.03)$$

As A , K , and N have constant grow rates, majority of fluctuations in real output ($Y-Y^*$) is attributable by fluctuations in unemployment ($U-U^*$). Thus, the Okun's Law model derives as,

$$Y_t - Y_t^* = -\varphi(U_t - U_t^*) + \omega_t \quad (2.04)$$

where asterisk indicates long-run (potential) levels of related variables; Y_t is natural logarithm of real output at time t ; U_t is natural logarithm of unemployment at time t ; and φ is the Okun's coefficient that describes negative relationship between unemployment gap and real output gap.

In turn, fluctuation of real output around potential (real output gap) also cause firms to adjust their employment (hire and fire workers) and cause unemployment to fluctuate around potential (unemployment gap). We express these relationships as:

$$E_t - E_t^* = \gamma(Y_t - Y_t^*) + \varepsilon_t \quad (2.05)$$

$$U_t - U_t^* = \alpha(E_t - E_t^*) + \mu_t \quad (2.06)$$

where $\gamma > 0$ and $\alpha < 0$; E_t is natural logarithm of employment at time t ; and U_t is natural logarithm of unemployment at time t ; Y_t is natural logarithm of real output at time t . We derive another form of Okun's Law model by plugging eq.2.05 into eq.2.06 as:

$$U_t - U_t^* = \beta(Y_t - Y_t^*) + r_t \quad (2.07)$$

where $\beta_1 = \alpha^* \gamma$ and $r_t = \mu_t + \alpha^* \varepsilon_t$. Notice that eq.2.07 is inverse of eq.2.04. Thus, the Okun's coefficient β should to be negative as it equates to $-1/\varphi$. The r_t is an error term which captures factors that shift the unemployment-output relationship. These factors include unusual changes in productivity or in labor force participation. Saying that “Okun's Law fits well” means that r_t is usually small. This form of Okun's law often labelled as “gap” version that –aims to identify how much the economy would produce “under conditions of full employment”– involves deviations of real output and unemployment rates from their full employment levels that, however, are not observable. Determining these values using appropriate statistical methods appears to be a key step in the estimation of Okun's coefficient. There are several methods available to isolate cyclical component from a time series and derive its smoothed series. Alongside univariate techniques of removing linear deterministic and quadratic trends, the differencing methodology is also an applicable tool. On the other hand, more advanced approaches such as Boschan-Ebanks (1978) Phase-Average Trend method (PAT), Beveridge-Nelson (1981) filter (BE), Hodrick-Prescott (1997) filter (HP), Baxter-King (1995) Bandpass filter (BK), and Christiano-Fitzgerald (1999) Bandpass filter (CF) are also capable of removing irregular stochastic and deterministic frequencies from the series.

Although this study uses gap version of Okun's law, two more versions of the law also exist.

$$CHANGEVERSION: \quad \Delta U_t = \beta_0 + \beta_1 \Delta Y_t + \varepsilon_t \quad (2.08)$$

$$DYNAMICVERSION: \quad \Delta U_t = \beta_0 + \sum_{i=1}^n \beta_i \Delta Y_{t+1-i} + \sum_{i=1}^m \theta_i \Delta U_{t-i} + \varepsilon_t \quad (2.09)$$

where Y and U stand for real output and unemployment rate respectively; Y^* represents potential output; U^* is the unemployment rate under full employment condition (or natural rate of unemployment); and ε_t is an error term.

The “change” or “difference” version of the law captures how changes in the unemployment rate move from one period to other in response to changes in real output. Indeed, it accounts contemporaneous correlation between output growth and movements in unemployment that is, how output growth varies simultaneously with changes in the unemployment rate. Whereas the dynamics version includes lags of output growth alongside with its current value to account variations in changes in current unemployment rate where the lag length is usually set as 4 quarters. This version minimizes loss of information as it accounts all available information (current and past information).

2.3.2. Country individual time series estimation

In order to examine the law during tranquil and recession regimes, we add recession-dummy variable into eq.2.07.

$$U_t - U_t^* = \beta_1 (Y_t - Y_t^*) + \beta_2 (Y_t - Y_t^*) DUMMY + o_t \quad (2.10)$$

where β_1 is Okun's coefficient during growing (tranquil) periods, while $\beta_1 + \beta_2$ is Okun's coefficient during recessionary periods. Thus, standard error of recession period Okun's coefficient is manually calculated with formula of $\sigma_{1+2} = \sqrt{\sigma_1^2 + \sigma_2^2}$.⁶

In this respect, we base our Okun's Law model according to eq.2.07 and eq.2.10 where ΔU_t and ΔY_t are natural logarithms of unemployment gap and real output gap at time t . We calculate long-run levels using HP technique with a degree of smoothing λ . The λ is set by using Ravn and Uhliq (2002) frequency rule: the number of periods per year divided by 4, raised to the power x , and multiplied by 1600. Hodrick and Prescott (1997) recommend the value 2 for x , whereas Ravn and

⁶ Covariance between 1 and 2 is assumed to be zero or very close to zero.

Uhliq (2002) suggest using 4 for x. Following Hodrick and Prescott (1997), we derived $\lambda=100$ for annual data, and $\lambda=1600$ for quarterly data to find out the trend (μ_t) that minimizes the sum as given by:

$$\min_{\{\mu_t\}_{t=0}^T} \left(\sum_{t=0}^T (y_t - \mu_t)^2 + \lambda \sum_{t=1}^{T-1} ((\mu_{t+1} - \mu_t) - (\mu_t - \mu_{t-1}))^2 \right) \quad (2.11)$$

2.3.3. Cross-sectional panel estimation

In order to address the argument of Beyer and Tasci (2012) regarding instability of Okun's law might be motivated by lack of dynamic aspects of the law, we equip the law model with dynamic aspects considering lags of real output gap. This makes sense as it might take time for firms to adjust employment in response of changes in output, i.e. firms do not hire or fire workers immediately demand changes. In this scenario, we follow backward stepwise regression (SOLS) methodology and let the model to decide which lags should be kept in the model and which should be eliminated. The stepwise methodology offers forward and backward selection techniques where first is used for fishing expedition and the second is used for fine-tuning. For a very large set of potential independent variables from which one wishes to extract a few, then stepwise direction should be forward. On the other hand, if we deal with modest-sized set of potential variables from which you wish to eliminate a few, then backward stepwise is favorable. If we denote cyclical component of a variable with Δ , then our backward stepwise formation can be expressed as:

$$\Delta U_t = \sum_{i=0}^4 \beta_i \Delta Y_{t-i} + \omega_t \quad (2.12)$$

We limited lags with four which can be regarded an optimal lag length for unemployment to assimilate fluctuations in real output. Plus, including further lags may also raise a collinearity problem which will bring bias to estimates. With backward stepwise methodology we carry out four tests, $H_{0i}: \beta_i = 0$, where $i = \{1,2,3,4\}$. The lowest partial F-test value F_x corresponding to $H_{0i}: \beta_i = 0$ or t-test value t_x is compared with the preselected significance values F_0 and t_0 . In case, $F_x < F_0$ or $t_x < t_0$, we exclude the lag and the model will shrunk. On contrary, if $F_x > F_0$ or $t_x > t_0$, then we do not exclude any lag leaving original model with 4 lags.

We also check if our series are cointegrated in long-run. If so, we estimate long-run Okun's Law coefficient using eq.(2.07) model in a panel dynamics OLS (DOLS) framework where leads and lags are specified with "Auto-Schwarz" maximum four leads-lags specification. The long-run coefficient covariances are computed using sandwich method under Bartlett kernel and Newey-West fixed bandwidth methodology. Our DOLS model provides the following linear orthogonality condition. We believe this technique will capture more variations in dependent variable comparing to panel OLS and panel SOLS.

In order to design our panel estimation model, we examine consistency and efficiency of GLS estimators through cross-section fixed (FE) and random effects (RE) as well as pooled estimation. All these specifications have potential advantages and disadvantages. The pooled model often generates biased estimates as it does not impose any controls for between-effects (unobserved heterogeneity between cross-sections such as culture, religion, gender, race, etc.) among cross-section which leads its residuals to be heteroskedastic. The cross-section fixed-effects model assumes that heterogeneity among all entities is time-invariant and fixed across entities, and it wipes out these between-effects (unobserved heterogeneity among cross-section) by allowing each entity to have their own intercept values. In other words, the fixed dummy variable controls for all time-invariant differences between entities where intercept varies among cross-sections and remains stable over the time horizon as below.

$$U_t - U_t^* = \beta_0 + \sum_{i=1}^{55} \lambda_i D_i + \beta_1 (Y_t - Y_t^*) + \epsilon_t \quad (2.13)$$

where D_i is a dummy variable which equates 1 for the country "i", and zero for others in the sample. The $\beta_0 + \lambda_i D_i$ controls time-invariant between-effect (cross-section) and ϵ_{it} is an idiosyncratic error term. This FE specification is based on two main assumptions: (1) $\epsilon_t \sim i.i.d. N(0, \sigma_e^2)$, and (2) exogeneity of covariates x_{ij} , i.e. $cov(\epsilon_{ij}, x_{ij}) = 0$ for all dependent variables where $Var(\epsilon_{ij}) = \sigma_e^2$. However, residuals of FE model might not always be the most efficient (although it is consistent) as it completely wipes out between-effects and its residuals account only within-effects (heterogeneity within cross-section, i.e. among variables of same cross-section).

On the other hand, random-effect model is a specific type of pooled estimation that assumes time-varying heterogeneity across entities, thus, it generates estimates closer, on average, to the true value of any particular country as below.

$$U_t - U_t^* = \beta_{0i} + \beta_1(Y_t - Y_t^*) + \epsilon_t \quad (2.14)$$

where $\beta_{0i} = \beta_0 + \omega_i$, $\omega_i \sim N(0, \sigma^2)$. When β_{0i} is plugged into eq.2.14, it turns,

$$U_t - U_t^* = \beta_0 + \beta_1(Y_t - Y_t^*) + r_t \quad (2.15)$$

where $r_t = \epsilon_t + \omega_i$. The ω_i controls between-entity errors, while ϵ_t controls within-entity errors. The residuals of RE model are often shrunk, and thus homoskedastic, and it also offer possibility of differential between cross-sections. However, due to potential correlation between covariates of explanatory variables and ω_i the estimates of RE model are often biased. Unlike FE model, it captures both “within” and “between” deviations, and allows all entities to have a time-varying value for intercept. In other words, “ D_i ” was a part of intercept in FE, and it becomes a part of error “ r_t ” in RE model.

Table 2.01. Panel Estimation Model Selection

First Step	Second Step	Decision
H ₀ of RFE test is not rejected (NO FIXED-EFFECT) H ₀ of BP LM test is not rejected (NO RANDOM-EFFECT)	NA	Data are poolable
H ₀ of RFE test is not rejected (NO FIXED-EFFECT) H ₀ of BP LM test is rejected (RANDOM-EFFECT)	NA	Random Effect Model
H ₀ of RFE test is rejected (FIXED-EFFECT) H ₀ of BP LM test is not rejected (NO RANDOM-EFFECT)	NA	Fixed Effect Model
H ₀ of RFE test is rejected (FIXED-EFFECT) H ₀ of BP LM test is rejected (RANDOM-EFFECT)	H ₀ of Hausman test is rejected	Fixed Effect Model
H ₀ of RFE test is rejected (FIXED-EFFECT) H ₀ of BP LM test is rejected (RANDOM-EFFECT)	H ₀ of Hausman test is not rejected	Random Effect Model

Notes: The null hypothesis for both Breush-Pagan LM tests is "No Random Effects". The null hypothesis for Redundant Fixed Effect test is "No Unobserved Heterogeneity (No Fixed Effect)". The null hypothesis for Hausman Test is "there is no correlation between unique errors and the regressors".

Source: The author's design

The trade-off between heteroskedasticity problem of FE and serial correlation problem of RE depends on data and sample. Thus, we let the data to decide which specification to use in panel framework. Employing Redundant Fixed Effects (RFE)

and Breusch-Pagan Lagrange Multiplier (BP LM) tests as well as Hausman test (if necessary) we find the best panel model that is appropriate for our data and sample (see table 2.01).

2.3.4. Autoregressive distributed lag (ARDL) model

2.3.4.1. Country individual ARDL model

Besides, we take Chinn et al. (2014)'s arguments seriously, that original Okun's formation does not incorporate long-term effect between the unemployment and output as the low-frequency information is eliminated by first differencing or by subtracting potential log-GDP and the omission of long-run effects can be costly if long-run relationships in fact exert a strong effect on short-run dynamics of series. Therefore, crediting Chinn et al. (2014) we also investigate Okun's law in Autoregressive Distributed Lag (ARDL) framework as potential cointegration between series is highly possible.

Thus, following Pesaran et al. (2001) we shape our unrestricted error correction model (UECM) for Okun's law with ARDL approach as below.

$$\Delta U_t = c + \tau + \sum_{i=1}^k \alpha_i \Delta U_{t-i} + \sum_{j=0}^l \beta_j \Delta Y_{t-j} + \phi_1 U_{t-1} + \phi_2 Y_{t-1} + \varepsilon_t \quad (2.16)$$

where residual term is White noise stationary. Subsequently, we formulate restricted/regular error correction model (RECM) as:

$$\Delta U_t = c + \sum_{i=1}^k \alpha_i \Delta U_{t-i} + \sum_{j=0}^l \beta_j \Delta Y_{t-j} + \lambda ECT_{t-1} + \varepsilon_t \quad (2.17)$$

where ECT_{t-1} is a residual term of long-run Okun's model $U_{t-1} = \beta_0 + \beta_1 Y_{t-1} + \varepsilon_{t-1}$ (β_1 is long-run Okun's coefficient). Here, ΔU_t and ΔY_t stand for first differences of unemployment rate and natural logarithm of real output respectively at time t . The ARDL approach also includes k and l optimal lags of dependent and independent variables respectively where k and l are determined in accordance with Schwarz information criterion (SIC). The short-run Okun's coefficient is represented by β_0 in eq.2.17 model that is expected to be negative due to the law. Additionally, λ is the coefficient of ECT_{t-1} (error correction term) that also should be negatively signed in

bounds of $-1 \leq \lambda \leq 0$, indicating convergence towards equilibrium, a positive sign indicates divergence from equilibrium. It shows the speed of self-adjustment of RECM model back to equilibrium (by correcting its previous period disequilibrium) following a shock that disturbs this equilibrium, and this last period's deviation from a long-run equilibrium influences the models short-run dynamics. In case λ brings positive estimate, then it signalizes that the model comprises autocorrelation problem in the model, which strictly needs to be fixed. In case $\lambda < -1$, then the model is not stable over time horizon, indicating potential structural breaks to should be corrected.

Pesaran et al. (2001) state that ARDL approach (bound test) is only valid for the set of series with $I(0)$ and $I(1)$ irrespective of whether the regressors are purely $I(0)$, purely $I(1)$ or mutually cointegrated, but none of the series should be integrated in order 2 and above. In Appendix table B2⁷, we report results of ADF unit root test for series of U , Y , ΔU_t , and ΔY_t where gap series of all countries are found stationary at level $I(0)$, while U and Y are either $I(0)$ or $I(1)$. This indicates that both original (eq.2.07 and eq.2.10) and ARDL (eqs.2.16-2.17) frameworks are applicable. Moreover, both ARDL models use HAC-robust Least Squares (LS) technique without including any whitening options to overcome potential problems of heteroskedasticity and serial correlation. For robustness, we also check stability of both UECM and RECM with CUSUM of squares test which examines changes in cumulative sum of recursive residuals over time.

Then, we carry out Wald test hypothesizing $H_0: \phi_1 = \phi_2 = 0$, to examine if U and Y have long-run interactions. We shall compare derived F-statistics with critical bound values of Pesaran et al. (2001, pp.300-301). Since we haven't constrained the intercept of our model, and ECM involves a linear (constrained) trend factor in equations, we consider lower and upper bounds' values of case IV that is specified for the model with unrestricted intercept and (restricted) linear trend. However, for some countries we have exclude the intercept and trend due to lack of significance, while some others have only constrained or unconstrained intercept without any trend factors. Thus, for these countries we consider lower and upper bounds' values of cases I, II, and III respectively. The case I is specified for the model with no

⁷Stationarity of the data used in this study is examined under ADF unit root test with equation of $\Delta Y_t = \theta_0 + \theta_1 T + \rho Y_{t-1} + \varepsilon_t$. The results of ADF unit root test are reported in Appendix table B2.

intercept and no trend; while the case II and III are specified for models with restricted and unrestricted intercepts respectively but no any trend factors. The long-run interaction between series occurs only if the Wald test's F-statistics exceeds the critical bounds, and validates application of further RECM analysis.

To measure long-run multiplier between Y and U , we shall use the formula $-\phi_2/\phi_1$ where numerator is -1 multiplied by the coefficient of Y_{t-1} , and denominator is the coefficient of U_{t-1} . On the other hand, we also can observe short-run dynamics associated with the model through impulse-response function that injects a "shock" of one standard deviation and displays its reaction. This impulse-response function also portrays dynamic interaction (causality) between unemployment and real output as well as its direction (which affects which at what magnitude).

Under impulse-response function, we employ **Granger causality analysis** in order to show that unemployment is a lagging variable to fluctuations in real output; thus, it can be used in our EWS model. This is based on fundamental concept that, if a series X "Granger-causes" a series Y , then past values of X should contain information that helps predict Y above and beyond the information contained in past values of Y alone. It is said that independent variable (x) "Granger-causes" the dependent variable (y) in case " x " has deterministic role in " y ", that is, if the coefficients on the lagged " x "s are statistically significant at a given level. To proceed this analysis we design our econometric setup in the context of bivariate linear autoregressive model of two variables Unemployment Gap ($\Delta U_t = U_t - U_t^*$) and Real Output Gap ($\Delta Y_t = Y_t - Y_t^*$) as following.

$$\Delta U_{c,t} = \sum_{i=1}^p \alpha_{1c,i} \Delta U_{c,t-i} + \sum_{j=1}^p \beta_{1c,j} \Delta Y_{c,t-j} + \varepsilon_{1c,t} \quad (2.18)$$

$$\Delta Y_{c,t} = \sum_{i=1}^p \alpha_{2c,i} \Delta U_{c,t-i} + \sum_{j=1}^p \beta_{2c,j} \Delta Y_{c,t-j} + \varepsilon_{2c,t} \quad (2.19)$$

where t notes the time period dimension of the panel, and c denotes the cross-sectional dimension. The p is the maximum number of lagged observations included in the model which is determined by SIC. The α and β are coefficients that show contributions of each lagged observations to the predicted values of $\Delta U_{c,t}$ and $\Delta Y_{c,t}$, and $\varepsilon_{1c,t}$ and $\varepsilon_{2c,t}$ are prediction errors for each time series respectively. If the

variance of $\varepsilon_{1c,t}$ (or $\varepsilon_{2c,t}$) is minimized by including lags of $\Delta Y_{c,t}$ (or $\Delta U_{c,t}$) terms in equation 2.18 (or 2.19), then it is said that $\Delta Y_{c,t}$ (or $\Delta U_{c,t}$) Granger-causes $\Delta U_{c,t}$ (or $\Delta Y_{c,t}$). This can be tested by performing a Wald test (F-test) of the null hypothesis of $H_{01}: \beta_1=0$ (or $H_{02}: \alpha_2=0$), given assumptions of covariance stationarity and linearity on $\Delta U_{c,t}$ and $\Delta Y_{c,t}$. The magnitude of a G-causality interaction can be estimated by the logarithm of the corresponding F-statistic (Geweke, 1982). This magnitude will certainly show inter-importance of unemployment and real output, that addresses whether firms adjust employment due to fluctuations in real output or movements in unemployment around its potential cause real output to fluctuate.

The standard approach of Granger causality analysis assumes stationarity and linearity of variables. On panel framework, it treats the panel data as one large stacked set of data, assuming all coefficients are same across all cross-sections (stacked/common coefficient with the exception of not letting data from one cross-section enter the lagged values of data from the next cross-section). This assumption might give misleading results on panels where cross-sections are considerably different in many dimensions. Thus, as an alternative approach we follow Dumitrescu-Hurlin (2012) (DH) methodology that allows all coefficients vary across cross-sections. DH test assumes there can be causality for some cross-section, but not necessarily for all. This approach employs standard Granger Causality regressions for each cross-section individually, performing Wald (F-test) test of p linear hypotheses $\beta_{11}=...=\beta_{1p}=0$ (or $\alpha_{21}=...=\alpha_{2p}=0$) to retrieve W_c , and take its average for N cross-sections deriving $\bar{W}$ which is termed as "*Wbar statistic*".

$$\bar{W} = \frac{1}{N} \sum_{i=1}^N W_c \quad (2.20)$$

where W_i is standard adjusted Wald statistics for cross-section c . The standardization of this statistic, appropriately weighted in unbalanced panels, follows a standard normal distribution that is termed as "*Zbar statistic*".

$$\bar{Z} = \sqrt{\frac{N}{2p}} * (\bar{W} - p) \quad (2.21)$$

This $\bar{Z}$ statistics is favored for panel datasets with large numbers of cross-sections (N) and time periods (T).

Moreover, we also investigate whether magnitude and significance of Granger causality between $\Delta U_{c,t}$ and $\Delta Y_{c,t}$ changes or not during pure recessionary and growing periods. Thus, we specify our Granger causality model as below.

$$\Delta U_{c,t} DUMMY_t = \sum_{i=1}^p \phi_{1i} \Delta U_{c,t-i} DUMMY_{t-i} + \sum_{j=1}^p \theta_{1j} \Delta Y_{c,t-j} DUMMY_{t-j} + r_{1t} \quad (2.22)$$

$$\Delta Y_{c,t} DUMMY_t = \sum_{i=1}^p \phi_{2i} \Delta U_{c,t-i} DUMMY_{t-i} + \sum_{j=1}^p \theta_{2j} \Delta Y_{c,t-j} DUMMY_{t-j} + r_{2t} \quad (2.23)$$

$$\begin{aligned} \Delta U_{c,t} (1 - DUMMY_t) &= \sum_{i=1}^p \gamma_{1i} \Delta U_{c,t-i} (1 - DUMMY_{t-i}) + \sum_{j=1}^p \lambda_{1j} \Delta Y_{c,t-j} (1 - DUMMY_{t-j}) + n_{1t} \end{aligned} \quad (2.24)$$

$$\begin{aligned} \Delta Y_{c,t} (1 - DUMMY_t) &= \sum_{i=1}^p \gamma_{2i} \Delta U_{c,t-i} (1 - DUMMY_{t-i}) + \sum_{j=1}^p \lambda_{2j} \Delta Y_{c,t-j} (1 - DUMMY_{t-j}) + n_{2t} \end{aligned} \quad (2.25)$$

where $DUMMY$ is recession-dummy variable that takes value of 1 during recessionary periods, and zero if otherwise. The models in 2.22 and 2.23 are designed to measure significance and magnitude of the causality during pure recessionary periods, whereas the models in 2.24 and 2.25 account only pure growing periods.

2.3.4.2. Panel ARDL model - pooled mean group (PMG) technique

For robustness and generalization, we examine ARDL models that are specified at eqs.2.16-2.17 under panel framework using Pooled Mean Group (PMG) technique. This specific technique is panel version of ARDL analysis. In addition, we augment eqs.2.16-2.17 with recession-dummy variables in order to observe whether long-run and short-run Okun's coefficients behave differently during growing (tranquil) and recessionary periods. Thus, we shape our unrestricted error correction model (UECM) Okun's Law model as:

$$\Delta U_t = c + \tau + \sum_{i=1}^k \alpha_i \Delta U_{t-i} + \sum_{j=0}^l (\beta_j \Delta Y_{t-j} + \theta_j \Delta Y_{t-j} DUMMY_{t-j}) + \phi_1 U_{t-1} + \phi_2 Y_{t-1} + \phi_3 Y_{t-1} DUMMY_{t-1} + \varepsilon_t \quad (2.26)$$

where DUMMY variable takes value of 1 during recessionary periods and zero during other periods. Long-run Okun's coefficient during tranquil (normal) periods is derived as $-\phi_2/\phi_1$, and during recessionary periods it is $-(\phi_2 + \phi_3)/\phi_1$.

Subsequently, we formulate restricted/regular error correction model (RECM) as:

$$\Delta U_t = c + \sum_{i=1}^k \alpha_i \Delta U_{t-i} + \sum_{j=0}^l (\beta_j \Delta Y_{t-j} + \theta_j \Delta Y_{t-j} DUMMY_{t-j}) + \lambda ECT_{t-1} + \varepsilon_t \quad (2.27)$$

where ECT_{t-1} is a residual term of long-run Okun's model $U_{t-1} = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-1} DUMMY_{t-1} + ECT_{t-1}$, ($\beta_1 = -\phi_2/\phi_1$ and $\beta_2 = -\phi_3/\phi_1$ are long-run Okun's coefficients derived from eq.2.18). The k and l optimal lags of dependent and independent variables respectively, where they are determined by Auto-Schwarz technique with maximum four lags. The λ is the coefficient of ECT_{t-1} (error correction term) that also should be negatively signed in bounds of $-1 \leq \lambda \leq 0$, indicating convergence towards equilibrium, a positive sign indicates divergence from equilibrium. The β_j and $\beta_j + \theta_j$ are short-run Okun's coefficient during tranquil (normal) and recessionary periods respectively. The standard errors of short- and long-run Okun's coefficient is computed manually with formula of $\sigma_{1+2} = \sqrt{\sigma_1^2 + \sigma_2^2}$.

2.4. Results and discussion

2.4.1. Okun's law estimation under OLS technique

2.4.1.1. Results of country individual time-series analysis

The paper empirically tests the validity of Okun's law in many dimensions over 1980-2016 across large sample of countries. We pay focus on different time periods (eq.2.07) in order to check whether the coefficient substantially varies across time intervals as few studies report (Meyer and Tasci, 2012; Owyang and

Sepkhposyan, 2012; Grant, 2017). Also, we examine whether the law substantially changes or not during tranquil and recessionary periods (eq.2.10).

Although we gather different results from each country, our findings mainly refer universality of Okun's law as it appears statistically significant in most countries. Thus, we confirm overall validity of the Okun's law. However, looking to time intervals one can easily see time-variation of Okun's law. Although these variations are usually modest in size, we cannot ignore overall instability of the law. Especially in Bulgaria, Croatia, Poland, Portugal, Russia, and South Korea.

Table 2.02 reports core results of these examinations (eq.2.07 and eq.2.10) where the Okun's coefficient varies across countries and time periods. Focusing on developed market sample, we find the lowest Okun's coefficients in Luxembourg (-0.06), Japan (-0.11), Austria (-0.14), Norway (-0.17), and Italy (-0.19), and the highest coefficients in Spain (-0.89), United States (-0.50), and Australia (-0.46) at 1% significance level over 1980-2016. It is noteworthy that the average Okun's coefficient in developed market sample is about -0.32, and shrinking analysis period to 1990-2016 does not change the average coefficient substantially. However, on country basis, we still explore some considerable variations. For instance, the absolute coefficient increases from -0.89 to -0.96 in Spain; from -0.50 to -0.55 in the U.S.; from -0.36 to -0.41 in Portugal; and from -0.24 to -0.33 in Switzerland. While it decreases from -0.30 to -0.26 in Denmark and from -0.17 to -0.13 in Norway. Shrinking the analysis period further to 2000-2016, depicts clearer picture. The average of developed sample slightly decreases to -0.29, while country individual coefficients substantially changes in the Australia, Finland, New Zealand, Portugal, South Korea, Sweden, and United Kingdom. We believe these bi-directional variations have multi-dimensional country-specific motives that are needed to be fixed with panel analysis.

On the other hand, emerging market sample yields relatively lower coefficient with average of -0.19 where the lowest ones are derived by China (-0.01), India (-0.02), Indonesia (-0.05), and Malaysia (-0.08), while the highest ones are generated by Greece (-0.36), Chile (-0.35), Brazil (-0.34), and South Africa (-0.30). It seems that Asian countries shrink the average coefficient of the sample down. The similar scenario was in role for developed markets sample where Japan was another Asian country with low coefficient. Besides, we observe that the law coefficient

substantially varies across time horizons. Shrinking analysis period to 1990-2016 and to 2000-2016 causes an increase in its absolute value in Greece (from -0.36 to -0.54), South Africa (from -0.30 to -0.39), Poland (from -0.21 to -0.73), and Turkey (from -0.12 to -0.23); while it seems to be somewhat stable in remaining countries.

Lastly, frontier and unrated markets sample yield relatively higher Okun's coefficient comparing to emerging markets. The average coefficient during 1990-2016 periods is about -0.28 which increases to -0.32 during 2000-2016 time interval. The lowest coefficients are observed in Romania (-0.13) and Slovenia (-0.18), while the highest coefficients are documented in Lithuania (-0.44), Cyprus (-0.42), Slovakia (-0.42), and Latvia (-0.41). The coefficients of remaining countries range between -0.20 and -0.36. Interestingly, all countries except Romania and Bulgaria, yield relatively stable Okun's coefficient within a given country across different time horizons.

The last column of table 2.02 displays results of Okun's Law relationship during pure growing (tranquil) and pure recessionary periods (eq.2.10) with "N" and "R" capped ΔY variables respectively. The coefficients of the law during recessionary periods are $(\beta_1 + \beta_2)$, and its standard error is calculated with formula of $\sigma_{1+2} = \sqrt{\sigma_1^2 + \sigma_2^2}$. We observe that Okun's relationship seems to be statistically insignificant only in three countries -*Belgium, Israel, and Singapore*- in developed market sample, while remaining majority of countries finds it valid and statistically significant. Notice that significance of Okun's coefficient in Belgium and Israel falls into 10%-15% band level. Plus, Singaporean unemployment-real output trade-off seems not working when we include 1980-1990 periods. However, Singapore yields a significant coefficient during 1990-2016 (-0.10) and 2000-2016 (-0.09) periods. The reason of failure of Okun's trade-off might be due to periods of 1984-1988 when Singapore experienced its first post-independence recession. Prior to the economic decline, Singapore had been enjoying a continuous GDP growth of 8.5 percent per year. The sharp and sudden downturn caused GDP shrink by -5 percent and unemployment rate doubled in a short-time.

Although the law appears valid during recessionary periods, we observe that Okun's coefficient shrinks in absolute magnitude. This supports results of Owyang and Sepkhposyan (2012) and Grant (2017). For instance, the coefficient considerably shrinks in few countries like France (N=-0.31, R=-0.20), Switzerland

($N=-0.29$, $R=-0.19$), and United States ($N=-0.52$, $R=-0.41$), where differences between tranquil (normal) and recession periods Okun's coefficients is about 10 bps. And overall significance of relationship in majority of countries weakens; especially it is more blatant in France, Italy, Japan, Israel, New Zealand, and Switzerland. More specifically, in case of emerging sample failure of relationship is obvious where Okun's coefficient is statistically insignificant in more than half of the sample. The results reveal that Okun's law collapses in China, India, Indonesia, Philippines, Poland, Russia, South Africa, Thailand, and Turkey. The law seems to not working in Philippines totally in all timer horizons, and Chinese, Indian, and Indonesian relationship appear to being fragile.

Coming to frontier and unrated markets, we explore that the law seems to be valid in majority of the sample during growing and recessionary periods with exception of Bulgaria, Iraq, Romania, and Slovakia where theoretical relationship totally collapses. Moreover, Bulgarian coefficient gets a positive sign during recessionary periods at 5% significance level. Plus, we observe that the coefficient, in absolute value, increases in some countries such as Croatia, Iceland, Latvia, and Trinidad & Tobago, while it decreases in remaining countries. Particularly, decreases are substantial in Argentina (drops from -0.32 to -0.19), Estonia (drops from -0.42 to -0.30), and Lithuania (drops from -0.50 to -0.37). These observations imply that there are other country-specific dynamics behind these bidirectional variations. Thus, we need to fix country-specific effect with panel analysis in order to find out whether Okun's coefficient varies substantially across different time horizons.

Table 2.02. Okun's Law estimation across different time horizons

Developed Markets	1980-2016			1990-2016			2000-2016			1980-2016 (N+R)			
	ΔY	R ²	N	ΔY	R ²	N	ΔY	R ²	N	ΔY^N	ΔY^R	R ²	N
Australia	-0.4593*** (0.0461)	0.6030	144	-0.4427*** (0.0770)	0.4386	104	-0.2651*** (0.0801)	0.2192	64	-0.4688*** (0.0665)	-0.4526*** (0.0879)	0.6032	144
Austria	-0.1371*** (0.0295)	0.2490	144	-0.1603*** (0.0317)	0.3198	104	-0.1847*** (0.0356)	0.4162	64	-0.1252*** (0.0340)	-0.1614*** (0.0600)	0.2529	144
Belgium	-0.3224*** (0.0575)	0.3116	144	-0.3196*** (0.0669)	0.3422	104	-0.2842*** (0.0780)	0.2953	64	-0.3767*** (0.0494)	-0.1462 (0.1091)	0.3404	144
Canada	-0.4555*** (0.0272)	0.7814	144	-0.4259*** (0.0293)	0.7679	104	-0.4101*** (0.0237)	0.8371	64	-0.4433*** (0.0263)	-0.4880*** (0.0532)	0.7829	144
Denmark	-0.3044*** (0.0543)	0.3228	144	-0.2656*** (0.0691)	0.2515	104	-0.2873*** (0.0819)	0.3352	64	-0.3160*** (0.0538)	-0.2875*** (0.0934)	0.3235	144
Finland	-0.3499*** (0.0696)	0.5176	144	-0.3642*** (0.0919)	0.4855	104	-0.1726*** (0.0218)	0.6398	64	-0.3434*** (0.0754)	-0.3578*** (0.1279)	0.5179	144
France	-0.2941*** (0.0374)	0.4325	144	-0.3075*** (0.0458)	0.4277	104	-0.2876*** (0.0657)	0.3731	64	-0.3139*** (0.0338)	-0.1959** (0.0833)	0.4422	144
Germany	-0.2314*** (0.0583)	0.3354	144	-0.2295*** (0.0662)	0.3356	104	-0.1850*** (0.0663)	0.3089	64	-0.2235*** (0.0580)	-0.2501*** (0.0851)	0.3364	144
Ireland	-0.2926*** (0.0389)	0.4489	144	-0.3318*** (0.0341)	0.5911	104	-0.3767*** (0.0393)	0.6511	64	-0.2642*** (0.0330)	-0.3360*** (0.0729)	0.4555	144
Israel	-0.1855*** (0.0510)	0.2119	85	-0.1855*** (0.0510)	0.2119	85	-0.1995*** (0.0573)	0.3862	65	-0.2043*** (0.0718)	-0.1484 (0.0986)	0.2164	85
Italy	-0.1894*** (0.0522)	0.2314	144	-0.2341*** (0.0615)	0.3387	104	-0.2550*** (0.0743)	0.4307	64	-0.2068*** (0.0534)	-0.1680* (0.0970)	0.2339	144
Japan	-0.1051*** (0.0163)	0.4059	144	-0.1119*** (0.0191)	0.4176	104	-0.1233*** (0.0303)	0.4103	64	-0.1266*** (0.0187)	-0.0708* (0.0398)	0.4331	144
Luxembourg	-0.0587*** (0.0115)	0.1591	132	-0.0605*** (0.0127)	0.1567	104	-0.0699*** (0.0149)	0.1891	64	-0.0573*** (0.0138)	-0.0619*** (0.0237)	0.1593	132
Netherlands	-0.3974*** (0.0459)	0.4321	144	-0.4184*** (0.0551)	0.5596	104	-0.3899*** (0.0613)	0.5700	64	-0.4167*** (0.0532)	-0.3511*** (0.0942)	0.4345	144
New Zealand	-0.2829*** (0.0593)	0.3451	115	-0.3184*** (0.0561)	0.4271	104	-0.1294* (0.0683)	0.098	64	-0.3026*** (0.0659)	-0.2318** (0.1077)	0.3495	115
Norway	-0.1702*** (0.0324)	0.2816	144	-0.1365*** (0.0408)	0.1688	104	-0.1875*** (0.0483)	0.2694	64	-0.1724*** (0.0387)	-0.1647*** (0.0603)	0.2818	144
Portugal	-0.3663*** (0.0733)	0.4286	132	-0.4142*** (0.0908)	0.4730	104	-0.5559*** (0.1039)	0.6162	64	-0.3515*** (0.0652)	-0.3990*** (0.1271)	0.4302	132
Singapore	0.0116 (0.0552)	0.0010	144	-0.0983*** (0.0112)	0.4090	104	-0.0913*** (0.0121)	0.3979	64	0.0760 (0.0714)	-0.1529 (0.1456)	0.0802	144
South Korea	-0.2861*** (0.0479)	0.6300	134	-0.3138*** (0.0471)	0.6777	104	-0.1392*** (0.0533)	0.1654	64	-0.3010*** (0.0588)	-0.2329*** (0.0771)	0.6361	144
Spain	-0.8932*** (0.0568)	0.7082	144	-0.9556*** (0.0549)	0.7548	104	-0.9244*** (0.0653)	0.7623	64	-0.8778*** (0.0697)	-0.9460*** (0.1442)	0.7090	144
Sweden	-0.3359*** (0.0663)	0.4402	144	-0.3472*** (0.0757)	0.4513	104	-0.2182*** (0.0417)	0.3555	64	-0.3508*** (0.0639)	-0.2979*** (0.0991)	0.4424	144
Switzerland	-0.2605*** (0.0395)	0.4146	144	-0.3298*** (0.0400)	0.5027	104	-0.3442*** (0.0479)	0.7079	64	-0.2849*** (0.0425)	-0.1885** (0.0887)	0.4254	144
United Kingdom	-0.3683*** (0.0581)	0.4947	144	-0.3433*** (0.0708)	0.4054	104	-0.2378*** (0.0248)	0.6204	64	-0.3798*** (0.0655)	-0.3171*** (0.1119)	0.4968	144
United States	-0.5002*** (0.0372)	0.7648	144	-0.5514*** (0.0560)	0.7137	104	-0.6052*** (0.0602)	0.7869	64	-0.5227*** (0.0393)	-0.4054*** (0.0620)	0.7713	144
Developed Average	-0.3210	0.4427	141	-0.3194	0.4428	103	-0.2885	0.4518	64	-0.3231	-0.2895	0.4532	141

Table 2.02. (continues)

Emerging Markets	1980-2016			1990-2016			2000-2016			1980-2016 (N+R)			
	ΔY	R ²	N	ΔY	R ²	N	ΔY	R ²	N	ΔY^N	ΔY^R	R ²	N
Brazil	-0.3404*** (0.0425)	0.4957	144	-0.3180*** (0.0325)	0.4231	104	-0.2768*** (0.0474)	0.3046	64	-0.3672*** (0.0451)	-0.3083*** (0.0574)	0.4994	144
Chile	-0.3491*** (0.0523)	0.5148	120	-0.3570*** (0.0582)	0.5100	104	-0.3135*** (0.0903)	0.4266	64	-0.3954*** (0.0550)	-0.2468** (0.0998)	0.5348	120
China	-0.0152 (0.0112)	0.0441	144	-0.0259** (0.0110)	0.1092	104	-0.0488*** (0.0154)	0.1490	64	-0.0124 (0.0126)	-0.0235 (0.0194)	0.0487	144
Czech	-0.2473*** (0.0307)	0.5714	92	-0.2473*** (0.0307)	0.5714	92	-0.2515*** (0.0393)	0.5668	64	-0.2541*** (0.0344)	-0.2194*** (0.0606)	0.5731	144
Greece	-0.3616*** (0.0865)	0.4125	144	-0.4830*** (0.0871)	0.5579	104	-0.5479*** (0.0770)	0.6864	64	-0.2519*** (0.0963)	-0.4205*** (0.1403)	0.4328	144
Hungary	-0.1778*** (0.0436)	0.2890	100	-0.1778*** (0.0436)	0.2890	100	-0.1988*** (0.0532)	0.3467	64	-0.1639** (0.0649)	-0.1978** (0.1005)	0.2916	100
India	-0.0175* (0.0093)	0.0664	144	-0.0158* (0.0097)	0.0814	104	-0.0032 (0.0049)	0.0071	64	-0.0179* (0.0096)	-0.0163 (0.0136)	0.0665	E
Indonesia	-0.0532** (0.0233)	0.0645	144	-0.0417 (0.0271)	0.0353	104	0.0638 (0.1268)	0.0173	64	-0.0728*** (0.0236)	-0.0234 (0.0386)	0.0779	
Malaysia	-0.0771*** (0.0118)	0.2226	124	-0.0635*** (0.0093)	0.2362	104	-0.0639*** (0.0149)	0.2419	64	-0.0772*** (0.0138)	-0.0763*** (0.0278)	0.2226	144
Mexico	-0.1570*** (0.0359)	0.5077	144	-0.2134*** (0.0343)	0.6933	104	-0.1409*** (0.0179)	0.5852	64	-0.1636*** (0.0394)	-0.1397** (0.0551)	0.5101	144
Philippines	0.0642 (0.0745)	0.0139	144	-0.0311 (0.0731)	0.0022	104	-0.0596 (0.1114)	0.0008	64	0.1026 (0.0757)	-0.0562 (0.1398)	0.0296	144
Poland	-0.2122** (0.0851)	0.1524	108	-0.2701** (0.1395)	0.1494	104	-0.7341*** (0.1293)	0.5103	64	-0.2771*** (0.0942)	0.0077 (0.1439)	0.2008	108
Russia	-0.0972*** (0.0374)	0.2106	104	-0.0972*** (0.0374)	0.2106	104	-0.1826*** (0.0279)	0.5637	64	-0.1422*** (0.0426)	-0.0421 (0.0588)	0.2658	104
South Africa	-0.3042*** (0.0635)	0.1554	144	-0.3287*** (0.0909)	0.1292	104	-0.3911*** (0.0945)	0.1768	64	-0.3263*** (0.0619)	-0.1935 (0.1795)	0.1596	144
Taiwan	-0.1227*** (0.0142)	0.4162	144	-0.1290*** (0.0175)	0.4113	104	-0.1377*** (0.0183)	0.4763	64	-0.1350*** (0.0171)	-0.0957*** (0.0268)	0.4254	144
Thailand	-0.1581*** (0.0367)	0.2597	144	-0.1316*** (0.0342)	0.3623	104	-0.0600** (0.0269)	0.1451	64	-0.1869*** (0.0483)	-0.1106 (0.0747)	0.2739	144
Turkey	-0.1251** (0.0421)	0.2708	144	-0.1518*** (0.0426)	0.3659	104	-0.2299*** (0.0432)	0.5869	64	-0.1600*** (0.0478)	-0.0818 (0.0662)	0.2970	144
Emerging Average	-0.1898	0.2949	137	-0.1907	0.3400	103	-0.2394	0.4119	64	-0.1877	-0.1464	0.4362	136

Notes: Numbers in the table are Okun's coefficients of eq.2.07 and eq.2.10 that are derived by LS technique where HAC-robust standard errors are presented in parentheses, and *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The sampled countries are classified according to S&P market classification where D, E, and F indicate Developed, Emerging, and Frontier markets. *N* and *R* capped ΔY in the last column of the table indicates Okun's relation during pure tranquil and recessionary periods respectively.

Table 2.02. (continues)

Frontier Markets	1980-2016			1990-2016			2000-2016			1980-2016 (N+R)			
	ΔY	R ²	N	ΔY	R ²	N	ΔY	R ²	N	ΔY^N	ΔY^R	R ²	N
Argentina	-0.2645*** (0.0585)	0.4540	144	-0.3276*** (0.0664)	0.5274	104	-0.3618*** (0.0689)	0.7169	64	-0.3190*** (0.0686)	-0.1928* (0.1034)	0.4793	144
Bulgaria	-0.2200*** (0.0738)	0.1204	105	-0.2200*** (0.0738)	0.1204	105	-0.3714*** (0.0594)	0.1706	65	-0.2606*** (0.0718)	0.1572** (0.0704)	0.1321	105
Croatia	-0.2042*** (0.0496)	0.2849	101	-0.2042*** (0.0496)	0.2849	101	-0.3590*** (0.0697)	0.3796	65	-0.1874*** (0.0567)	-0.2604** (0.1065)	0.2913	144
Cyprus	-0.4232*** (0.0964)	0.3649	84	-0.4232*** (0.0964)	0.3649	84	-0.4819*** (0.1015)	0.4129	64	-0.3991*** (0.1186)	-0.4486** (0.2235)	0.3661	144
Estonia	-0.3695*** (0.0543)	0.6553	84	-0.3695*** (0.0543)	0.6553	84	-0.4008*** (0.0584)	0.7107	64	-0.4199*** (0.0785)	-0.2977** (0.1198)	0.6726	144
Latvia	-0.4101*** (0.0431)	0.7218	84	-0.4101*** (0.0431)	0.7218	84	-0.4368*** (0.0437)	0.0771	64	-0.3470*** (0.0362)	-0.4791*** (0.0519)	0.7405	84
Lithuania	-0.4351*** (0.0621)	0.5596	84	-0.4351*** (0.0621)	0.5596	84	-0.4837*** (0.0534)	0.7717	64	-0.4973*** (0.0938)	-0.3714*** (0.1290)	0.5713	84
Romania	-0.1031 (0.0678)	0.0790	112	-0.1255* (0.0738)	0.1077	104	-0.1894*** (0.0489)	0.2469	64	-0.1738*** (0.0448)	-0.0247 (0.1093)	0.1203	112
Slovenia	-0.1833*** (0.0296)	0.4430	80	-0.1833*** (0.0296)	0.4430	80	-0.1882*** (0.0302)	0.4766	64	-0.1842*** (0.0225)	-0.1810** (0.0716)	0.4430	80
Trinidad & Tobago	-0.1448*** (0.0459)	0.1469	94	-0.1448*** (0.0459)	0.1469	94	-0.1141** (0.0511)	0.1233	58	-0.0921** (0.0455)	-0.3558*** (0.0814)	0.2247	94
Venezuela	-0.1935*** (0.0175)	0.5825	144	-0.2004*** (0.0206)	0.6136	104	-0.1952*** (0.0222)	0.7460	64	-0.2298*** (0.0232)	-0.1613*** (0.0396)	0.6007	144
Iceland	-0.2170*** (0.0302)	0.4582	76	-0.2170*** (0.0302)	0.4582	76	-0.2354*** (0.0269)	0.4941	64	-0.1972*** (0.0300)	-0.2463*** (0.0732)	0.4639	76
Iraq	-0.0781 (0.0509)	0.1306	94	-0.0781 (0.0509)	0.1306	94	-0.2227*** (0.0422)	0.3792	64	-0.0743 (0.0542)	-0.0833 (0.0727)	0.1310	94
Slovakia	-0.4179*** (0.0627)	0.5175	89	-0.4179*** (0.0627)	0.5175	89	-0.3954*** (0.0722)	0.4922	64	-0.4712*** (0.0647)	-0.0794 (0.2374)	0.5709	89
Frontier Average	-0.1870	0.5183	144	-0.2830	0.4247	92	-0.3168	0.4427	64	-0.2863	-0.2572	0.4358	112

2.4.1.2. Results of panel OLS analysis

For robustness, we examine Okun's Law in a panel framework. We find that RFE Likelihood ratio test cannot reject null hypothesis indicating no fixed-effects in the data sample. Consequently, we find that BP LM test firmly rejects null hypothesis implying that the data has random-effect characteristics. Although these results suggest RE as appropriate model (see table 2.01), we also schedule Hausman test for robustness. The result of this test once again confirms that the RE is most appropriate model for our data. Notwithstanding, we report all panel specification results in left-hand side of table 2.03, and DOLS and SOLS estimations in right-hand side of the table.

Table 2.03. Results for Okun's Law Model with Panel Dynamic Least Squares

	One Regime State			Two Regime State			Dynamic State	
	<i>Pooled</i>	<i>Random</i>	<i>Fixed</i>	<i>Pooled</i>	<i>Random</i>	<i>Fixed</i>	<i>DOLS</i>	<i>SOLS</i>
ΔY_t	-0.1924*** (0.0174)	-0.1924*** (0.0174)	-0.1938*** (0.0168)	-	-	-	-0.2688*** (0.0130)	ΔY_t -0.1253*** (0.0067)
ΔY^N	-	-	-	-0.2017*** (0.0184)	-0.2016*** (0.0185)	-0.2022*** (0.0181)	-	ΔY_{t-1} -0.0459*** (0.0091)
ΔY^R	-	-	-	-0.1778*** (0.0356)	-0.1779*** (0.0359)	-0.1803*** (0.0353)	-	ΔY_{t-2} -0.0402*** (0.0076)
C	-	-0.00005 (0.0002)	-0.00005 (0.0002)	-	-0.00002 (0.0002)	-0.00002 (0.0002)	-	ΔY_{t-3} - ΔY_{t-4} -0.0559*** (0.0046)
R^2	0.2657	0.2657' 0.2657''	0.2678	0.2667	0.2667' 0.2667''	0.2687	0.4030	0.3442
N	6941	6941	6941	6941	6941	6941	6789	6761

Notes: The Okun's coefficients are estimated with panel least squares (eqs.2.07-2.10-2.13-2.15), panel dynamic least squares (DOLS, eq.3.07), and panel stepwise least squares (SOLS, eq.2.12) techniques where HAC-robust standard errors are presented in parentheses, and *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. Panel has 55 cross-sections with 145 periods. The numbers in parentheses are HAC/White cross-section standard errors, and the numbers in brackets are their t-statistics. DOLS is specified with "Auto-Schwarz" maximum four leads-lags specification where long-run coefficient covariances are computed using sandwich method under Bartlett kernel and Newey-West fixed bandwidth methodology. SOLS has stepwise backwards selection methodology that tests past 4-lagges and intercept with p-value of 0.10 criterion. The analysis period is adjusted as 1980Q1 - 2016Q1. The superscripts "N" and "R" indicate estimations for tranquil and recessionary periods respective. The single quotation mark in the R-squared column indicates weighted R^2 , while double quotation indicates unweighted R^2 . Redundant Fixed Effects test fails to reject the null hypothesis, while BP LM test and Hausman test reject the null hypothesis.

Although RFE and BP LM tests suggest using RE specification, Swamy-Arora (1972) estimator of variance components of random effect assigns zero weight for cross-section rho number. Thus, it indicates that data sample is poolable. The estimates of pooled and RE specifications, in table 2.04, also confirms this incidence as both specifications derive identical coefficients. In this respect, we believe that pooling our data in panel framework would not generate any bias, and estimations of DOLS and SOLS -that do not incorporate any effect specifications- are completely reliable.

In left part of the table, RE (identical with pooled) and FE panel models predict very close Okun's Law coefficient, which is about -0.19 when we do not distinguish growing-recessionary periods, at 1% significance level. It implies five-to-one relationship. On the other hand, when we distinguish growing (tranquil) and recessionary periods, we observe the Okun's coefficient is slightly higher/lower during growing/recessionary periods. OLS panel models predict that growing-period coefficient is about -0.20 at 1% significance level, whereas recession-period coefficient is nearly -0.18 which is also statistically significant at 1% level even

though its standard error increases twofold during recession periods. These findings support our previous observations of relatively lower or insignificant coefficients during recessionary periods in country-individual OLS estimation (see table 2.02 that majority of developed countries' law coefficients slightly decrease during recession; especially it is blatant in France, Japan, Switzerland, and United States, while the coefficient in nearly half of frontier and unrated markets turn insignificant).

The right part of the table report estimation results for DOLS and SOLS. The DOLS finds long-run Okun's coefficient as -0.27 that refers to almost four-to-one relationship by accounting 40% variations in unemployment gap. When lags are included in SOLS, the coefficient on the current ΔY_t is smaller, and the three lags appear statistically significant, implying delays in the full adjustment of unemployment to output (Adanu, 2005; Ball et al., 2012). The sum of the coefficients on current and lagged output gives -0.2673 which is almost equal to the long-run Okun's coefficient estimated by DOLS (-0.2688). The SOLS clearly shows lag decomposition of the law. We consider both DOLS and SOLS in pooled panel environment without imposing any effect specifications, as we already have observed Swamy-Arora (1972) estimator of variance components of random effect assigns zero weight for cross-section rho number which indicates poolability of data.

2.4.2.Okun's law estimation under ARDL technique

2.4.2.1. Results of country individual ARDL analysis

Crediting Chinn et al (2014), we further examine Okun's law under ARDL framework using eqs.2.16-2.17 in order to account both short- and long-term impact of fluctuations in real output gap on unemployment gap. Table 2.04 reports results of country-individual UECM analysis where existence of long-run Okun's Law coefficient is tested by $H_0: \phi_1=\phi_2=0$ and its F-statistics is given in the table. We compare this F-statistics with upper-lower bound values at related case in table 2.05. The results find long-run interaction between unemployment and real output in majority of sampled countries. The long-run Okun's multiplier is manually calculated with formula $-\phi_2/\phi_1$ where numerator is -1 multiplied by the coefficient of Y_{t-1} , and denominator is the coefficient of U_{t-1} . and this estimate is reported in table 2.04 as ΔY^{LR} . The table reveals that developed sample has average of -0.13 long-run Okun's coefficient, while emerging and frontier markets have -0.08 and -0.16 law

coefficients respectively. Among developed markets, the lowest long-run Okun's relationship occurs in South Korea with -0.03, followed by Belgium (-0.03), Switzerland (-0.04), United States (-0.05), Luxembourg (-0.05), and Australia (-0.05). Whereas the high level of long-run relationship is observed in New Zealand with -0.39, followed by Netherlands with -0.27, France with -0.26, Portugal with -0.21, and Denmark with -0.21 at 1% significance level. We fail to detect long-run Okun's interaction in few developed countries (Finland, Italy, Norway, Singapore, and Sweden) and in majority of emerging markets where a negative long-run relationship only exists in Chile (-0.04), Greece (-0.40), Philippines (-0.04), Russia (-0.12), and Thailand (-0.01). Notice that Greece has the highest (in absolute value) long-run coefficient among all sampled countries. It can be addressed to high share of labor employment (low share of capital formation) in Greece's output and high degree of temporary employment in the Greek labor market.

On the other hand, the long-run Okun's coefficient within frontier and unrated markets' sample is quite stronger in magnitude. The relationship exists in majority of the sample, except Argentina, Croatia, and Venezuela. Cyprus derives the highest long-run coefficient among frontier markets with -0.31 at 1% significance level. As this country is under Greek influence and culturally akin to Greece, we believe that share of labor employment in output and degree of temporary employment is also high in Cyprus. These factors persist over time horizon, therefore, long-run Okun's coefficient also relatively higher comparing to rest of the sample.

Interestingly, we document positive and statistically long-run relationship between unemployment and real output in Austria (0.01), China (0.01), Mexico (0.02), and Iceland (0.07). These findings appear ambiguous, contradicting to the law theory. There might be few reasons behind this dynamics. First, we suspect continuously increasing in immigrant employment, while native employment decreases. Second, if production mainly depends on capital and machinery, contribution of human labor employment will be very low. Alongside with new technological development, firms easily scale the productivity up during economic recoveries even they continue to cut labor costs. Third, it may occur due to slow growth in output which, in turn, causes high unemployment to linger, i.e. similar scenario jobless recovery during Great Recession. Fourth, extremely rigidity or flexibility of labor markets might also emerge such a positive relation in long-run.

Fifth, in order to mitigate misleading results in examination of Okun's law, one should also consider hours per employee. As we have not considered it here, we think that firms reduce hours per employee rather firing workers during recessionary periods, so that quasi-positive interaction between unemployment and real output might emerge.

Table 2.04. ARDL Unrestricted Error-Correction Model (UECM) Results for Okun's Law

	Y_{t-1}	U_{t-1}	ΔY_t	ΔY_{t-1}	ΔY_{t-2}	ΔY_{t-3}	ΔU_{t-1}	ΔU_{t-2}	ΔU_{t-3}	Intercept	Trend	Case	F-test $\phi_1 = \phi_2 = 0$	ΔY_{t-1}^R $-\phi_2/\phi_1$	R ²	N
Argentina	0.0007** (0.0004)	-0.0224* (0.0136)	-0.1021*** (0.0257)	-	-	-	0.3079*** (0.0766)	-	-	-	-	I	2.02	-	0.2375	142
Australia	-0.0018*** (0.0008)	-0.0349*** (0.0135)	-0.0858*** (0.0257)	-0.1313*** (0.0267)	-	-	0.333*** (0.0783)	0.1618** (0.0740)	-	0.0116*** (0.0037)	-	II	13.41***	-0.0507*** (0.0146)	0.5780	141
Austria	0.0008*** (0.0002)	-0.0509*** (0.0150)	-0.0304 (0.0215)	-0.0512** (0.0220)	-0.0660*** (0.0208)	-	-	-	-	-	-	I	17.16***	0.0141*** (0.0017)	0.1963	141
Belgium	-0.0026* (0.0016)	-0.0841*** (0.0258)	-	-	-	-	0.0299 (0.0822)	0.3110*** (0.0781)	0.2182*** (0.0826)	0.0183** (0.0083)	-	III	5.36*	-0.0311** (0.0146)	0.1823	140
Brazil	-0.0568*** (0.0188)	-0.0742*** (0.0298)	-0.1808*** (0.0389)	-0.1431*** (0.0400)	-	-	-	-	-	0.2223*** (0.0723)	0.0004*** (0.0002)	IV	3.12	-	0.3365	142
Bulgaria	-0.0107** (0.0047)	-0.1055*** (0.0306)	-	-	-	-	0.4351*** (0.0909)	-0.3028*** (0.0949)	0.394*** (0.0928)	-	-	III	6.14**	-0.1061*** (0.0370)	0.3240	101
Canada	-0.0040*** (0.0012)	-0.0427** (0.0180)	-0.2144*** (0.0324)	-0.1467*** (0.0358)	-0.0704** (0.0319)	-	-	-	-	0.0233*** (0.0062)	-	III	5.86**	-0.0927*** (0.0296)	0.5742	141
Chile	-0.0038*** (0.0013)	-0.0998*** (0.0253)	-0.1817*** (0.0343)	-0.0925*** (0.0322)	-0.1231*** (0.0325)	-	-	-	-	0.0290*** (0.0071)	-	III	8.49***	-0.0371*** (0.0134)	0.3734	119
China	0.0003*** (0.0001)	-0.0214*** (0.0046)	-	-	-	-	0.7752*** (0.0422)	-	-	-	-	I	11.14***	0.0094*** (0.0003)	0.8434	142
Croatia	0.0005** (0.0003)	-0.0296** (0.0138)	-	-	-	-	0.6547*** (0.0577)	-	-	-	-	I	2.32	-	0.6543	99
Cyprus	-0.0929*** (0.0331)	-0.3026*** (0.0878)	-0.1323 (0.1034)	-0.3310*** (0.1042)	-	-	-	-	-	0.6866*** (0.2438)	0.0010*** (0.0004)	IV	4.67*	-0.3068*** (0.0344)	0.2783	82
Czech	-0.0042* (0.0025)	0.0053 (0.0229)	-0.0951*** (0.0319)	-0.1112*** (0.0331)	-	-	0.0046 (0.1043)	0.3120*** (0.0926)	-0.2236** (0.0965)	0.0198* (0.0104)	-	III	2.45	-	0.4600	88
Denmark	-0.0033*** (0.0013)	-0.0152* (0.0093)	-0.0251* (0.0153)	-0.0564*** (0.0156)	-0.0459*** (0.0155)	-	0.6009*** (0.0576)	-	-	0.0159*** (0.0064)	-	II	3.33*!	-0.2116** (0.0868)	0.6795	141
Estonia	-0.0124*** (0.0039)	-0.0764*** (0.0305)	-0.0387 (0.0414)	-0.1035*** (0.0392)	-0.1045*** (0.0391)	-0.1150*** (0.0407)	-	-	-	-	-	III	6.01**	-0.1617*** (0.0600)	0.4201	80
Finland	-0.0014 (0.0009)	-0.0075 (0.0060)	-0.0810*** (0.0175)	-0.0733*** (0.0175)	-	-	0.3757*** (0.0779)	0.2703*** (0.0727)	-	0.0072* (0.0038)	-	III	2.40	-	0.7302	141
France	-0.0024*** (0.0008)	-0.0090*** (0.0025)	-0.0894*** (0.0336)	-0.0905*** (0.0366)	-0.1055*** (0.0347)	-	0.2569*** (0.0775)	-	-	0.0125*** (0.0032)	-	III	7.32**	-0.2585*** (0.0343)	0.5261	141
Germany	-0.0020* (0.0011)	-0.0174* (0.0095)	-0.0614*** (0.0186)	-0.0509*** (0.0191)	-	-	0.5449*** (0.0655)	-	-	0.0107** (0.0046)	-	III	4.95*	-0.1122*** (0.0082)	0.5330	142
Greece	-0.0488*** (0.0103)	-0.1213*** (0.0240)	-	-	-	-	0.5425*** (0.0804)	0.1833** (0.0805)	-	0.2054*** (0.0431)	0.0003*** (0.0001)	IV	8.70***	-0.4045*** (0.0199)	0.5852	141
Hungary	0.0007 (0.0015)	-0.0444*** (0.0153)	-0.0664** (0.0281)	-0.0707** (0.0295)	-	-	0.3944*** (0.0872)	-	-	0.0007 (0.0070)	-	I	3.37*!	0.0162 (0.0348)	0.3738	98
Iceland	0.0109*** (0.0043)	-0.1574*** (0.0380)	-0.0510** (0.0244)	-0.0634** (0.0261)	-0.0921*** (0.0266)	-0.0847*** (0.0256)	-	-	-	-	-	III	8.64***	0.0687*** (0.0184)	0.3104	72
India	-0.0004 (0.0007)	-0.0096 (0.0161)	-	-	-	-	0.3308*** (0.0849)	0.2345*** (0.0861)	-	0.0023 (0.0045)	-	II	8.51***	-0.0237 (0.0301)	0.2166	141
Indonesia	0.0002 (0.0002)	-0.0120 (0.0092)	-	-	-	-	0.7062*** (0.0846)	-0.0305 (0.1050)	-0.1949** (0.0834)	-	-	I	0.95	-	0.4545	140
Iraq	-0.0026** (0.0011)	-0.0551*** (0.0143)	-0.0415*** (0.0130)	-	-	-	1.5634*** (0.0871)	-1.2669*** (0.1270)	0.5853*** (0.0867)	-	-	III	7.90***	-0.0465*** (0.0142)	0.8807	90
Ireland	-0.0021*** (0.0008)	-0.0316*** (0.0087)	-0.0557*** (0.0222)	-0.0555*** (0.0217)	-0.0497** (0.0218)	-	0.4961*** (0.0739)	-	-	0.0136*** (0.0038)	-	III	6.92**	-0.0654*** (0.0169)	0.5646	141
Israel	-0.0098*** (0.0025)	-0.1084*** (0.0321)	-0.0786* (0.0460)	-0.0715 (0.0464)	-0.0727 (0.0468)	-0.1041** (0.0464)	-	-	-	-	-	III	8.57***	-0.0898*** (0.0215)	0.2960	81
Italy	-0.0003 (0.0015)	-0.0314*** (0.0122)	-	-	-	-	0.1283 (0.0823)	0.2789*** (0.0817)	0.2537*** (0.0845)	0.0043 (0.0065)	-	III	3.62	-	0.2521	140
Japan	-0.0021*** (0.0008)	-0.0236* (0.0124)	-0.0192** (0.0093)	0.0490*** (0.0092)	-0.0318*** (0.0092)	-0.0245*** (0.0092)	-	-	-	0.0108*** (0.0031)	-	III	13.62***	-0.0876*** (0.0254)	0.3275	140
Latvia	-0.0007 (0.0045)	-0.1161*** (0.0334)	-0.1318** (0.0649)	0.1562*** (0.0662)	-0.1375** (0.0662)	-	-	-	-	0.0228 (0.0378)	-	II	7.49***	-0.0060 (0.0311)	0.3470	81
Lithuania	-0.0101* (0.0053)	-0.0694** (0.0328)	-0.1894*** (0.0635)	-0.1347** (0.0628)	-	-	-	-	-	0.0991** (0.0460)	-	II	3.95*	-0.1452** (0.0725)	0.2078	82
Luxembourg	-0.0034 (0.0026)	-0.0721*** (0.0240)	-	-	-	-	0.3741*** (0.0866)	0.2177*** (0.0878)	-	0.0232 (0.0247)	0.0001 (0.0000)	IV	4.40*!	-0.0471* (0.0280)	0.3128	129

Table 2.04. (continues)

	Y_{t-1}	U_{t-1}	ΔY_t	ΔY_{t-1}	ΔY_{t-2}	ΔY_{t-3}	ΔU_{t-1}	ΔU_{t-2}	ΔU_{t-3}	Intercept	Trend	Case	F-test $\phi_1 = \phi_2 = 0$	ΔY^{LR} $-\phi_2/\phi_1$	R ²	N
Malaysia	-0.0147** (0.0074)	-0.1384*** (0.0542)	-	-	-	-	0.2341*** (0.0932)	-	-	0.0509** (0.0247)	0.0002* (0.0001)	IV	2.63	-	0.0890	122
Mexico	0.0016* (0.0009)	-0.0665*** (0.0229)	-0.0777*** (0.0172)	-0.0744*** (0.0174)	-	-	-	-	-	-0.0034 (0.0036)	-	III	4.90*	0.0237** (0.0112)	0.3207	142
Netherlands	-0.0279*** (0.0060)	-0.1036*** (0.0170)	-	-	-	-	0.4756*** (0.0801)	0.0851 (0.0925)	0.2573*** (0.0814)	0.1166*** (0.0245)	0.0002*** (0.0001)	IV	12.67***	-0.2770*** (0.0318)	0.6708	140
New Zealand	-0.0759*** (0.0212)	-0.2044*** (0.0441)	-	-	-	-	0.1113 (0.0893)	0.4312*** (0.0824)	0.2012** (0.0917)	-	-	IV	8.36***	-0.3907*** (0.0247)	0.3699	114
Norway	-0.0136*** (0.0050)	-0.0400** (0.0201)	-	-	-	-	-	-	-	0.0539*** (0.0192)	0.0001*** (0.0001)	IV	3.78	-	0.0755	143
Philippines	-0.0054*** (0.0021)	-0.1439*** (0.0457)	-	-	-	-	-0.2590*** (0.0804)	-	-	0.0354*** (0.0112)	-	III	5.64*	-0.0370*** (0.0089)	0.1670	142
Poland	-0.0010 (0.0012)	-0.0289*** (0.0091)	0.0111 (0.0141)	-0.0594*** (0.0139)	-	-	0.5239*** (0.0851)	0.2441*** (0.0855)	-	0.0086* (0.0053)	-	III	5.51*	-0.0333 (0.0363)	0.7502	105
Portugal	-0.0178** (0.0089)	-0.0837*** (0.0282)	-0.1200*** (0.0323)	-	-	-	0.1548* (0.0836)	0.2637*** (0.0841)	0.2964*** (0.0886)	0.0749** (0.0363)	0.0002** (0.0001)	IV	4.46*!	-0.2117*** (0.0425)	0.4257	128
Romania	-0.0361*** (0.0097)	-0.1810*** (0.0401)	-	-	-	-	0.1577* (0.0881)	0.2485*** (0.0886)	-	0.1562*** (0.0404)	0.0002*** (0.0001)	IV	7.41***	-0.2125*** (0.0285)	0.2530	109
Russia	-0.0175*** (0.0054)	-0.1581*** (0.0404)	-	-	-	-	0.3068*** (0.0894)	-	-	0.0835*** (0.0240)	0.0001* (0.0001)	IV	6.94***	-0.1163*** (0.0165)	0.2785	102
Singapore	-0.0016* (0.0009)	-0.0469*** (0.0172)	-	-	-	-	0.5543*** (0.0688)	-	-	0.0078** (0.0037)	-	III	3.75	-	0.3283	142
Slovakia	-0.0088*** (0.0032)	-0.0547* (0.0292)	-0.1849*** (0.0455)	-0.0492 (0.0450)	-0.1191*** (0.0450)	-0.1225*** (0.0455)	-	-	-	-	-	II	6.32***	-0.1604*** (0.0596)	0.3159	88
Slovenia	-0.0768*** (0.0145)	-0.3971*** (0.0691)	-	-	-	-	0.1922** (0.0948)	-0.0730 (0.0965)	0.3291*** (0.0959)	-	-	IV	11.10***	-0.1964*** (0.0161)	0.4089	76
South Africa	0.0032** (0.0016)	-0.0574** (0.0285)	-	-	-	-	-	-	-	-	-	I	2.22	-	0.0281	143
South Korea	-0.0020*** (0.0005)	-0.0634*** (0.0210)	-0.1230*** (0.0160)	-0.0849*** (0.0182)	-	-	0.1515* (0.0822)	0.2129*** (0.0711)	-	0.0133*** (0.0022)	-	III	16.23***	-0.0316*** (0.0073)	0.5780	131
Spain	-0.0055*** (0.0018)	-0.0409*** (0.0095)	-0.2245*** (0.0717)	-0.3514*** (0.0721)	-0.1890*** (0.0749)	-	0.3240*** (0.0862)	-0.4003*** (0.0832)	0.2080*** (0.0831)	0.0354*** (0.0089)	-	III	10.78***	-0.1334*** (0.0507)	0.5592	140
Sweden	-0.0227* (0.0131)	-0.0379* (0.0198)	-0.1002*** (0.0237)	-0.0753*** (0.0256)	-0.0716*** (0.0231)	-	0.3821*** (0.0706)	-	-	0.0933* (0.0525)	0.0002* (0.0001)	IV	1.67	-	0.5610	141
Switzerland	-0.0010** (0.0005)	-0.0231*** (0.0058)	-0.0385*** (0.0119)	-0.0463*** (0.0125)	-	-	0.7905*** (0.0392)	-	-	-0.0034* (0.0020)	-	III	8.01***	-0.0434*** (0.0161)	0.8237	142
Taiwan	-0.0006 (0.0004)	-0.0340*** (0.0137)	-0.0358*** (0.0072)	-0.0426*** (0.0076)	-0.0225*** (0.0080)	-0.0191*** (0.0075)	0.2871*** (0.0798)	-	-	0.0049*** (0.0013)	-	III	12.13***	-0.0149 (0.0131)	0.5482	140
Thailand	-0.0011** (0.0006)	-0.0991*** (0.0252)	-	-	-	-	0.7706*** (0.0802)	-0.1987** (0.0853)	-	0.0065*** (0.0026)	-	III	7.76**	-0.0111** (0.0051)	0.4802	141
Trinidad & Tobago	-0.0496*** (0.0122)	-0.5106*** (0.0952)	-	-	-	-	-	-	-	0.4844*** (0.1056)	-0.0003** (0.0002)	IV	9.63***	-0.0976*** (0.0097)	0.2450	93
Turkey	-0.0166** (0.0084)	-0.0647*** (0.0243)	-0.0517*** (0.0151)	-	-	-	0.2615*** (0.0800)	-	-	0.0616** (0.0293)	0.0002** (0.0001)	IV	2.80	-	0.2127	142
United Kingdom	-0.0034*** (0.0008)	-0.0279*** (0.0070)	-0.0635*** (0.0187)	-0.0521*** (0.0191)	-	-	0.7172*** (0.0421)	-	-	0.0170*** (0.0037)	-	III	9.91***	-0.1213*** (0.0164)	0.8500	142
United States	-0.0020*** (0.0006)	-0.0433*** (0.0098)	-0.1915*** (0.0246)	-0.0934*** (0.0285)	-0.0377 (0.0285)	-	0.2368*** (0.0824)	0.1676** (0.0729)	-	0.0133*** (0.0029)	-	III	12.21***	-0.0452*** (0.0136)	0.7114	141
Venezuela	-0.0273** (0.0135)	-0.0923** (0.0379)	-0.0855*** (0.0157)	-0.0541*** (0.0170)	-0.0423*** (0.0162)	-	-	-	-	0.1196** (0.0574)	0.0002** (0.0001)	IV	2.01	-	0.3303	141

Notes: The numbers in the table are estimates of UECM model eq.2.16 that are predicted by ARDL technique over 1980Q1-2016Q1. The ARDL model selection specification is set for Schwarz information criterion (SIC) with maximum dependant and dynamic regressor lags of four. Stability of country-individual each ARDL models is checked with CUSUM test, and we fail to detect any structural breaks or instability. Each case is specified different, so their critical values are also different (given in table 2.05). The case I has no intercept and no trend; Case II has restricted intercept and no trend; Case III has unrestricted intercept and no trend; and Case IV has both unrestricted intercept and trend. The long-run interaction between series occurs only if the Wald test's F-statistics exceeds the critical bounds (given in table 2.05). The long-run Okun's multiplier is manually calculated with formula $-\phi_2/\phi_1$ where numerator is -1 multiplied by the coefficient of Y_{t-1} , and denominator is the coefficient of U_{t-1} . And this estimate is reported in table 2.04 as ΔY^{LR} . The HAC-robust standard errors are presented in parentheses, and *, **, and *** denote significance at 10%, 5%, and 1% levels respectively.

Table 2.05. Critical Values for Bound Testing

Critical Value Bounds					
Significance		10%	5%	2.50%	1%
CASE I	I0(Lower) Bound	2.44	3.15	3.88	4.81
	I1(Upper) Bound	3.28	4.11	4.92	6.02
CASE II	I0 (Lower) Bound	3.02	3.62	4.18	4.94
	I1 (Upper) Bound	3.51	4.16	4.79	5.58
CASE III	I0 (Lower) Bound	4.04	4.94	5.77	6.84
	I1 (Upper) Bound	4.78	5.73	6.68	7.84
CASE IV	I0 (Lower) Bound	4.05	4.68	5.30	6.10
	I1 (Upper) Bound	4.49	5.15	5.83	6.73

Notes: The numbers in the table are critical F-statistics values for ARDL Bound Testing derived from Pesaran et al. (2001, pp.300-301) for four different cases. I0 and I1 indicate lower and upper bounds respectively.

Source: Pesaran et al (2001, pp.300-301)

Further, we employ RECM analysis, for those countries where statistically significant long-run Okun's interaction has been found, in order to find out at what speed the system corrects its previous term disequilibrium. We report results of this analysis in table 2.06 where λ is a coefficient of ECT_{t-1} that is residual term of long-run Okun's model $U_{t-1} = \beta_0 + \beta_1 Y_{t-1} + ECT_{t-1}$, i.e. β_1 is long-run Okun's coefficient that documented in eq.2.16 and reported in table 2.05. This lambda (λ) show how quickly cointegrated series converge back to equilibrium following a shock that disturbs this equilibrium. Table 2.06 reports that λ in all countries, statistically significant long-run Okun's interaction has been found, is negative in bounds of $-1 \leq \lambda \leq 0$ and statistically significant at 1% level, indicating smoothness and stability of our RECM model.

We observe that average value of λ in developed, emerging, and frontier markets are -0.06, -0.07, and -0.17 respectively. This implies that speeds of self-adjustment relating to discrepancy in developed and emerging markets are considerably low comparing to frontier markets. Majority of extant literature generally finds low λ due to long memory of time series variables, government interventions by frequently changing policies, and impact of external factors, the convergence is gradually slow. Plus, speed of adjustment is fairly similar in countries that culturally akin each other. For instance, nearly 3.48% of previous period's disequilibrium is corrected in Australia in current periods, while correction speed is 4.26% in Canada

and 4.32% in United States. Likewise, adjustment speed in United Kingdom, Australia, and Ireland is very close to each other, it is about 3%. Further examples can be Japan (0.02%) - China (0.02%) and France (1%) - Germany (1.73%). The lowest and highest correction speeds are documented in India and Trinidad & Tobago with λ of 0.1% and 53% respectively, where both are statistically significant at 1% level. Low/high might be related with short/long memory of time series variables, high/less degree of government interventions (changing focus of policies), and high/less impact of external factors.

On the other hand, table 2.06 also reports short-run Okun's coefficient in column ΔY_t and its lags in ΔY_{t-1} , ΔY_{t-2} , and ΔY_{t-3} . The results once again confirm validity of short-run Okun's Law across countries. In particular, all developed countries derive negative signed and statistically significant short-run Okun's coefficients without any exceptions. The highest (in absolute value) coefficient is recorded in Spain with -0.22, followed by Canada with -0.21 and United States with -0.19. Whereas, the lowest coefficient is documented in Luxembourg with -0.01, followed by Japan -0.02, Denmark with -0.02, and Austria with -0.03. However, these magnitudes of ΔY_t appear shrunk comparing our country-individual OLS estimations at table 2.02. Because, ΔY_t only shows current period's fraction of Okun's Law coefficient. In case we incorporate it with its lag coefficients, we will derive somewhat closer estimates as in table 2.02. Thus, we consider it with sum of lagged coefficients. From this perspective, the results once again confirm that Spain gets the highest short-run Okun's coefficient with -0.76.

On the other hand, emerging and frontier countries also derive plausible results. Apparently, the law fails to work in China, India, Philippines, and Slovenia. Indeed, similar scenario for these countries was already observed in country-specific OLS estimation at table 2.02 where Okun's Law either failed to be valid or failed to be dynamically stable across time horizon. The highest short-run Okun's coefficient is recorded in Cyprus with -0.46, followed by Latvia and Slovakia with -0.42; whereas, the lowest coefficients are documented in Russia and Thailand with -0.02.

Table 2.06. ARDL Restricted Error-Correction Model (RECM) Results for Okun's Law

	ΔY_t	ΔY_{t-1}	ΔY_{t-2}	ΔY_{t-3}	ΔU_{t-1}	ΔU_{t-2}	ΔU_{t-3}	Intercept	λ
Australia	-0.0858*** (0.0234)	-0.1313*** (0.0246)	-	-	0.3329*** (0.0768)	0.1618** (0.0720)	-	-	-0.0348*** (0.0055)
Austria	-0.0304* (0.0208)	-0.0511** (0.0216)	-0.0659*** (0.0202)	-	-	-	-	-	-0.0509*** (0.0087)
Belgium	-0.0792** (0.0341)	-	-	-	0.0068 (0.1097)	0.2912*** (0.0955)	0.2115** (0.0937)	0.0175*** (0.0055)	-0.0776*** (0.0249)
Bulgaria	-0.0845** (0.0436)	-	-	-	0.4160*** (0.0889)	-0.3172*** (0.0929)	0.3842*** (0.0903)	0.0989*** (0.0349)	-0.0867*** (0.0308)
Canada	-0.2144*** (0.0316)	-0.1467*** (0.0356)	-0.0703** (0.0315)	-	-	-	-	0.0232*** (0.0060)	-0.0426*** (0.0124)
Chile	-0.1817*** (0.0326)	-0.0925*** (0.0319)	-0.1231*** (0.0321)	-	-	-	-	0.0290*** (0.0062)	-0.0997*** (0.0241)
China	0.0009 (0.0009)	-	-	-	0.7803*** (0.0423)	-	-	-	-0.0213*** (0.0045)
Cyprus	-0.1322 (0.0985)	-0.3310*** (0.0948)	-	-	-	-	-	0.6875*** (0.1805)	-0.3025*** (0.0798)
Denmark	-0.0250* (0.0141)	-0.0564*** (0.0138)	-0.0459*** (0.0144)	-	0.6009*** (0.0551)	-	-	-	-0.0152*** (0.0048)
Estonia	-0.0387 (0.0395)	-0.1035*** (0.0386)	-0.1045*** (0.0387)	-0.1149*** (0.0396)	-	-	-	0.1145*** (0.0320)	-0.0764*** (0.0219)
France	-0.0893*** (0.0324)	-0.0904*** (0.0361)	-0.1054*** (0.0344)	-	0.2569*** (0.0750)	-	-	0.0125*** (0.0029)	-0.0090*** (0.0023)
Germany	-0.0613*** (0.0182)	-0.0509*** (0.0188)	-	-	0.5448*** (0.0631)	-	-	0.0106*** (0.0032)	-0.0173*** (0.0055)
Greece	-0.0536*** (0.0172)	-	-	-	0.5023*** (0.0783)	0.1734** (0.0770)	-	0.2129*** (0.0392)	-0.1246*** (0.0230)
Hungary	-0.0664** (0.0271)	-0.0707** (0.0288)	-	-	0.3944*** (0.0856)	-	-	-	-0.0444*** (0.0138)
Iceland	-0.0509** (0.0235)	-0.0633** (0.0256)	-0.0920*** (0.0261)	-0.0847*** (0.0253)	-	-	-	-0.0779*** (0.0189)	-0.1574*** (0.0376)
India	-0.0012 (0.0034)	-	-	-	0.3288*** (0.0825)	0.2346*** (0.0819)	-	-	-0.0010*** (0.0003)
Iraq	-0.0414*** (0.0123)	-	-	-	1.5633*** (0.0861)	-1.2669*** (0.1261)	0.5852*** (0.0860)	0.0367*** (0.0090)	-0.0551*** (0.0138)
Ireland	-0.0557*** (0.0220)	-0.0554*** (0.0215)	-0.0497** (0.0217)	-	0.4960*** (0.0730)	-	-	0.0136*** (0.0033)	-0.0315*** (0.0084)
Israel	-0.0786* (0.0454)	-0.0715* (0.0461)	-0.0726* (0.0464)	-0.1040** (0.0458)	-	-	-	0.0844*** (0.0197)	-0.1083*** (0.0260)
Japan	-0.0192** (0.0092)	-0.0490*** (0.0091)	-0.0317*** (0.0091)	-0.0245*** (0.0090)	-	-	-	0.0107*** (0.0020)	-0.0236*** (0.0045)
Latvia	-0.1318** (0.0610)	-0.1562*** (0.0604)	-0.1375** (0.0643)	-	-	-	-	-	-0.1161*** (0.0242)
Lithuania	-0.1894*** (0.0607)	-0.1346** (0.0607)	-	-	-	-	-	-	-0.0693*** (0.0199)
Luxembourg	-0.0143* (0.0078)	-	-	-	0.3691*** (0.0864)	0.2175*** (0.0856)	-	-0.0252*** (0.0068)	-0.0735*** (0.02000)
Mexico	-0.0777*** (0.0171)	-0.0744*** (0.0173)	-	-	-	-	-	-0.0034** (0.0014)	-0.0665*** (0.0212)
Netherlands	-0.0611*** (0.0201)	-	-	-	0.4466*** (0.0777)	0.0665 (0.0891)	0.2573*** (0.0777)	0.1118*** (0.0191)	-0.0960*** (0.0165)
New Zealand	-0.0648** (0.0268)	-	-	-	0.0738 (0.0878)	0.4129*** (0.0801)	0.2327*** (0.0895)	0.9071*** (0.1628)	-0.2353*** (0.0423)
Philippines	-0.0572 (0.0593)	-	-	-	-0.2501*** (0.0797)	-	-	0.0356*** (0.0105)	-0.1423*** (0.0427)

Table 2.06. (continues)

	ΔY_t	ΔY_{t-1}	ΔY_{t-2}	ΔY_{t-3}	ΔU_{t-1}	ΔU_{t-2}	ΔU_{t-3}	Intercept	λ
Poland	0.0111 (0.0139)	-0.0594*** (0.0138)	-	-	0.5238*** (0.0844)	0.2440*** (0.0833)	-	0.0085*** (0.0024)	-0.0288*** (0.0086)
Portugal	-0.1199*** (0.0298)	-	-	-	0.1548* (0.0823)	0.2637*** (0.0820)	0.2963*** (0.0870)	0.0750*** (0.0202)	-0.0836*** (0.0227)
Romania	-0.0564* (0.0335)	-	-	-	0.1458* (0.0862)	0.2351*** (0.0866)	-	0.1502*** (0.0364)	-0.1644*** (0.0400)
Russia	-0.0210* (0.0125)	-	-	-	0.2924*** (0.0860)	-	-	0.0841*** (0.0200)	-0.1531*** (0.0365)
Slovakia	-0.1848*** (0.0436)	-0.0491 (0.0435)	-0.1191*** (0.0437)	-0.1225*** (0.0445)	-	-	-	-	-0.0547*** (0.0124)
Slovenia	-0.0413 (0.0313)	-	-	-	0.1619* (0.0957)	-0.0776 (0.0937)	0.3252*** (0.0926)	0.6434*** (0.1228)	-0.3693*** (0.0705)
South Korea	-0.1230*** (0.0148)	-0.0848*** (0.0173)	-	-	0.1515* (0.0799)	0.2129*** (0.0701)	-	0.0133*** (0.0020)	-0.0633*** (0.0111)
Spain	-0.2245*** (0.0699)	-0.3513*** (0.0706)	-0.1889*** (0.0743)	-	0.3240*** (0.0848)	-0.4002*** (0.0826)	0.2079*** (0.0812)	0.0354*** (0.0070)	-0.0409*** (0.0088)
Switzerland	-0.0384*** (0.0118)	-0.0462*** (0.0124)	-	-	0.7905*** (0.0389)	-	-	-0.0034*** (0.0010)	-0.0230*** (0.0057)
Taiwan	-0.0357*** (0.0068)	-0.0426*** (0.0074)	-0.0225*** (0.0079)	-0.0190*** (0.0074)	0.2871*** (0.0763)	-	-	0.0049*** (0.0008)	-0.034*** (0.0069)
Thailand	-0.0231* (0.0136)	-	-	-	0.7432*** (0.0816)	-0.1905** (0.0844)	-	0.0066*** (0.0017)	-0.0951*** (0.0250)
Trinidad & Tobago	-0.1269* (0.0653)	-	-	-	-	-	-	0.5064*** (0.0892)	-0.5297*** (0.0932)
United Kingdom	-0.0635*** (0.0182)	-0.0521*** (0.0186)	-	-	0.7172*** (0.0400)	-	-	0.0169*** (0.0037)	-0.0278*** (0.0062)
United States	-0.1914*** (0.0241)	-0.0933*** (0.0280)	-0.0376 (0.0283)	-	0.2368*** (0.0817)	0.1675** (0.0718)	-	0.0132*** (0.0024)	-0.0432*** (0.0087)

Notes: The numbers in the table are estimates that are derived by VECM model at eq.2.17 over 1980Q1-2016Q1 where HAC-robust standard errors are given in parentheses. The lags in the model are determined by Schwarz information criterion (SIC) with maximum allowed four lags. The lambda (λ) shows at what speed the ARDL model corrects its previous period disequilibrium. It is coefficient of ECT_{t-1} that is residual term of long-run Okun's model $U_{t-1} = \beta_0 + \beta_1 Y_{t-1} + ECT_{t-1}$ where β_1 is long-run Okun's coefficient that documented in eq.2.16 and reported in table 2.04 (Y^{LR}). The asterisks denote statistical significance in following order *: 10%, **: 5%, and ***: 1% significance levels.

2.4.2.2. Results of panel ARDL (PMG) analysis

Panelizing ARDL is important from perspective of robustness and generalization of the findings. Table 2.07 reports PMG estimation results where long-run Okun's coefficient of our sample appears approximately -0.12 which is statistically significant at 1% level. It is almost equate to country-individual average of long-run Okun's coefficients that are reported in table 2.05. The short-run equation predicts Okun's coefficient as -0.08 at 1% significance level. This also represents mean value of country-individual short-run law coefficients reported in table 2.06. In addition, the short-run equation predicts λ as -0.0568 at 1% significance level. It

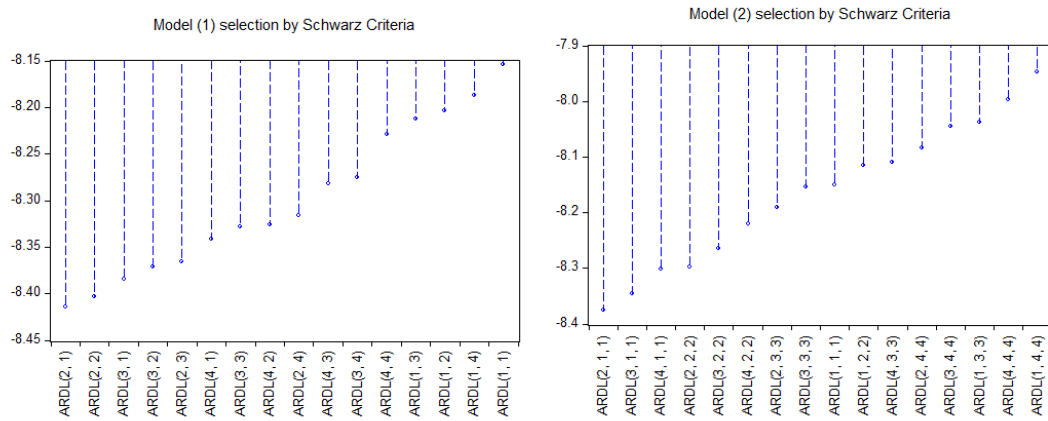
indicates that the system correct 5.68% of last period's disequilibrium in current period.

Table 2.07. Pooled Mean Group ARDL Short- and Long-Run Okun's Coefficient

	(1)	(2)
	Long-Run Okun's Law	Long-Run Okun's Law
Y^N	-0.1168*** (0.0083)	-0.1611*** (0.0132)
Y^R	-	-0.1537*** (0.0132)
	Short-Run Okun's Law	Short-Run Okun's Law
λ	-0.0568*** (0.0081)	-0.0455*** (0.0045)
ΔU_{t-1}	0.3646*** (0.0358)	0.3302*** (0.0375)
ΔY^N	-0.0797*** (0.0092)	-0.0609*** (0.0110)
ΔY^R	-	-0.0611*** (0.0110)
Intercept	0.0431*** (0.0083)	-0.0437*** (0.0058)
Trend	0.00004*** (0.0000)	-0.00005*** (0.0000)
Log Likelihood	29986.48	30094.45
Models Evaluated	16	16
Selection Method	Auto-SIC (max.4 lags)	Auto-SIC (max.4 lags)
Selected Model	ARDL(2, 1)	ARDL(2, 1, 1)
Total Panel Obs.	6838	6838

Notes: The numbers in the table are estimates that are derived by ARDL models eq.2.26-2.27 using Pooled Mean Group (PMG) panel technique. First column (1) reports long-run (UECM) and short-run (RECM) Okun's coefficient using eqs.2.16-2.17. Second column (2) reports long-run (UECM) and short-run (RECM) Okun's coefficient distinguishing pure tranquil and recessionary periods using eqs. 2.26-2.27. The lags in the model are determined by Schwarz information criterion (SIC) where four lags dynamic regressors and four autoregressive lags are allowed alongside with fixed regressors of intercept and linear trend. We have evaluated 16 models in different lag distribution structures, and we select ARDL(2,1) and ARDL(2,1,1) models for (1) and (2) respectively as they generate the lowest SIC value (see figure 2.01). The λ is coefficient of ECT_{t-1} which is residual term of long-run Okun's model $U_{t-1} = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-1} DUMMY_{t-1} + ECT_{t-1}$ where β_1 and β_2 are long-run Okun's coefficients during tranquil and recessionary periods respectively. It shows at what speed the ARDL model corrects its previous period disequilibrium. The standard errors are in HAC-robust characteristics and they are given in parentheses. The asterisks denote statistical significance in following order, *: 10%, **: 5%, and ***: 1% significance levels.

Figure 2.01. ARDL Model Selection by Schwarz Criteria



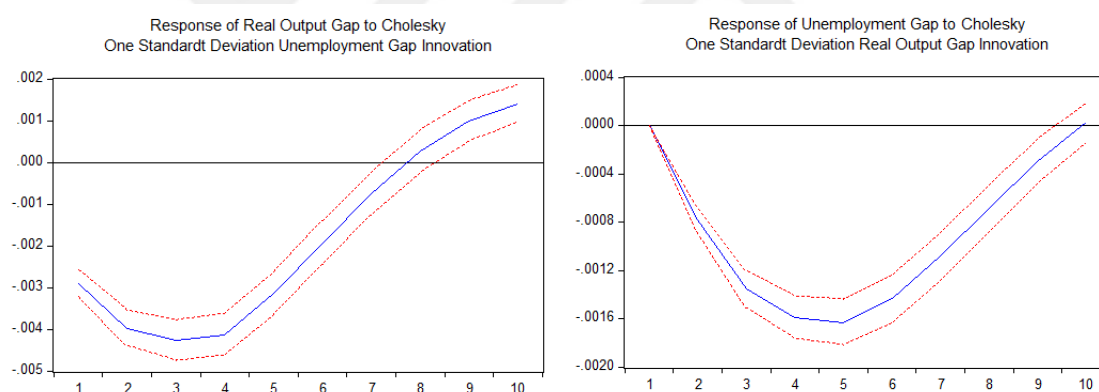
Notes: These figures show how ARDL Model specifications for eqs.2.15-2.18 in table 2.06 are selected under Schwarz Criteria evaluating 16 different lag-structure specified models.

On the other hand, the right-hand side part of table 2.07 is our main focus as this analysis reports behaviour and stability of long- and short-run Okun's coefficients during pure growing and recessionary periods. In country-individual OLS analysis, we have observed that Okun's coefficient slightly shrinks both in magnitude and significance, but mainly remains valid during recessionary periods. Results of table 2.07 cement this finding. The long-run equation predicts Okun's coefficient as -0.16 during growing periods at 1% significance level, while it slightly shrinks down to -0.15 during recessionary periods preserving its significance. The short-run equation estimates Okun's coefficient as -0.06 during pure tranquil (normal) periods at 1% significance level, while it remains stable (not changing in both magnitude and significance) during recessionary periods. This confirms overall stability of Okun's Law across time horizon including normal and abnormal economic periods. In addition, λ derives value of -0.0455 at 1% significance level. It implies that the model converges towards equilibrium by correcting 4.55% of previous period's divergence from this equilibrium following a shock. Although it is regarded as quite low speed of adjustment, it is in line with most recent literature that also finds generally low λ .

2.4.2.3. Impulse-response function and Granger causality

In addition, we observe reaction of short-run dynamics of unemployment gap and real output gap using impulse-response function that traces out how the changes in one variable impact on current and future values of the endogenous variables in the model. This technique can be used to depict the time path of dependent variables in ARDL model, to shocks from all the explanatory variables. If the model is stable, any shock should die out by declining to zero. This also means that short-run disequilibrium, following a shock, timely mitigates and converges to the long-run equilibrium. An unstable model would generate an explosive time path where short-run values of the variable will diverge from its equilibrium values.

Figure 2.02. Okun's Law interaction under Panel Impulse-Response Test



Notes: These figures show reaction of unemployment gap to real output gap and vice versa in response to injection of one-time shock of Cholesky one standard deviation innovation into the error term.

Figure 2.02 depicts the impulse response functions of the log of first differences of the variables (real output and unemployment) to one-time Cholesky "shock" of one standard deviation innovations. The two graphs are based on the output of the ARDL model with analytic response standard error over 10 quarters and Cholesky degrees of freedom adjusted, that shows the response to Chelosky one standard deviation innovation. Each graph, as shown in plots, includes a point estimation of impulse response functions as well as lower and upper bounds for a 95% confidence interval. As usual, the solid blue lines depict the real output/unemployment percent change in response to a standard deviation of one in

the unemployment/real output, whereas the dotted red lines show the 95% error bands.

The graph shows that the response of real output to the shock in unemployment is consistent and parallel to our expectations. It documents a strong and negative reaction for approximately 7 quarters. Moreover, the reaction is in increasing trend (in absolute values it goes negatively stronger) up to third quarter where it reaches negative peak point. From third up to seventh quarter the reaction steadily slows down up in decreasing trend, where afterward it subsides to zero. On the other hand, reaction of unemployment gap to an unexpected shock to real output gap is much stronger and persistent over the time horizons. Initially, it declines in increasing trend (goes negatively stronger) up to fifth quarter, where after the reaction takes decreasing trend. The reaction dies out in ninth quarter and totally stabilizes. This reaction appear much more long-lived comparing to the reaction of real output.

Findings of Impulse-Response function show that Okun's law work bidirectional through the sample. Although Okun (1962) originally investigates impacts of unemployment fluctuation to real output gap, there are sizeable literature that studies the opposite (Lee, 2000; Freeman, 2001; Adanu, 2005). To get further insights into the dynamic interaction of unemployment and real output as well as its direction (which affects which at what magnitude), the study proceeds with a Granger causality analysis. Table 2.08 presents results of the pair-wise Granger causality tests between unemployment gap and real output gap on panel dataset during recessionary and growing periods. The results reveal very strong bi-directional causality at 1% significance level under both standard Granger and DH approaches. The panel A of the table reports standard Granger causality approach where magnitude causality running from real output gap to unemployment gap is much stronger (4.57) than vice versa causality (3.56). The DH approach also estimates superiority of $\Delta Y \rightarrow \Delta U$ causality than opposite $\Delta U \rightarrow \Delta Y$ causality, but its estimated magnitude is relatively lower than the standard approach. We believe DH estimates are more appropriate as it accounts heterogeneity between panel cross-sections. These findings strictly indicate that firms adjust employment in response to fluctuations in real output, thus using real output gap as explanatory variable of unemployment gap is more accurate, even though the opposite also still works.

Table 2.08. Panel Pairwise Granger Causality Test of Okun's Law

Panel A: Standard Approach	Obs	F-Statistic	Magnitude	Probability
ΔY does not Granger cause ΔU	6721	96.2685	4.5671	9.00E-80
ΔU does not Granger cause ΔY	6721	35.0476	3.5567	5.00E-29
ΔY^N does not Granger cause ΔU^N	6721	10.9219	2.3907	8.00E-09
ΔU^N does not Granger cause ΔY^N	6721	2.4357	0.8902	0.0451
ΔY^R does not Granger cause ΔU^R	6721	13.3984	2.5951	7.00E-11
ΔU^R does not Granger cause ΔY^R	6721	22.7844	3.1261	1.00E-18
Panel B: Dumitrescu-Hurlin Approach	W-Stat.	Zbar-Stat.	Magnitude	Probability
ΔY does not homogeneously cause ΔU	17.4864	33.5334	3.5125	0.0000
ΔU does not homogeneously cause ΔY	9.76571	14.2269	2.6551	0.0000
ΔY^N does not homogeneously cause ΔU^N	8.1496	10.1855	2.3209	0.0000
ΔU^N does not homogeneously cause ΔY^N	6.3873	5.7789	1.7542	8.00E-09
ΔY^R does not homogeneously cause ΔU^R	16.0115	29.8452	3.3960	0.0000
ΔU^R does not homogeneously cause ΔY^R	18.2959	35.5577	3.5712	0.0000

Notes: The analysis captures the periods of 1980Q1-2016Q1 allowing maximum of four lags. Panel-A reports standard Granger causality approach results, whereas Panel-B reports Dumitrescu-Hurlin approach causality. The subscript "N" and "R" denote tranquil and recessionary periods respectively.

When we account growing and recessionary periods separately, we reveal interesting results. Both standard and DH approaches show that the superiority of $\Delta Y \rightarrow \Delta U$ causality continues during growing (tranquil) periods. On the other hand, the $\Delta U \rightarrow \Delta Y$ causality gets superiority during recessionary periods both in standard and DH approaches. For instance, standard approach estimates $\Delta U^R \rightarrow \Delta Y^R$ causality (during recessionary periods) as F-statistics of 22.7844 (or magnitude of 3.1261), while the opposite causality ($\Delta Y^R \rightarrow \Delta U^R$) is just 13.3984 (or 2.5951 magnitude). Likewise, DH approach also confirms superiority of $\Delta U^R \rightarrow \Delta Y^R$ causality during recessionary periods (see last two rows of panel B at table 2.08). This core finding indicates that movements in unemployment around its potential cause real output to fluctuate during recessionary periods. Thus, in examination of crisis-prone countries it is better to use unemployment gap as explanatory variable for real output gap.

Besides, the shrunk in magnitudes of causalities during tranquil (normal) and recessionary periods is motivated by characteristics of dummy variable as its lag often is zero. Even though, the results remain consistent. Thus, we conclude that

the Okun's law comprises a strong bi-directional causality running from unemployment gap to real output gap and the opposite. Inter-importance of Okun's law is in favor of $\Delta Y \rightarrow \Delta U$ causality, indicating that response of firms to fluctuations in real output by adjusting employment is more significant than the response of real output to unemployment fluctuations. This statement continues to hold when we examine pure tranquil (growing) periods, however, during pure recessionary periods the inter-importance turns opposite, indicating that the response of real output to unemployment fluctuations is more significant than the firms response to movements in real output gap.

2.5. Concluding remarks

This chapter examines dynamics of unemployment during tranquil and recessionary economic periods under Okun's Law framework with a broader country-time sample using up-to-date data over 1980-2016. Although our findings refer universality of Okun's Law indicating its overall validity in most countries, we observe substantially time-variation (instability) in the Okun's relationship which confirms most recent studies (Meyer and Tasci, 2012; Owyang and Sepkhposyan, 2012; Grant, 2017). In other words, the coefficient varies across countries as well as across time periods.

We find that developed markets have average Okun's coefficient of -0.42, while emerging, frontier, and unclassified markets have average coefficients of -0.21, -0.19, and -0.16 respectively. The lowest Okun's coefficients are documented in Luxembourg (-0.08), Austria (-0.16), Japan (-0.17), and Norway (-0.27) at 1% significance level. These results are in line with extant literature (Lee, 2000; Freeman, 2001; Perman and Tavera, 2005; Ball et al, 2012). The main driving force behind low Okun's coefficient is high institutional rigidity in labor markets; especially in Japan that "*lifetime employment*" tradition makes employers reluctant to dismiss employees.

On the other hand, we observe that the highest Okun's coefficients are estimated in Spain (-0.95), Netherlands (-0.59), and Australia (-0.57) at 1% significance level. Spanish coefficient is in line with most recent literature (Ball et al., 2012) that refers to extraordinarily high frequency of temporary (flexible) employee

contracts in Spain which offers firms an easy opportunity to amend their employment in response to output changes.

The main contribution of this study is that it measures Okun's coefficient during pure tranquil and recessionary periods. When we distinguish these two periods, we observe the Okun's coefficient preserves its statistical significance in both periods, but it is slightly higher during tranquil comparing to recessionary periods. More specifically, the coefficient during tranquil periods is -0.20 at 1% significance level, while it is -0.18 during recessionary periods preserving significance at 1% level even though its standard error increases twofold. Thus, we conclude that dynamics Okun's relation is fairly valid over different time horizons and economic environments. However, we find out that Okun's coefficient considerable shrinks during recessionary periods. This finding is in line with Owyang and Sepkhposyan (2012) and Grant (2017) who also document similar shrunk. Eventually, we believe that this information can be utilized as signalling indicator in an early crisis warning system.

In addition, we also examine Okun's law under ARDL framework assessing its short- and long-run magnitudes. We find short-run Okun's coefficient as -0.06 and long-run coefficient as -0.16 both significant at 1% level. We document that these magnitudes remain stable (not changing in both magnitude and significance) during recessionary periods. This confirms overall stability of Okun's Law across time horizon including normal and abnormal economic periods. We detect speed of error correction as -0.0455 at 1% significance level which implies that the model converges towards equilibrium by correcting 4.55% of previous period's divergence from this equilibrium following a shock. Majority of extant literature generally finds low adjustment speed due to long memory of time series variables, government interventions by frequently changing policies, and impact of external factors, the convergence is gradually slow. Besides, we observe that speed of adjustment is fairly similar in countries that culturally akin each other such as Canada-United States, United Kingdom-Australia-Ireland, Japan-China, and Germany-France.

Lastly, we examine causality between real output and unemployment, to determine which is lagged and which is leading indicator. As a result, we document strong bidirectional causality. However, causality running from fluctuations in unemployment rate to movements in real output is stronger than vice versa causality

during recessionary periods. This core finding indicates that movements in unemployment around its potential cause real output to fluctuate during recessionary periods, and impulse-response function shows that response of real output to the shock in unemployment is strong negative and lasts for approximately 6-7 quarters. Thus, in examination of crisis-prone countries it is better to use unemployment gap as explanatory variable for real output gap.



CHAPTER THREE

AN EARLY CRISIS SIGNALING FRAMEWORK

3.1. Introduction

Economists and financial regulatory authorities have often been accused of failing to predict economic imbalances in advance. Very first theoretical examination and attempt of establishing a predictive crisis model began with Krugman (1979) and Bilson (1979) who mainly focus on currency and balance-of-payment crises as they were weak fundamentals with high volatility and vulnerability after collapse of Bretton Woods system. However, these early models were mainly based on backward-looking indicators that are linked with fiscal deficits, so that they simply failed to predict the collapse of European Exchange Rate Mechanism in 1992-1993 which was later explained by forward-looking indicators such as market expectation (Obstfeld, 1994, 1996, 1997).

The collapse of East Asian currencies that was motivated by Thai Baht devaluation in 1997-1998 has significantly influenced mainstream of modeling EWS (Eichengreen et al, 1995, 1996; Frankel and Rose, 1996; Kaminsky et al, 1998; Kaminsky and Reinhart, 1999; Berg and Pattillo, 1998, 1999; Demirguc-Kunt and Detragiache, 2000; Bussiere and Fratzscher, 2006). Both Krugman-type and Obstfeld-type policies fail to explain the currency turmoil which was motivated by asset bubbles in Thailand and “*fast and furious*” contagiousness of crises due to tight bilateral trade links and business interdependence between neighbor countries. Since that date countries became more internationalized and the Great Recession of 2008-2009 has shown that crisis might spillover not only to neighbor countries, but also to other countries that have tight bilateral trade links and business interdependence with crisis-origin country. Majority of existing EWS models have failed to anticipate this global crisis as they were mainly designed to forecast a certain type of crisis only (currency crash, banking crisis, fiscal crisis). Thus, it has risen an idea of establishing more generalized (common) EWS framework which is capable of accounting all types of crisis (currency crashes, banking crisis, debt crisis, equity and labor market crashes, and international spillovers).

In this respect, the study aims to establish more generalized EWS that accurately forecasts various types of impending crisis events earlier leaving a considerable time for policy-makers to dispose the shock completely or mitigate their consequences. Our EWS model improves existing models in several patterns.

First, it introduces a more generalized model that is capable of accounting various types of crisis using Distributed Lag Logit technique (DLL) under Almon's (1965) approach in multivariate framework. This specific methodology captures both short- and long-run impacts of leading indicators using dynamic lag selection technique based on Schwarz information criterion (SIC).

Second, to our best knowledge, the study uses the largest sample size for EWS by covering 41 countries from developed, emerging, and frontier markets. It provides country-specific analysis and results for EWS on 41 countries individually accounting all types crises between 1980 and 2016.

Third, the study takes into account a broad set of financial and economic indicators with few new indicators that have not been used before. It strengthens the EWS model by accounting contagion effects through three different channels (Masson, 1998): 1) Country-specific shocks; 2) Global resource-specific shocks; and 3) Speculation- or Expectation-motivated shocks. The literature widely uses equity markets as a proxy for country-specific shocks; however, these data for some countries are limited. Thus, considering reciprocal trade links and interdependence of countries, we introduce a brand-new contagion factor that would ideally reflect country-specific spillovers.

In order to account speculation- and expectation-motivated shocks, we utilize joint frequencies of Google search trends and scientific research publications. Although we detect a positive correlation between two contagiousness proxies (trade interconnectedness factor and speculation-expectation factor), we conclude that it remains weak to cause collinearity in the EWS model.

For global shocks, we use proxy of changes in world crude oil prices. Unlike other two contagiousness proxies, the sign (direction of correlation) oil proxy varies across sampled countries. We observe that economies of oil exporter (producer) countries would be negatively affected by price downfalls causing increase in

probability of crisis outbreak, while other countries (mainly oil importers) would enjoy low oil prices which lead their crisis probability to decrease.

Fourth, we introduce two brand-new optimal threshold selection methods namely, False-to-True ratio (ϕ) and Risk Aversion rate (Ω), that help to evaluate predictive power of the DLL EWS model more accurately. Although vast body of existing literature widely uses Kaminsky et al (1998)'s (KLR) Noise-to-Signal ratio, it fails to distinguish consequences of "*false alarms*" (type II error) and "*missed alarms*" (type I error). Therefore, we regard noise-to-signal ratio as a risky threshold. The ϕ is an augmented version of KLR's Noise-to-Signal ratio and it appears as the best methodology in theoretical ground that derives maximum accuracy for EWS by minimizing overall incorrectness of the model disregarding cost weights of type I and type II errors.

Additionally, we show that Ω is the most secure and risk-averse technique that considers minimizing type I error as well as overall incorrectness of EWS model. It automatically finds optimal trade-off between type I error (missing alarm) and type II error (false alarm), unlike Demirguc-Kunt and Detragiache (2000)'s Loss Function (θ) which depends on preference and on degree of risk-aversion (trade-off between false and missing alarms) of the decision-makers. On the one hand, taking pre-emptive action in response to a false alarm for non-crisis events is costly from a decision-maker's perspective. On the other hand, the cost of not getting an early alarm for upcoming actual crisis might be several-fold if early actions by decision-makers could have been useful in preventing or at least mitigating the affects of the crisis.

We comparatively evaluate prediction power our generalized DLL EWS model in 41 different countries with KLR's Noise-to-Signal (λ), Demirguc-Kunt and Detragiache (2000)'s Loss Function (θ), and with our two new threshold selection techniques. We observe that in nearly half of the sample θ , Ω , and ϕ finds the same cut-off probability level, while λ sets threshold at "*crazy*" levels.

The remainder of the chapter is structured as following order. Next section briefly reviews existing literature of EWS approach with their practical implementations. Third section plots econometric setup of our EWS model with descriptive analysis of data inputs. Fourth section examines the model and

interprets key findings of the study. The final section summarizes and concludes the study.

3.2. Literature review

EWS literature mainly focuses on fiscal deficit problems, currency crashes, and banking crises (Krugman, 1979; Bilson, 1979; Obstfeld, 1994, 1996, 1997; Eichengreen et al, 1995, 1996; Frankel and Rose, 1996; Kaminsky et al, 1998; Kaminsky and Reinhart, 1999; Berg and Pattillo, 1998, 1999; Demirguc-Kunt and Detragiache, 2000; Bussiere and Fratzscher, 2006; Davis and Karim, 2008; Reinhart and Rogoff, 2011; Babecky et al, 2014; Boonman et al, 2017) utilizing three generations of methodologies. The collapse of Bretton Woods system in 1971-1972 accumulated interests in floating exchange rates, and it triggered the outbreak of first generation framework which is mainly based on backward-looking indicators that are linked with fiscal deficits (balance-of-payment problem), as explained in Krugman (1979) and Bilson (1979). They show that disturbance of balance of payments has central role in currency crashes. A country generally finance its fiscal deficits by increasing money supply through selling reserves which accumulates pressure for devaluation of money under fixed exchange rate regime. Thus, declines in reserves and balance of payments might be a good indicator of currency crises. In other words, any depreciative pressure leads policy-makers either to devalue the currency (so it is defined as "crisis") or to defend it by selling reserves until all reserves exhaust and speculative attacks start under fixed exchange rate regime.

However, this system failed to predict and explain the collapse of European Exchange Rate Mechanism (ERM) in 1992-1993. As a result it led to development of second generation crisis predicting framework, with pioneering role by Obstfeld (1994, 1996, 1997), that incorporate forward-looking indicators such as investors' expectations. Even though there is no any sign of worsening in financial fundamentals and no any disturbance in policies, the crisis still can occur if investors shift their expectations due to possibility of multiple equilibria. Thus, policy-makers are dependent to the self-fulfilling expectations of the market and they have to account and assess these behaviors when they optimize economic policies. In other words, policy-makers should decide whether to defend or to release the peg by assessing trade-off between costs of two scenarios. Under this framework, leading indicators for the market expectation might be proxied by national stock market

index which often has been regarded as a good leading indicator for many types of crises.

The collapse of Thai baht in 1997 caused a domino effect emerging series of rapid currency devaluations in many Asian markets casting a doubt on these models. Both models failed to predict and explain these crashes as East Asian countries were neither in substantial fiscal deficits as a result of Krugman-type policy disturbances that lead to speculative attacks due to exhaust of international reserves nor in Obstfeld-type trade-off distress that compel the policy-makers to defend the peg or to devalue as unemployment and inflation rate were considerable low in these countries alongside with average economic growth of 7% during 1993-1996. The asset bubble in Thailand had loaded a heavy pressure on depreciation of Thai baht. Thailand's decision to release the peg to the US dollar caused wave of speculations on currency and it emerged "*fast and furious*" contagion effects causing around 70% lost in East Asian currencies and stock markets. The consequences and contagiousness were mitigated with the financial aid provided by IMF.

This event has rekindled interest on developing early crisis warning system. The papers authored by Eichengreen et al (1995, 1996), Frankel and Rose (1996), Kaminsky, Lizondo and Reinhart (1998), Kaminsky and Reinhart (1999), Berg and Pattillo (1998, 1999), Demirguc-Kunt and Detragiache (2000), and Bussiere and Fratzscher (2006), have significantly influenced mainstream of modeling EWS causing birth of third generation framework that is mainly concerned with issue of contagion. Eichengreen et al (1995, 1996) introduced logit/probit approach where set of leading indicators (both backward- and forward-looking) jointly contribute to likelihood probability of crisis occurrence. They use equity markets as a proxy for contagion. Masson (1998) underlines three main reasons of contagion.

First, a common external shocks that might affect all countries such as rise in world crude oil prices, fluctuations in LIBOR and the US interest rates, appreciation of the US dollar, British Pound, Euro or Gold prices against other emerging currencies.

Second, globalization of markets brought tight interconnectedness between countries which make a pave for easy transition of financial imbalances. As an

illustration, suppose that a country "A" has great economic partnership trade (exports, imports, trade links, FDI, etc.) with country "B", and less connection with country "C". In case of crisis occurrence in country "A", there is high probability of spillover of the crisis to the country "B" due to high connections reciprocally, and less probability to the country "C".

Third, speculations or expectations that cause shifts in investors (market) sentiments. There might be a bandwagon (herding) effect in the market where individual follows other individuals' actions in decision-making. In this mechanism, small negative news in country "A" might turn to massive snowballs in other countries due to macro-similarities that eventually lead to a crisis.

3.2.1. Crisis Definition, Indicators Determination, and Model Specification

Common way of defining crisis in the literature is building an index of speculative pressure or exchange market pressure considering a weighted average of (real or nominal) exchange rate changes, international reserves changes and interest rates movements where weights are assigned to maintain equal volatility of indicators, preventing one to dominate others, and binarize crisis variable considering if this constructed index crosses determined specific threshold level.

Eichengreen et al (1995, 1996) base their model by establishing Speculative Pressure on Exchange rate (SPE) index as following.

$$SPE_{at} = \alpha e_{at} + \beta(i_{at} - i_{Rt}) - \gamma(r_{at} - r_{Rt}) \quad (3.01)$$

where e_{at} denotes exchange rate (domestic price in terms of a 's currency), i_{at} and i_{Rt} are short-term interest rate of country a and reference country (Eichengreen et al (1996) refers to Germany), and r indicates ratio of international reserves to narrow money (M1). The α , β , and γ are weights that are assigned to maintain equal volatility of indicators, preventing one to dominate others. They define the "crisis" as extreme deviations in the index as following.

$$Crisis_{at} = \begin{cases} 1, & \text{if } SPE_{at} \geq \overline{SPE}_a + \frac{3}{2}\sigma_{SPE} \\ 0, & \text{otherwise} \end{cases} \quad (3.02)$$

where $\overline{SPE}$ and σ_{SPE} are sample mean and standard deviation of SPE index respectively. Then, they setup following multivariate probit model.

$$Crisis_{at} = \omega Crisis_{bt} + \lambda I(L)_{at} + \varepsilon_{at} \text{ where} \quad (3.03)$$

$$Crisis_{bt} = \begin{cases} 1, & \text{if } Crisis_{bt} = 1, \text{ for any } b \neq a \\ 0, & \text{otherwise} \end{cases} \quad (3.04)$$

where $I(L)_{at}$ stands for current and lagged indicator variables such as capital controls, political elections, domestic credit expansion, inflation, output growth, labour market indicators, central government budget balance to GDP, and current account balance to GDP. They test this model over 20 industrial countries between periods of 1959 and 1993. They find statistically significant contagion effects, i.e. a currency crisis elsewhere augments probability of crisis occurrence in domestic country by around 8%.

On the other hand, Frankel and Rose (1996) examine currency crashes in panel of 105 developing countries over 1971-1992 under probit approach defining the crash as "*a decrease in the value of the local currency of at least 25%*". Rather discrete percentage changes, they measure change in natural logarithm of nominal exchange rates.

$$Crisis_{at} = \begin{cases} 1, & \text{if } \frac{E_{at} - E_{a,t-1}}{E_{a,t-1}} \leq -0.25 \\ 0, & \text{otherwise} \end{cases} \quad (3.05)$$

$$Crisis_{at} = \beta_i X_{at} + \varepsilon_{at} \quad (3.06)$$

where E_{at} and $E_{a,t-1}$ are natural logarithm of current and lagged nominal exchange rates, X_{at} is set of explanatory indicators such as domestic credit expansion, government budget balance to GDP, reserves to imports, current account to GDP, real output growth rate, total debt to GNP, real effective exchange rate (REER), and FDI. They find out that FDI-to-debt ratio is a good leading indicator for currency crash, where a low ratio indicates higher likelihood of the crisis. They conclude the crashes occur FDI inflows and reserves sharply decrease, while domestic credit grows rapidly and REEX is over-valued.

Kaminsky and Reinhart (1996, 1999) and Kaminsky et al (1998) (hereinafter KLR) introduce leading indicator (signaling) approach considering volatility and

vulnerability of indicators and converting them into binary signals; signal issues when a given indicator exceeds (or drops below) the critical threshold. They predict currency imbalances by establishing Index of Currency Market Turbulence (CMT) in spirit of Eichengreen et al (1995).

They get weighted average of the rate of change of the exchange rate and of international reserves, with appropriate weights that equalize volatilities of two components preventing one to dominate the index.

$$CMT_{at} = \frac{e_{at} - e_{a,t-1}}{e_{a,t-1}} - \frac{\sigma_e}{\sigma_R} \left(\frac{R_{at} - R_{a,t-1}}{R_{a,t-1}} \right) \quad (3.07)$$

where e_{at} and R_{at} are rates of change of exchange rate and of reserves respectively with their standard deviations as σ_e and σ_R . They define "crisis" as three standard deviation increase in CMT above its mean value.

$$Crisis_{at} = \begin{cases} 1, & \text{if } CMT_{at} \geq \overline{CMT}_a + 3 \sigma_{CMT} \\ 0, & \text{otherwise} \end{cases} \quad (3.08)$$

where $\overline{CMT}$ and σ_{CMT} are sample mean and standard deviation of CMT index respectively. They monitor fifteen different indicators⁸ on monthly basis. They consider 24 month of signaling horizon with optimal threshold that minimized the noise-to-signal ratio (false-to-good signals). They find that exports, deviations of the REER from its long-run steady state, ratio of broad money to gross foreign reserves, output, and equity prices have the best track record with this signaling approach.

Bussiere and Fratzscher (2006) develop the EWS framework further by classifying three regimes as tranquil, crisis, and recovery periods. They establish Exchange Market Pressure (EMP) following Kaminsky et al (1998) as,

$$EMP_{at} = \omega_{REER} \left(\frac{REER_{at} - REER_{a,t-1}}{REER_{a,t-1}} \right) + \omega_i (i_{at} - i_{a,t-1}) - \omega_R \left(\frac{R_{at} - R_{a,t-1}}{R_{a,t-1}} \right) \quad (3.09)$$

where EMP_{at} is weighted average of the change of the REER, plus of interest rate (i) and negative of foreign reserves (R). The ω indicates weight of related factor that

⁸These indicators as international reserves, import, export, terms of trade, deviations of REER from its steady long-run equilibrium, short-term US interest rate, M1 and M2 money balances, domestic credit to GDP, real deposit interest rates, lending to deposit interest rate, stock of commercial banks deposits, ratio of broad money to gross foreign reserves, index of output, and index of equity prices.

equalized conditional volatilities of all three components to prevent dominance of one in *EMP*.

$$Crisis_{at} = \begin{cases} 1, & \text{if } EMP_{at} \geq \overline{EMP}_a + 2 \sigma_{EMP} \\ 0, & \text{otherwise} \end{cases} \quad (3.10)$$

They construct a multinomial logit model with three regimes as follows.

$$Y_{at} = \begin{cases} 1, & \text{if } Crisis_{a,t-k} = 1 \quad \text{where } \exists k = 1, \dots, 12 \\ 2, & \text{if } Crisis_{a,t+k} = 1 \quad \text{where } \exists k = 1, \dots, 12 \\ 0, & \text{otherwise} \end{cases} \quad (3.11)$$

where Y_{at} stands for logistic regimes: $Y_{at}=1$ for a pre-crisis periods of 12 month prior to crisis occurrence; $Y_{at}=2$ for a post-crisis (recovery) periods for crisis time and 12 month following the end of the crisis; $Y_{at}=0$ for tranquil periods. As a result, they find that distinguishing recovery regime separately matters in terms of clearly observing behaviors of indicators during normal and abnormal periods. They reveal overvaluation of exchange rate is a significant indicator of crisis that 1%, 2%, 5%, and 10% increases in rates above its long-run equilibrium leads 1%, 2%, 6.3%, and 18% increase in crisis probability. In addition, they document that five-to-one relation between contagion factor and crisis as 5% increase in contagion factor leads 1% increase in crisis probability. We believe distinguishing recovery regime from recession and tranquil periods matters for Bussiere and Fratzscher (2006) due to their definition of crisis. The crisis in their study is subjected to EMP index which is fairly volatile due to volatility of exchange rates. In this respect, EMP might behave differently during tranquil, crisis, and recovery periods.

Alternatively, few other methodologies are also utilized in developing early warning systems such as OLS approach by Sachs et al (1996), Bussiere and Mulder (2000), and Frankel and Saravelos (2012); Artificial neural network by Nag and Mitra (1999), Franck and Schmied (2003), Fioramanti (2008), and Sarlin and Marghescu (2011); Fisher's linear discriminant analysis by Burkart and Coudert (2002); Markov switching approach by Abiad (2003); Binary classification tress method by Duttagupta and Cashin (2011); Random forest technique by Alessi and Detken (2011) that bootstraps and aggregates a multitude of decision trees; Multiple Indicator Multiple Cause (MIMIC) model by Rose and Spiegel (2012); Machine learning methods (k-Nearest Neighbors, Extreme Learning Machines, Support Vector Machines) by Holopainen and Sarlin (2016); and Dynamic binary probit

model by Kauppi and Saikkonen (2008), Bismans and Majetti (2013), Candelon et al. (2014), and Antunes et al (2016).

After failure of existing EWS in anticipating Great Recession of 2008-2009 many studies attempt to develop more robust EWS (Rose and Spiegel, 2012; Frankel and Saravelos, 2012; Bismans and Majetti, 2013; Candelon et al, 2014; Antunes et al, 2016; Holopainen and Sarlin, 2016). For instance, Holopainen and Sarlin (2016) conduct cross-validate and recursive horse race of conventional statistical (OLS, Logit/Probit, Discriminant Analysis/Quadratic Discriminant Analysis, Signaling Approach, Trees approach, Random Forest approach) and more recent machine learning methods (k-Nearest Neighbors, Extreme Learning Machines, Support Vector Machines) and find recent machine learning approaches outperform conventional statistical methods. On the other hand, studies such as Bismans and Majetti (2013), Candelon et al (2014), and Antunes et al (2016) show that adding a dynamic component to the multivariate modeling of systemic banking crises substantially improves accuracy of EWS both in- and out-of-sample.

3.3. Data and methodology

3.3.1.Specifying the model

Despite sizeable literature and methodology on EWS, there is no a generalized form that accounts various types of crises including currency turmoil, banking, financial and economic disturbances. Although majority of existing literature has been focused on KLR approach, we prefer to use probit/logit models as Eichengreen et al (1995, 1996) due to three reasons. First, as noted in Demirguc-Kunt and Detragiache (2000) logit models have better in-sample performance comparing to KLR signal approach. Second, the KLR framework does not account degree of vulnerability of countries. We believe this degree varies across countries. Third, assuming a certain optimal threshold " T_i " for indicator " I " the KLR framework comprises loss of information as it does not differentiate if the T_i is crossed by x or $5x$ or $100x$. We adopt this logit model into Distributed Lag Logit (DLL) under Almon's (1965) approach in multivariate framework. This specific methodology helps us to capture cumulative and delayed impacts of leading indicators on crisis event accurately. To our best knowledge, this model has not been used in prior literature. We base our DLL multivariate logit model as below.

$$Prob(Crisis_{at} = 1 | \beta X_{a,t-m}) = F(\beta X_{a,t-m}) = \frac{e^{\beta X_{a,t-m}}}{1 + e^{\beta X_{a,t-m}}} \quad (3.14)$$

where,

$$F(\beta X_{a,t-m}) = \beta_0 + \sum_{i=1}^n \sum_{j=1}^m \beta_i X_{ai,t-j} + \varepsilon_{at} \quad (3.15)$$

Here, X_{at} stands for an " n " set of signaling indicators; F is a logistic cumulative distribution function; and $Crisis=1$ is estimated one or m lags before the occurrence of a crisis. Unlike Eichengreen et al (1995, 1996) we do not incorporate current values of indicators as our objective is to predict crisis in advance with past values of signaling variables. Crediting Bussiere and Fratzscher's (2006) post-crisis bias, we consider only lags of indicators in our EWS model. Choosing the length of lag " m " or signal horizon is also a critical issue. Rather than presumably choosing 1 or 2 years of time length, one should regard its optimality through trade-off between two facts. First, economic disturbances tend to occur in a short time horizon rather long-lasting weakening of economic fundamentals. One might expect that signaling of indicators will be significant, thus EWS model will issue better signals with high predictive accuracy as we approach closer to the actual time of crisis. Second, policy-makers would desire to have a considerable longer time length prior to the crisis in order to take significant preventive actions to fix the disturbance. In this respect, we define signaling horizon as 6 quarters. Although we bound the lags length with maximum -6 (past 6 quarters), we allow them to be dynamic for each indicator variables. In other words, some indicators for country " A " might have only one lag, while some other indicators might 2-6 lags. The system will automatically determine lag length of each indicator separately using Schwarz information criterion (SIC). Thus, the lag length " m " dynamically varies between 1 quarter to 6 quarters across countries and their indicator variables.

3.3.2. Defining the crisis

Although each crisis is different and unique in its nature and characteristics, all of them have fairly similar consequences, disturbing the real output of the economy. Thus, decision-makers design all their policies for the sake of maintaining a sustainable growth in real output. In this respect, we refer the word "*crisis*" to a

shrink in real output for the sake of generalized model. The real output and growth in real output are defined as below:

$$\begin{aligned} Real\ Output_{a,t} &= \frac{Nominal\ Output_{a,t}}{Inflation_{a,t}} \\ Real\ Output\ Growth_{a,t} &= \frac{Real\ Output_{a,t} - Real\ Output_{a,t-1}}{Real\ Output_{a,t-1}} \end{aligned} \quad (3.12)$$

where inflation is proxied by GDP deflator. We transform the "crisis" variable into binary dummy form as below.

$$Crisis_{at} = \begin{cases} 1, & Real\ Output\ Growth_{a,t} \leq 0 \\ 0, & otherwise \end{cases} \quad (3.13)$$

The real output attracts wide concern in both macroeconomics and finance. Because, it is one of the primary indicators used to gauge the health of a country's economy as it summarizes aggregated demand and supply. Any shrinkages in real output might negatively affect whole societies by generating dramatic consequences.

We do not distinguish recovery periods separately, because we could not identify these periods on the basis of real output growth that fluctuate around zero. The crisis occurs when it falls down the zero line, and all periods for above zero line referred as tranquil periods. We believe distinguishing recovery regime from recession and tranquil periods matters for Bussiere and Fratzscher (2006) due to their definition of crisis. The crisis in their study is subjected to *EMP* index which is fairly volatile due to volatility of exchange rates. In this respect, *EMP* might behave differently during tranquil, crisis, and recovery periods. However, in our case it won't work.

3.3.3.Determining signaling indicators and integrating into the model

Following sizeable relevant literature, the study elaborates a sizeable set of leading indicators that might add turmoil pressure on countries' economic and financial activities and eventually generate an impact on real output. These indicators are Inflationary (*CPI*) pressure, Unemployment (*UD*) pressure, Purchasing

Managers' Index (*PMI*)⁹ fluctuations, Construction production index (*CONPI*) fluctuations, Industrial Production Index (*IPI*) fluctuations, Balance of payment (*BOPY*) pressure, Government Balance (*GOVY*) pressure, Liquidity and Foreign Reserves (*RESMON*) pressure, Real Effective Exchange rate (*REER*) pressure, Banking Credit (*CRDY*) bubble, World Oil Prices (*OIL*), Contagion Effect (*CON*), and Speculations and Expectations (*SPEX*). Unlike many other papers, we do not consider interest rate, broad money supply growth, export and imports, and stock market indexes as leading indicator due to various reasons. We believe interest rate is a lagging indicator for crisis as it is tuned by regulatory authorities in response to disturbances in financial flows. We disregard broad money supply growth and exports and imports indicators; because we prefer to use inflation rate and balance of payment variables instead of them. Although the stock market index is often regarded as a good proxy for many types of crises, we could not to include this indicator due to data limitations for 41 sampled countries for the periods of 1980-2016. For the sake of using stock equity market index, we would have to halve either sample size or analysis period. Instead, we use three contagiousness factors such as *CON*, *OIL*, and *SPEX*.

Besides, we use Inflationary (*CPI*) and Unemployment (*UD*) pressures due to their leading impacts on the real output which we have shown in our Phillips curve and Okun's law analysis. In chapter one, we have shown that inflation is largely lagging variable; thus, it is better to use expected inflation in the EWS model in order to reflect inflationary pressure in the economy. We also have shown that this expected inflation depicts behavioural changes during recessionary periods; therefore, it might yield a signal for upcoming crisis and it should be used in the EWS model.

On the other hand, unemployment rate has been largely ignored in the EWS literature due to two facts: (1) They argue that it is a lagging indicator for crisis due to it follows output with a delay; (2) Large body of the literature studies financial crisis like currency crashes, asset bubbles, and banking failures. However, for the sake of establishing more generalized EWS model, we account unemployment pressure in our EWS model. Because, in our previous chapter we have already

⁹ PMI is an indicator of the economic health of the manufacturing sector and it is based on five major indicators: new orders, inventory levels, production, supplier deliveries and the employment environment.

shown statistically strong bidirectional causality between unemployment rate and the output. Our findings in previous chapters also reveal that these relationships tend to comprise structural and behavioural changes during recessionary periods. It is noteworthy that we have also observed shrink in Okun's coefficient (unemployment-output weakens). In this respect, they can be used as leading indicator of the crisis in our EWS model. However, to avoid collinearity problem that is motivated by high correlation between these inflation and unemployment, we transform unemployment rate into binary form (UD) as below.

$$UD_{at} = \begin{cases} 1, & |U_{c,at}| \geq \left| \frac{3}{2} \sigma_{U_c} \right| \text{ or } STR > 0 \\ 0, & \text{otherwise} \end{cases} \quad (3.16)$$

where STR accounts structural changes in behavior of the Okun's relationships and U_c is fluctuation of unemployment rate around its long-run steady equilibrium (NAIRU). In other words, U_c is a cyclical component of de-trended unemployment rate using HP technique with a degree of smoothing λ . The λ is set by using Ravn and Uhliq (2002) frequency rule: the number of periods per year divided by 4, raised to the power x , and multiplied by 1600. Hodrick and Prescott (1997) recommend the value 2 for x , whereas Ravn and Uhliq (2002) suggest using 4 for x . Following Hodrick and Prescott (1997), we derived $\lambda=100$ for annual data, and $\lambda=1600$ for quarterly data to find out the trend (μ_t) that minimizes the sum as given by:

$$\min_{\{\mu_t\}_{t=0}^T} \left(\sum_{t=0}^T (y_t - \mu_t)^2 + \lambda \sum_{t=1}^{T-1} ((\mu_{t+1} - \mu_t) - (\mu_t - \mu_{t-1}))^2 \right) \quad (3.17)$$

As we already have included balance of payment per GDP ($BOPY$) indicator, we do not consider export and import variables in the model due to "*double counting information*" problem. On the other side, the stock market index is probably most efficient leading indicator of crisis. However, we fail to include it due to data limitation for 41 sampled countries for the periods of 1980-2016. We also believe that stock market index is an instant responsive variable that is prone to speculations and expectations of overall market. Masson (1998) also refers it as ideal proxy for contagion impact of crisis. As we already included expectative and speculation pressure ($SPEX$) and trade interdependence factor (CON) into model we may exclude equity market indexes due to two reasons. First, $SPEX$ and CON have early signaling power comparing to stock market indexes. Second, equity

markets are lagging indicator for *SPEX* and *CON*, thus fluctuations in these factors will show up in equity market indexes with delay. In this respect, including both into the model might cause collinearity and "*double counting information*" problem.

Moreover, due to high correlations between *PMI*, *CONPI*, and *IPI* indexes, we composite them into one index, namely, Composite Leading Indicator (*CLI*) index in order to avoid collinearity problem.

$$CLI_{at} = \frac{1}{\sigma_{PMI}} PMI_{at} + \frac{1}{\sigma_{CONPI}} CONPI_{at} + \frac{1}{\sigma_{IPI}} IPI_{at} \quad (3.18)$$

where the weights of the components are assigned on the basis to equalize their volatility in order to prevent one dominating the *CLI*. We believe de-trended *CLI* (using 3.17 technique) will provide early signals of turning points in business cycles showing fluctuation of the economic activity around its long term potential level.

On the other hand, we proxy inflationary pressure with consumer price index (*CPI*); fiscal pressure with Balance-of-payment per GDP (*BOPY*); government budget pressure with government balance per GDP (*GOVY*); liquidity and reserves pressure with the stock of foreign exchange reserves expressed in terms of goods imports that shows how many months of imports could be purchased using the reserves (*RESMON*); currency pressure with real effective exchange rate (*REER*); asset bubble pressure with domestic bank credits per GDP (*CRDY*); and contagiousness pressure with world crude oil prices (*OIL*), specially designed interdependence contagion factor (*CON*), and overall speculations and expectations (*SPEX*). Data for these indicators are retrieved from Thomson Reuters Eikon DataStream. Utilizing technique in equation 4.17, we derive cyclical components for *CPI*, *CLI*, *BOPY*, *GOVY*, *CRDY*, and *REEX* to be used in our EWS equations at 3.14-3.15.

Thus, expanded version of our EWS model in equation 3.15 can be written as below with optimal threshold of T_a , which we refer as unified common EWS framework for all types of economic and financial crises.

$$\begin{aligned}
& Prob(Crisis_{at} = 1) \\
& = \beta_0 + \beta_1 CPI_{a,t-m_1}^c + \beta_2 UD_{a,t-m_2} + \beta_3 CLI_{a,t-m_3}^c + \beta_4 BOPY_{a,t-m_4}^c + \beta_5 GOVY_{a,t-m_5}^c \\
& + \beta_6 RESMON_{a,t-m_6} + \beta_7 REER_{a,t-m_7}^c \\
& + \beta_8 CRDY_{a,t-m_8}^c + \beta_9 CON_{a,t-m_9} + \beta_{10} OIL_{a,t-m_{10}} + \beta_{11} SPEX_{a,t-m_{12}} \\
& + \varepsilon_{at}
\end{aligned} \tag{3.19}$$

associated with

$$S = \begin{cases} 1, & \text{if } Prob(Crisis_{at} = 1) = \frac{e^{\beta X_{a,t-m}}}{1 + e^{\beta X_{a,t-m}}} \geq T_a \\ 0, & \text{otherwise} \end{cases} \tag{3.20}$$

where S represents signal of EWS model; m_i stands for dynamic lag length (varies across explanatory indicators) with maximum of -6; the superscript “c” indicates cyclical component of related indicator (fluctuations around its long-run steady equilibrium); UD is fluctuations in unemployment rate around NAIRU that is transformed into binary form in equation 3.16 to avoid collinearity with CPI ; $BOPY^c$ and $GOVY^c$ are in form of percentage of GDP and de-trended with equation 3.17; $RESMON$ is in terms of months that stock reserves can cover import goods; and CON , OIL (changes in oil price), and $SPEX$ are three contagiousness variables included into model crediting Masson (1998)’s three reasons of contagion effects.

One of the most important contributions of our EWS model is accounting contagion effects accurately on the basis of between-country trade interdependences. Existing literature uses crisis-elsewhere dummy (Eichengreen et al, 1995, 1996; Frankel and Saravelos, 2012), crisis in neighbor (close geographic distance) or in common membership or in common language dummy (Zhu and Yang, 2008), number of previous crisis experienced (Kindman, 2010), and correlation of equity market return residuals (Bussiere and Fratzscher, 2006) to proxy contagion effects of crisis. However, these proxies are biased as they comprise loss or misleading information due to two facts. First, the crisis-elsewhere concept accounts all crises over the world disregarding between-country trade partnerships and relationships. Suppose that country “A” has high volume of trade interactions with country “B” while it has zero volume with country “C”. In this case, country A’s crisis-elsewhere dummy will get value of 1 in country C experiences recession. Normally, contagion effect from C to A should be zero as there is no

trade interdependence between countries. Second, if one defines crisis as negative growth in real output, then crisis-elsewhere dummy might get value of 1 in majority of time-series. For instance, when we construct crisis-elsewhere variable for our sample that comprises 41 countries over 1980-2016 on quarterly basis and we observe that this variable gets value of 1 in 143 quarters out of total 144 quarters.

On the other hand, Zhu and Yang's (2008) contagiousness proxy of crisis in neighbor, crisis in common membership area, and crisis in common language countries also do not reflect any trade or business interdependence between countries' economies. Bussiere and Fratzscher's (2006) correlation of equity market return residuals might be fair proxy for measuring interdependence between countries, however, it is not a straight-forward technique. In this study, we introduce new technique to accurately measure degree of contagion effects between countries. First, we derive data for import and export from Resource Trade Database¹⁰ (RTD) that has been developed by Chatham House to enable users to explore the fast-evolving dynamics of international trade in natural resources, the sustainability implications of such trade, and the related interdependencies that emerge between importing and exporting countries and regions (see figure 3.01). This database includes the monetary values and masses of trade in over 1,350 different types of natural resources and resource products, including agricultural, fishery and forestry products, fossil fuels, metals and other minerals, and pearls and gemstones. It contains raw materials, intermediate products, and by-products.

The RTD presents data for all flows (import and export) of each country with remaining countries. For instance, according to RTD 2007 data Turkey has export flows to 194 unique countries, while it has import flows from 169 unique countries. And volume of data will help us to measure degree of interdependence between countries as below.

$$TI_{a \rightarrow b, t} = \frac{EX_{a \rightarrow b, t} + IM_{a \rightarrow b, t}}{EX_{a, t} + IM_{a, t}} \quad (3.21)$$

¹⁰ <https://resourcetrade.earth/data?year=2007&units=value>

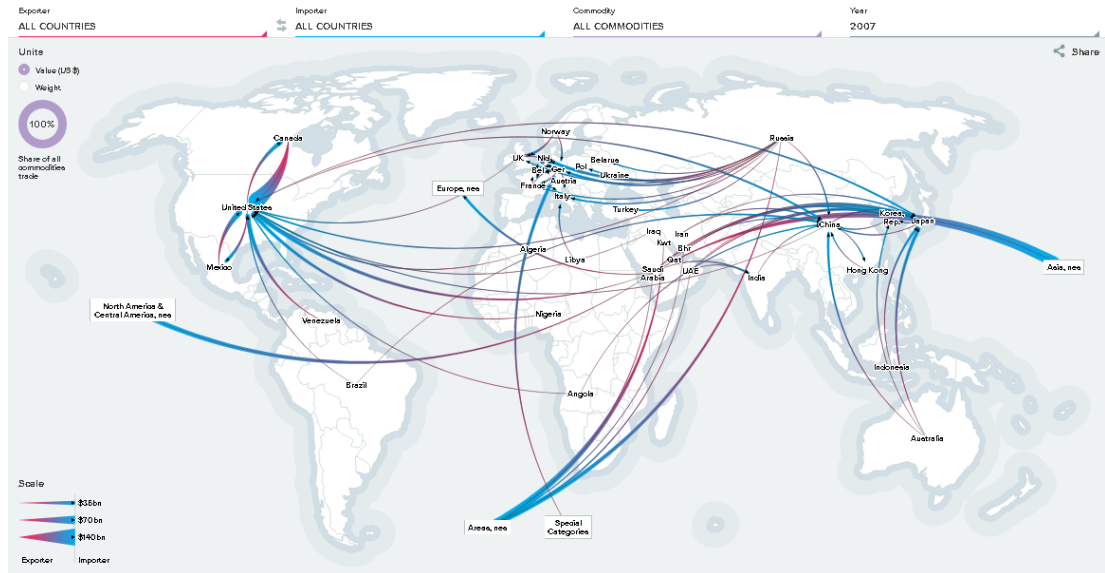
where $TI_{a \rightarrow b,t}$ indicates trade interdependence of country “a” to country “b” at time t ¹¹; $EX_{a \rightarrow b,t}$ and $IM_{a \rightarrow b,t}$ are export and import flows from country “a” to country “b” at time t ; $EX_{a,t}$ and $IM_{a,t}$ are total export and import flows of country “a” at time t . Thus, $TI_{a \rightarrow b,t}$ will actually show relative share of trade flows of country “a” to “b” in totally trade flows of country “a”. In this respect, TI will accurately measure trade interdependence of between countries. Then, we derive CON variable using following technique.

$$CON_{a \rightarrow b,t} = DUMMY_{b,t} * TI_{a \rightarrow b,t} \quad (3.22)$$

$$CON_{a,t} = \frac{\sum_{i=1}^{N-1} DUMMY_{i,t} * TI_{a \rightarrow i,t}}{N - 1} \quad (3.23)$$

where $CON_{a \rightarrow b,t}$ is degree of contagion of country “a” towards crisis in country “b”; $DUMMY_{b,t}$ is dummy recession variable for country “b” where 1 indicates recessionary and zero tranquil periods; $TI_{a \rightarrow b,t}$ is trade interdependence of country “a” to country “b” at time t . In equation 3.23, $CON_{a,t}$ indicates average degree of contagion of country “a” towards crises in sampled countries.

Figure 3.01. Trade Links between countries in 2007



Source: Resource Trade Database¹⁰

¹¹ It is worth to note that $TI_{a \rightarrow b,t} \neq TI_{b \rightarrow a,t}$. In other words, in and out flows from country “a” to “b” and from country “b” to “a” are not same in volume.

Besides, our EWS model comprises two other contagiousness factors such as world crude oil price changes and speculations and expectations (*SPEX*) in the markets. The *SPEX* has long been omitted in previous studies due to difficulties in measuring it. However, we attach great importance to this variable due to two facts. First, when crisis occurs elsewhere the contagion effect outbreaks as a snowball, it initially gets shape in expectation of the market and grows gradually. When it ripens, investors recognize it, so it transitions to equity markets causing herding effect (bandwagon effect).

In this respect, using just a binary dummy variable for expectations or contagiousness might cause loss of information. Thus, we proxy speculations and expectations (*SPEX*) of crisis in the market using through two channels: Google Search Trends¹² for 2004-2016 period and Google Scholar¹³ scientific research publications for 1980-2016 period. For search trends we gather data for terms such as "*economic crisis*", "*financial crisis*", "*economic slowdown*", "*economic recession*", and "*asset bubble*", and for scientific research we scan scholarly publications that subject crisis topics. The *SPEX* accounts shifts in investors' (market) sentiment and expectations significantly. Unlike previous EWS models, we do not add equity markets indicator as a proxy for contagion effect. Because its impact would be already absorbed by crisis expectation variable and lest collinearity we disregard it.

3.3.4.Determining threshold level

Determining optimal threshold value for T_a also plays critical role in goodness-of-fit and evaluation of our EWS given in equation 3.19. The literature widely uses KLR's noise-to-signal ratio in determination of thresholds; however, it fails to distinguish consequences of "*false alarms*" (type II error) and "*false silence or missed alarms*" (type I error). Needless to raise default agreement of which is worse type I error or type II error, we believe that missing alarms for actual crisis events might be extremely costly comparing to the cost of taking preventive actions as a result of false alarms for non-crisis events (Demirguc-Kunt and Detragiache, 2000). Therefore, we regard noise-to-signal ratio as risky threshold. Additionally, we

¹² <https://trends.google.com/trends/explore?date=all&q=economic%20crisis>

¹³ https://scholar.google.com/scholar?q=recession&hl=en&as_sdt=0%2C5&as_ylo=1980&as_yhi=1981

establish loss function of policy-makers that shows trade-off balance between type I and type II error. Thus, the optimal threshold of EWS model will depend on preference and on degree of risk-aversion (trade-off between false and missing alarms) of the decision-makers. On the one hand, taking pre-emptive action in response to a false alarm of potential crisis is costly from a decision-maker's perspective. On the other hand, the cost of not getting an early alarm for upcoming actual crisis might be several-fold if early actions by decision-makers could have been useful in preventing or at least mitigating the affects of the crisis.

Table 3.01. Selecting Optimal Threshold

	<i>Crisis within 6 quarters (Crisis=1)</i>	<i>No Crisis within 6 quarters (Crisis=0)</i>
<i>Signal was issued (Signal=1)</i>	A (True Alarm)	B (Type II error) (False Alarm)
<i>No Signal was issued (Signal=0)</i>	C (Type I error) (False Silence/ Missed Alarm)	D (True Silence)

Source: The author's design

The KLR Noise-to-Signal ratio (λ^T) technique is defined as following in equation 3.24.

$$\lambda^T = \frac{\Pr(\text{Type II error})}{1 - \Pr(\text{Type I error})} = \frac{\Pr(E = 2)}{1 - \Pr(E = 1)} = \frac{e_2^T}{1 - e_1^T} = \frac{B/(B + D)}{A/(A + C)} \quad (3.24)$$

The second shortfall of the KLR's noise-to-signal technique is that when probability of type II error is zero, the ratio will derive 0 notwithstanding to probability of type I error (there will be no difference whether it is 0.01 or 0.99). In other words, the noise-to-signal technique prefers to undertake more missed signal rates for the sake of nulling false signal rate. Thus, this technique does not primarily aim to predict and prevent potential crisis, but aims to minimize false alarms for non-crisis events. To resolve this issue, we augment λ^T and derive False-to-True ratio (ϕ^T) as following.

$$\begin{aligned} \phi^T = \text{False To True}(T) &= \frac{\Pr(S = 0|R = 1) + \Pr(S = 1|R = 0)}{\Pr(S = 1|R = 1) + \Pr(S = 0|R = 0)} \\ &= \frac{\Pr(\text{typeI}) + \Pr(\text{typeII})}{[1 - \Pr(\text{typeI})] + [1 - \Pr(\text{typeII})]} \end{aligned}$$

$$= \frac{e_1^T + e_2^T}{(1 - e_1^T) + (1 - e_2^T)} = \frac{\frac{C}{A+C} + \frac{B}{B+D}}{\frac{A}{A+C} + \frac{D}{B+D}} = \frac{C(B+D) + B(A+C)}{A(B+D) + D(A+C)} \quad (3.25)$$

where P stands for probability; R and S are binary variable that represent recession and signal of EWS respectively. If recession occurs R takes value of 1 and vice versa. Similarly, if EWS issues signal S takes value of 1 and zero if otherwise. The e_1^T and e_2^T are probabilities of type I and type II errors in relation to threshold " T " respectively.

On the other hand, Demirguc-Kunt and Detragiache (2000) and Bussiere and Fratzscher (2006) criticize λ^T and introduce minimizing policy-maker's loss function technique that assign weights to type I and type II errors on the basis of decision-maker's preference as below.

$$\begin{aligned} \theta^T &= \text{Loss Function}(T) \\ &= \omega \Pr(R = 1) \Pr(S = 0 | R = 1) + (1 - \omega) \Pr(R = 1) \Pr(S = 1 | R = 0) \\ &= \omega R_1^T e_1^T + (1 - \omega) R_0^T e_2^T \\ &= \omega \left(\frac{A + C}{A + B + C + D} \right) \left(\frac{C}{A + C} \right) + (1 - \omega) \left(\frac{B + D}{A + B + C + D} \right) \left(\frac{B}{B + D} \right) \\ &= \frac{\omega C + (1 - \omega) B}{A + B + C + D} \end{aligned} \quad (3.26)$$

where ω is cost of missing a crisis, while $1 - \omega$ is cost of taking pre-emptive action. In other words, ω is ex-ante (predetermined) input variable based on decision maker's preference which also indicates decider's degree of risk aversion. The R_1^T and R_2^T are unconditional probabilities of $R=1$ (recession) and $R=0$ (tranquil) in relation to threshold " T " respectively.

Besides, we also introduce a brand-new technique for determining less-risky optimal threshold as following.

$$\begin{aligned} \Omega^T &= \text{Risk Aversion}(T) = \Pr(S = 0 | R = 1) + \Pr(E = 1 \cup E = 2) \\ &= e_1^T + e_{total}^T \\ &= \left(\frac{C}{A + C} \right) + \left(\frac{B + C}{A + B + C + D} \right) \end{aligned} \quad (3.27)$$

This ratio aims to derive minimum total error of EWS model giving emphasizes to type I error. It is worth to note that Ω^T would have very similar characteristics with θ^T if policy-maker gives more weight on type I error. Unlike θ^T , it does not require ex-ante input weights, instead it automatically finds optimal trade-off between type I and type II error in respect to minimize overall EWS model error.

3.4. Analysis and findings

3.4.1. Estimation of EWS model

Prior to analysis we employ Augmented Dickey-Fuller unit root test with individual intercept and trend factor in order to check whether explanatory indicators that are included into the model comply with stationarity condition and we find all variables are stationary at level. Then, we run our EWS model given in equation 3.19 for 41 sampled countries separately using Maximum Likelihood DLL Estimation technique with Newton-Raphson optimization method and Marquardt step method. Table 3.02 reports the estimates that are derived by maximum iterations of 500 with convergence tolerance rate of 0.0001 and their covariances (that are given in parenthesis) are obtained by Huber-White sandwich estimator methodology. The superscripts over parentheses imply lag lengths of each explanatory indicator which are dynamically varying across each series and countries with maximum lag length of 6 quarters.

The outcome of analysis reveals several findings. First, we document that fluctuations of composite leading indicator (CLI^c) around its long-run steady state have significant role in predicting upcoming crisis in all 41 countries without any exceptions. Its lag length varies between 1-2 quarters for all countries, indicating that the CLI^c starts to issue signal closer to the event time. Besides, its sign indicates inverse relationship between CLI^c and crisis probability, however, we cannot bring a straight-forward interpretation regarding its magnitude due to estimation characteristics of logit models.

Table 3.02. Estimation Output of DLL EWS model

	CPI ^C	UD	CLI ^C	BOPY ^C	GOVY ^C	RESMON	REEX ^C	CRDY ^C	CON	OIL	SPEX	intercept	McFadden R ²	N
AG	3.54* (2.09) ³	2.42*** (0.73) ¹	-405.32*** (107.10) ¹	-108.37*** (27.28) ¹	-13.40*** (5.631) ²	-0.20* (0.11) ³	-35.79 (37.44) ³	7.73* (4.32) ²	255.60*** (99.18) ¹	-5.87 (6.89) ³	0.0083* (0.0049) ¹	-12.18*** (2.72)	0.5922 [0.0000]	R0=82 R1=40
AU	696.26*** (150.28) ¹	13.47*** (2.98) ³	-9082.21*** (2041.04) ²	-186.52*** (60.78) ³	-263.59*** (66.00) ⁴	-5.47*** (1.27) ³	159.11*** (32.93) ¹	50.66* (29.90) ³	477.49*** (136.89) ¹	29.32** (13.74) ¹	0.0476*** (0.0118) ⁴	-55.08*** (12.34)	0.8358 [0.0000]	R0=125 R1=15
BD	336.56*** (112.97) ²	1.40** (0.70) ¹	-2605.96*** (580.67) ¹	-189.33*** (65.53) ²	-107.96*** (37.27) ²	-3.07*** (0.90) ¹	376.32*** (150.51) ¹	6.52 (5.03) ¹	5.92 (90.18) ²	60.22*** (15.17) ³	0.0108** (0.0052) ⁴	-15.15** (6.56)	0.5790 [0.0000]	R0=101 R1=39
BG	138.02*** (55.32) ³	0.58 (0.59) ⁴	-5907.74*** (956.71) ¹	-65.18*** (17.66) ³	-12.01 (17.01) ²	-6.74*** (1.64) ¹	448.22*** (111.81) ²	26.09*** (9.23) ⁴	193.97*** (68.38) ¹	26.38*** (6.88) ³	0.0114** (0.0049) ¹	22.68** (10.48)	0.7567 [0.0000]	R0=115 R1=25
BR	5.49*** (2.24) ¹	0.49 (0.84) ¹	-2512.37*** (921.77) ¹	-67.72* (39.66) ¹	-91.32*** (36.56) ¹	-0.29** (0.14) ²	-70.05** (31.39) ²	19.10*** (7.32) ²	345.09** (163.90) ¹	23.63** (11.42) ¹	0.0183*** (0.0072) ¹	-9.47*** (3.30)	0.5961 [0.0000]	R0=73 R1=29
CH	78.31*** (21.91) ¹	8.35*** (2.05) ³	-1133.56*** (250.24) ¹	-21.15 (29.94) ¹	-635.64*** (186.01) ¹	-0.19 (0.26) ¹	321.61*** (95.60) ²	52.48*** (16.39) ¹	462.15** (200.39) ¹	43.25*** (13.64) ²	0.0824*** (0.0273) ⁴	37.93*** (12.41)	0.8277 [0.0000]	R0=128 R1=12
CL	155.63*** (59.71) ⁴	3.28*** (1.07) ²	-636.85*** (262.82) ¹	-113.26*** (37.15) ¹	-56.04** (26.98) ⁴	-0.76*** (0.30) ¹	-116.02 (78.64) ²	10.14** (4.35) ²	331.59* (179.39) ³	44.52*** (16.72) ³	0.0070* (0.0041) ⁴	-25.91*** (8.62)	0.6343 [0.0000]	R0=77 R1=21
CN	248.23*** (72.08) ³	1.50* (0.85) ¹	-1368.45* (773.79) ²	-78.44*** (33.04) ¹	-66.02** (30.79) ⁴	-0.49 (0.77) ¹	244.96*** (84.63) ³	28.46 (20.03) ⁴	146.99*** (55.33) ¹	-24.60** (10.59) ²	0.0227*** (0.0088) ⁴	-0.3476 (1.81)	0.6048 [0.0000]	R0=118 R1=22
CZ	187.21*** (60.01) ¹	4.87*** (1.42) ³	-4416.71*** (1131.91) ²	-162.56*** (37.28) ⁴	-199.09*** (53.68) ⁴	-0.35 (0.63) ⁴	785.60*** (188.08) ³	26.91*** (7.48) ²	238.47** (125.85) ³	93.92*** (26.80) ¹	0.0134*** (0.0051) ³	-38.07*** (9.94)	0.7449 [0.0000]	R0=65 R1=23
DK	53.67** (28.49) ³	3.06*** (0.63) ¹	-1568.26*** (417.27) ¹	-105.37*** (29.44) ¹	-7.61 (9.15) ⁴	-0.14 (0.16) ¹	207.16** (88.47) ⁴	1.374 (1.22) ¹	78.94* (46.68) ⁴	-11.65* (6.88) ⁴	0.0047** (0.0021) ³	-5.92*** (1.90)	0.4659 [0.0000]	R0=83 R1=56
ES	23.92 (33.92) ¹	2.84** (0.55) ³	-1069.73** (527.76) ¹	-189.56*** (40.73) ³	-134.97*** (37.20) ²	-0.84*** (0.34) ²	20.57 (57.29) ³	1.53*** (0.60) ⁴	183.57*** (57.47) ¹	28.28*** (8.02) ¹	0.0027 (0.0026) ⁴	-7.03*** (1.08)	0.5961 [0.0000]	R0=103 R1=37
FN	67.43 (48.19) ⁴	2.65*** (0.68) ¹	-898.55*** (221.62) ¹	-35.09* (20.73) ¹	-50.28*** (18.28) ⁴	-0.53* (0.31) ⁴	164.66*** (66.89) ⁴	3.64** (1.78) ¹	108.02* (63.71) ⁴	33.18*** (11.81) ¹	0.0047 (0.0035) ¹	-10.26*** (3.45)	0.6038 [0.0000]	R0=96 R1=43
FR	383.19* (225.59) ⁴	3.77*** (1.20) ¹	-2532.53*** (712.75) ¹	-269.29** (114.02) ⁴	-250.06*** (82.69) ³	-2.77*** (1.09) ¹	345.47* (186.18) ¹	3.41 (24.35) ¹	150.56* (81.03) ¹	19.79* (11.22) ¹	0.0104** (0.0044) ⁶	-3.43* (1.98)	0.6323 [0.0000]	R0=118 R1=20
GR	-11.11 (12.45) ³	3.16*** (0.62) ¹	-469.01** (206.19) ¹	-11.55 (9.03) ¹	-30.71*** (12.91) ¹	-0.42*** (0.13) ¹	-163.53* (89.18) ¹	37.69** (17.20) ¹	83.15* (49.28) ⁶	13.73* (7.90) ⁴	0.0049** (0.0026) ¹	-2.28*** (0.79)	0.5261 [0.0000]	R0=80 R1=58
HN	66.08** (29.42) ¹	1.64** (0.78) ⁴	-1648.35*** (466.02) ¹	-30.16*** (9.65) ¹	-123.15*** (27.68) ⁴	-2.88*** (0.60) ¹	-494.85*** (117.26) ¹	51.69*** (15.09) ¹	248.62*** (75.93) ²	48.13*** (17.23) ⁵	0.0132*** (0.0053) ¹	-30.68*** (6.361)	0.6745 [0.0000]	R0=72 R1=23
ID	62.55** (30.44) ⁴	6.18*** (2.36) ²	-3334.67*** (1094.88) ¹	-124.02** (53.21) ¹	-229.08*** (76.76) ⁴	-1.69*** (0.70) ¹	238.66** (117.86) ¹	19.13 (17.32) ³	491.53** (237.76) ⁵	61.08** (31.03) ¹	0.0244** (0.0107) ¹	1.32 (3.33)	0.7967 [0.0000]	R0=100 R1=30
IN	12.89 (35.31) ³	6.81*** (2.55) ¹	-2463.13** (1276.68) ¹	-66.20* (40.75) ¹	-37.65 (32.64) ¹	-0.90*** (0.34) ¹	-162.35* (112.88) ¹	74.61* (44.77) ³	155.26 (124.06) ⁵	56.20*** (22.86) ³	0.0049** (0.0026) ¹	-1.90 (1.47)	0.7343 [0.0000]	R0=113 R1=26
IR	79.40* (46.06) ²	2.30** (0.97) ¹	-1402.17*** (295.16) ¹	-50.92*** (17.29) ¹	-36.41*** (9.27) ²	-0.17 (0.24) ¹	458.34*** (164.64) ¹	6.83*** (2.48) ²	92.53** (44.92) ⁵	27.59*** (9.44) ⁴	0.0040* (0.0023) ⁴	-5.09*** (1.51)	0.6270 [0.0000]	R0=93 R1=46
IT	135.95*** (45.28) ¹	3.36*** (0.65) ¹	-1722.70*** (317.03) ²	-39.58 (32.50) ¹	-172.73*** (38.85) ¹	-0.07 (0.25) ¹	40.78 (51.59) ³	5.51*** (1.50) ¹	180.14*** (56.39) ⁶	15.34** (6.77) ⁴	0.0089*** (0.0029) ¹	-10.90*** (2.97)	0.5591 [0.0000]	R0=89 R1=49
JP	-62.22 (75.58) ¹	2.79*** (0.57) ¹	-1922.74*** (421.18) ¹	-146.50*** (35.78) ¹	-48.76*** (18.18) ⁴	-0.15*** (0.04) ²	40.39 (27.68) ¹	-49.89*** (12.04) ¹	170.78** (75.22) ¹	37.72*** (9.25) ²	0.0069*** (0.0024) ⁵	-6.46*** (1.26)	0.5217 [0.0000]	R0=84 R1=55
KO	231.53*** (68.98) ¹	11.52*** (2.92) ³	-3194.71*** (1009.43) ¹	-880.15*** (244.67) ¹	-366.21*** (84.08) ¹	-2.33*** (0.67) ¹	-101.88* (57.82) ³	103.60*** (29.80) ⁶	808.32*** (170.88) ³	186.69*** (49.29) ²	0.0470** (0.0208) ²	0.92 (3.31)	0.8307 [0.0000]	R0=125 R1=13
MX	87.12*** (32.54) ¹	6.659*** (1.89) ¹	-1324.94*** (398.50) ¹	-183.27*** (61.09) ⁴	-113.75*** (41.68) ¹	-0.72* (0.38) ⁴	-108.75** (49.26) ¹	51.79** (23.66) ²	313.67** (151.85) ¹	-37.98* (20.61) ¹	0.0047 (0.0052) ⁶	-6.87*** (2.57)	0.7416 [0.0000]	R0=99 R1=39
MY	188.25*** (49.16) ⁴	5.09*** (1.22) ⁴	-2155.32*** (329.42) ¹	-29.58 (19.18) ³	-85.74*** (19.67) ¹	0.01 (0.19) ¹	-185.98* (85.29) ³	16.18** (7.01) ³	208.79*** (54.87) ¹	-23.96** (11.55) ⁴	0.0139*** (0.0043) ¹	-15.84*** (2.85)	0.8508 [0.0000]	R0=103 R1=20
NL	165.21*** (46.02) ³	2.98*** (0.61) ¹	-1035.86*** (325.48) ²	-74.79*** (21.85) ¹	-23.76 (17.67) ³	-1.02*** (0.40) ²	-395.20*** (106.63) ²	16.03** (7.84) ⁴	195.85*** (57.04) ¹	-1.69 (6.53) ¹	0.0056** (0.0027) ²	-2.77*** (0.79)	0.5558 [0.0000]	R0=104 R1=36
NW	25.12** (12.47) ¹	1.96*** (0.49) ¹	-1057.08*** (258.81) ¹	-17.98*** (5.12) ³	-51.46*** (19.63) ⁴	-0.96*** (0.23) ²	-126.49*** (53.17) ⁴	2.33 (5.70) ²	230.90*** (51.66) ¹	-20.33*** (6.54) ⁶	0.0070*** (0.0024) ⁵	-10.86*** (2.26)	0.4584 [0.0000]	R0=90 R1=97
OE	101.52* (60.86) ¹	0.74 (0.68) ³	-2289.56*** (476.38) ¹	-33.96 (29.52) ¹	-5.13 (28.90) ³	-0.68** (0.33) ¹	19.54 (198.37) ³	31.74** (15.99) ³	94.42** (45.52) ¹	25.12*** (9.26) ²	0.0115*** (0.0047) ¹	-3.39*** (1.27)	0.5471 [0.0000]	R0=103 R1=37
PH	12.46* (7.37) ⁴	1.92* (1.08) ²	-6217.14** (2760.15) ¹	-175.30** (76.01) ¹	-89.04** (39.42) ³	-0.38** (0.18) ¹	85.36*** (35.45) ³	23.92 (22.01) ²	730.34*** (281.15) ¹	53.01** (24.61) ¹	0.0096** (0.0046) ¹	-6.70*** (2.81)	0.8502 [0.0000]	R0=111 R1=20
PO	28.78*** (8.26) ⁴	3.24** (1.61) ¹	-6728.63*** (1866.27) ¹	-44.19 (32.18) ⁴	-17.11*** (6.99) ²	-2.35*** (0.96) ¹	115.40* (68.20) ⁴	138.57*** (54.02) ²	484.28*** (161.71) ³	22.30** (10.29) ¹	0.0167*** (0.0070) ³	-29.18*** (9.89)	0.7089 [0.0000]	R0=81 R1=22
PT	22.02 (28.95) ²	2.36*** (0.81) ¹	-1535.35*** (545.90) ¹	-58.13*** (21.79) ¹	-19.39* (11.82) ²	-0.29** (0.12) ⁴	252.73*** (98.90) ³	2.23 (10.17) ³	163.97** (79.08) ²	21.88** (10.70) ¹	0.0060** (0.0032) ⁴	-5.70*** (1.96)	0.5714 [0.0000]	R0=84 R1=34
RM	33.88** (14.58) ²	2.74*** (1.10) ³	-2838.67*** (686.01) ¹	-40.17*** (15.82) ¹	-22.71** (11.03) ¹	-1.11*** (0.32) ¹	25.82 (21.67) ³	90.07*** (35.54) ¹	187.43*** (75.50) ⁴	31.18** (15.46) ²	0.0100** (0.0050) ¹	2.71* (1.51)	0.6638 [0.0000]	R0=62 R1=38

Table 3.02. (continues)

	CPI ^c	UD	CLI ^c	BOPY ^c	GOVY ^c	RESMON	REEX ^c	CRDY ^c	CON	OIL	SPEX	intercept	McFadden R ²	N
RS	-1.61 (4.15) ⁴	2.23*** (0.77) ²	-1051.83*** (253.75) ¹	-21.53*** (8.66) ¹	-64.71*** (14.53) ¹	-0.14** (0.06) ¹	9.43*** (2.79) ³	23.67* (14.09) ⁴	157.82 (112.40) ⁶	-19.52* (11.40) ²	0.0069*** (0.0029) ³	-1.27 (1.08)	0.6725 [0.0000]	R0=66 R1=33
SA	31.15 (28.49) ¹	2.36* (1.39) ²	-689.34** (344.73) ¹	-86.13*** (35.70) ³	-95.86*** (37.60) ²	-0.49** (0.24) ¹	64.92** (30.03) ²	1.09 (14.97) ¹	667.97*** (279.51) ⁴	26.56 (19.94) ¹	0.0165** (0.0084) ⁶	-4.21* (2.32)	0.7484 [0.0000]	R0=100 R1=38
SD	569.68** (255.45) ³	3.37*** (1.20) ³	-10788.9*** (4209.69) ¹	-77.72* (43.98) ³	-104.86*** (38.69) ³	-1.21*** (0.50) ¹	562.69*** (215.60) ²	53.13*** (17.91) ³	522.39*** (200.52) ⁴	59.32* (34.51) ³	0.0365 (0.0267) ¹	-13.38 (8.76)	0.8446 [0.0000]	R0=96 R1=44
SP	67.47** (32.00) ⁴	3.47** (1.64) ⁴	-773.14*** (265.00) ¹	-6.15 (13.71) ¹	-61.34*** (23.42) ¹	-1.20*** (0.40) ¹	350.36 (277.25) ²	18.26* (10.75) ⁵	167.03* (89.66) ⁴	25.49* (14.67) ²	0.0152** (0.0077) ³	-16.77*** (5.41)	0.7147 [0.0000]	R0=116 R1=23
SW	171.95** (76.31) ⁴	3.16*** (0.80) ³	-1047.69*** (356.96) ¹	-19.33 (23.55) ²	-265.03*** (70.43) ¹	-0.04 (0.04) ⁴	149.46*** (62.58) ²	-5.32 (12.37) ⁴	158.14** (72.04) ¹	13.86* (8.11) ³	0.0034 (0.0028) ²	-4.05*** (0.94)	0.5528 [0.0000]	R0=109 R1=31
TH	110.65*** (40.99) ¹	1.32* (0.83) ²	-768.24*** (271.58) ¹	-31.54*** (12.10) ¹	-20.43* (12.20) ¹	-0.31* (0.17) ¹	77.82 (67.18) ¹	16.03** (8.11) ⁴	184.25* (101.46) ¹	13.87 (10.20) ⁴	0.0084** (0.0037) ⁴	-5.68*** (1.80)	0.6768 [0.0000]	R0=109 R1=30
TK	34.86*** (10.83) ¹	7.91*** (2.13) ¹	-1206.60*** (288.48) ¹	15.15 (28.66) ¹	-118.94*** (31.19) ¹	-1.94*** (0.41) ¹	-284.47*** (63.17) ²	168.98*** (39.70) ⁴	593.78*** (173.38) ¹	48.34*** (15.02) ⁴	0.0392*** (0.0104) ⁶	4.47*** (1.78)	0.8238 [0.0000]	R0=79 R1=32
TW	20.30*** (6.05) ¹	6.38*** (1.40) ¹	-297.57*** (76.82) ¹	-15.67 (11.90) ²	-38.11 (30.35) ¹	-0.07 (0.08) ²	162.47* (92.82) ³	28.66* (15.86) ¹	254.27** (134.79) ³	16.85* (10.17) ³	0.0063** (0.0027) ⁶	-8.94*** (2.19)	0.6314 [0.0000]	R0=111 R1=27
UK	101.71* (60.29) ²	7.25*** (2.30) ⁴	-2933.60*** (927.82) ²	-314.68*** (111.48) ¹	-173.79** (89.04) ²	-4.05** (1.76) ¹	325.47*** (105.70) ²	96.68*** (34.64) ¹	437.45** (190.62) ⁵	67.75*** (22.77) ³	0.0271*** (0.0091) ¹	-27.40*** (8.15)	0.7690 [0.0000]	R0=125 R1=14
US	2501.52** (1165.63) ¹	5.38*** (2.06) ²	-9935.81*** (3346.60) ²	-871.88*** (366.02) ¹	-334.82*** (114.24) ¹	-16.61*** (6.66) ¹	324.07*** (121.37) ³	12.27** (5.92) ²	371.73*** (146.72) ²	153.73*** (51.03) ¹	0.0487*** (0.0144) ⁴	-38.43*** (13.36)	0.8538 [0.0000]	R0=123 R1=17
VE	19.33*** (5.48) ²	4.53*** (0.89) ¹	-175.01*** (60.86) ¹	-12.76*** (5.01) ¹	-28.51*** (10.49) ⁴	-0.12 (0.09) ³	23.33 (18.20) ⁴	20.18* (11.94) ²	99.50** (51.97) ¹	-18.48* (10.38) ²	0.0058*** (0.002) ³	-6.18*** (1.41)	0.6362 [0.0000]	R0=84 R1=55

Note: The first column of the table shows sampled 41 countries (for abbreviation please refer to Appendix table A1). The numbers in the table are coefficients derived by DLL Estimation with Newton-Raphson optimization method and Marquardt step method. The estimates are derived by maximum iterations of 500 with convergence tolerance rate of 0.0001. The standard errors are presented in the parentheses that are computed with the Huber-White sandwich covariance estimator. The superscripts over parentheses imply lag lengths of each explanatory indicator which are dynamically varying across each series and countries with maximum lag length of 6 quarters. We report goodness-of-fit for each country in terms of McFadden's pseudo R² value with probability of LR statistics in brackets. The last column shows observations where R0 and R1 indicate tranquil and recessionary periods respectively. The sum of these two gives total observations for related country.

Moreover, we observe that CPI^c , UD , $REEX^c$, $CRDY^c$, CON , and $SPEX$ derive positive signs in majority of countries that indicate an increase in these variables increases crisis probability within upcoming 6 quarters. Apparently, inflation factor (CPI^c) is insignificant only in Finland, Greece, India, Japan, Russia, Spain, South Africa, while unemployment factor is insignificant only in Belgium and Austria. Japan has been long experiencing low and inert inflation, even in some periods inflation has turned into negative rate. However, insignificance of inflation in other countries remains ambiguous. It is worth to note that in previous chapter we documented bidirectional causality between real output and unemployment (Okun's Law). Although, unemployment is regarded lagging indicator of crisis (shrink in output triggers an increase in unemployment) in literature, we document that it is also a leading indicator of crisis (output is responsive to fluctuation in unemployment). This indicator fails to be statistically significant only in Belgium and

Austria, while for remaining 39 countries it is statistically significant indicator of crisis. The signal length of *UD* appears to be 1 quarter in nearly half of the sampled countries, while it is 4 quarters in four countries such as Hungary, Malaysia, Singapore, and United Kingdom (for Belgium it is insignificant).

The real effective exchange rate factor also appears to be a significant indicator of crisis. It has a key role in assessing countries' trade capabilities (exports and imports) that indicate overall competitiveness of an economy. The results for *REEX*^c are in line with previous literature. Its positive sign indicates a significant overvaluation of real exchange rate might cause crisis within six quarters. In other words, when domestic prices of goods and services are higher comparing to their prices abroad, exports decrease causing fiscal/trade balance to go deficit which increases probability of crisis event.

In case of contagion effects factor, all three indicators (*CON*, *OIL*, *SPEX*) add significant contribution into our EWS model. Especially, our newly designed *CON* variable improves our model remarkable. This indicator fails to be statistically significant only in two countries: Germany and India. For remaining 39 sampled countries *CON* is highly significant factor in forecasting upcoming crises. The lags of *CON* and *SPEX* variables seem to be positively correlated in many countries; however, this correlation remains weaker to cause collinearity problem. Moreover, these two variables generally have different signaling horizons. *CON* more likely to signal upcoming crisis one or two quarters in advance, while *SPEX* tend to send alarms four quarters in advance.

The estimated sign for *OIL* varies across countries and seemingly crude oil producer and exporter countries tend to have negative sign, while oil purchaser/importer countries tend to have positive sign. For instance, Russia, whose majority of economy depends of oil exports, derives a negative coefficient of -19.52 which is statistically significant at 10% level. Similarly, other oil exporter countries such as Canada, Norway, Denmark, Mexico, and Venezuela also derive negative and statistically significant coefficients.

On the other hand, *BOPY*^c, *GOVY*^c, and *RESMON* get negative sign in almost all countries, implying inverse relationship between these variables and crisis probability. Any increase in these indicators decreases probability of crisis

occurrence within 6 quarters. The estimates of these three indicators in case of Taiwan seem to be statistically insignificant. Moreover, China, Italy, Malaysia, Switzerland, and Taiwan derive insignificant *BOPY^c* and *RESMON* where their reasons remain vague.

Pre last column reports McFadden's pseudo R^2 value and LR statistics in brackets that show overall fits and significance of the model respectively. According to these data, we find that the U.S derives the best fit by accounting 85.38% variations of actual crisis. It is followed by Malaysia with 85.08%, Philippines with 85.02%, Sweden with 84.46%, Australia with 83.58%, and South Korea with 83.07%. The lowest fit is documented in Norway that has McFadden R^2 value of 45.84%, followed by Denmark with 46.59%, Japan with 52.17%, and Greece with 52.61%. The sample's overall average fitness is around 67.35%.

3.4.2.Evaluation of EWS model under different thresholds

However, to more be precise about overall fitness and significance of our EWS models for each country we carry Expectation-Prediction Evaluation (EPE) analysis with different threshold selection techniques. Table 3.03 reports outcome of this analysis with four threshold selection techniques that are explained in previous section. According to the results, we observe that KLR's Noise-to-Signal ratio (λ) derives high threshold level; consequently, the number of missed alarms for actual crisis (false silence) is high. Alongside with high cost of missed alarms, this technique also does not serve for objectives of EWS that is to predict crisis in advance. For instance, in Argentinean case λ determines the optimal threshold as 0.98-0.99 which 100% predicts tranquil periods, however, its success of forecasting crisis periods are just 20%.

On the other hand, our technique False-to-True ratio (ϕ) seems to be deriving better threshold level. However, it does not distinguish between costs of False Silence (type I error) and False Alarm (type II error) as they have equal weight in formula. Although this method finds a threshold where errors (incorrectness) of EWS are effectively minimized, it still might be a risky threshold level as cost of type

I error usually higher than cost of type II error. For Argentinean model, it chooses 0.51-0.54 threshold level that accounts 96.34% of tranquil periods and 85% of crisis periods.

Demirguc-Kunt and Detragiache's (2000) Loss Function (θ) technique seems to be fairly good methodology for threshold selection. However, this method requires ex-ante inputs for weights of type I and type II errors. In this study, we assume policy-makers in all country consider one-to-five ($\omega=0.8$) trade-off between two types of errors. With these settings, θ determines optimal threshold level as 0.22-0.24 which predicts 81.71% of tranquil periods and 95% of crisis periods.

Our new Risk Aversion (Ω) technique also determines the same threshold level as θ . The advantage of our technique is that it won't require ex-ante arbitrary weight inputs, but it automatically finds the optimal weights considering minimization of type I error and overall incorrectness of EWS model. Therefore, we regard this method as most optimal risk-averse technique.

Table 3.03.Evaluation of EWS Model with different Threshold techniques

		Min θ		Min Ω		Min ϕ		Min λ	
		Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis
AG	Threshold	p=0.22-0.24		p=0.22-0.24		p=0.51-0.54		p=0.98-0.99	
	Alarm	38	15	38	15	34	3	8	0
	No Alarm	2	67	2	67	6	79	32	82
	% Correct	95.00	81.71	95.00	81.71	85.00	96.34	20.00	100.00
	% Incorrect	5.00	18.29	5.00	18.29	15.00	3.66	80.00	0.00
	λ Noise-to-signal	0.1925		0.1925		0.0431		0.0000	
	ϕ False-to-True	0.1318		0.1318		0.1029		0.6667	
	Ω Risk Aversion	0.1893		0.1893		0.2238		1.0623	
AU	θ Loss Function	0.0377		0.0377		0.0443		0.2098	
	Threshold	p=0.38-0.44		p=0.38-0.44		p=0.38-0.44		p=0.59-0.61	
	Alarm	14	2	14	2	14	2	13	0
	No Alarm	1	123	1	123	1	123	2	125
	% Correct	93.33	98.40	93.33	98.40	93.33	98.40	86.67	100.00
	% Incorrect	6.67	1.60	6.67	1.60	6.67	1.60	13.33	0.00
	λ Noise-to-signal	0.0171		0.0171		0.0171		0.0000	
	ϕ False-to-True	0.0431		0.0431		0.0431		0.0714	
BD	Ω Risk Aversion	0.0881		0.0881		0.0881		0.1476	
	θ Loss Function	0.0086		0.0086		0.0086		0.0114	
	Threshold	p=0.13		p=0.13		p=0.60-0.67		p=0.60-0.67	
	Alarm	37	29	37	29	29	0	29	0
	No Alarm	2	72	2	72	10	101	10	101
	% Correct	94.87	71.29	94.87	71.29	74.36	100.00	74.36	100.00
	% Incorrect	5.13	28.71	5.13	28.71	25.64	0.00	25.64	0.00
	λ Noise-to-signal	0.3026		0.3026		0.0000		0.0000	
BG	ϕ False-to-True	0.2037		0.2037		0.1471		0.1471	
	Ω Risk Aversion	0.2727		0.2727		0.3278		0.3278	
	θ Loss Function	0.0529		0.0529		0.0571		0.0571	
	Threshold	p=0.14		p=0.10		p=0.14		p=0.87-0.88	
	Alarm	24	8	25	13	24	8	16	0
	No Alarm	1	107	0	102	1	107	9	115
	% Correct	96.00	93.04	100.00	88.70	96.00	93.04	64.00	100.00
	% Incorrect	4.00	6.96	0.00	11.30	4.00	6.96	36.00	0.00
BR	λ Noise-to-signal	0.0725		0.113		0.0725		0.0000	
	ϕ False-to-True	0.0580		0.0599		0.0580		0.2195	
	Ω Risk Aversion	0.1043		0.0929		0.1043		0.4243	
	θ Loss Function	0.0171		0.0186		0.0171		0.0514	
	Threshold	p=0.30		p=0.30		p=0.30		p=0.88-0.91	
	Alarm	29	9	29	9	29	9	12	1
	No Alarm	0	64	0	64	0	64	17	72
	% Correct	100.00	87.67	100.00	87.67	100.00	87.67	41.38	98.63
CH	% Incorrect	0.00	12.33	0.00	12.33	0.00	12.33	58.62	1.37
	λ Noise-to-signal	0.1233		0.1233		0.1233		0.0331	
	ϕ False-to-True	0.0657		0.0657		0.0657		0.4285	
	Ω Risk Aversion	0.0882		0.0882		0.0882		0.7627	
	θ Loss Function	0.0176		0.0176		0.0176		0.1353	
	Threshold	p=0.06-0.09		p=0.06-0.09		p=0.06-0.09		p=0.52-0.60	
	Alarm	12	7	12	7	12	7	10	0
	No Alarm	0	121	0	121	0	121	2	128
CL	% Correct	100.00	94.53	100.00	94.53	100.00	94.53	83.33	100.00
	% Incorrect	0.00	5.47	0.00	5.47	0.00	5.47	16.67	0.00
	λ Noise-to-signal	0.0547		0.0547		0.0547		0.0000	
	ϕ False-to-True	0.0281		0.0281		0.0281		0.0909	
	Ω Risk Aversion	0.0500		0.0500		0.0500		0.1810	
	θ Loss Function	0.0100		0.0100		0.0100		0.0114	
	Threshold	p=0.20		p=0.20		p=0.20		p=0.66-0.69	
	Alarm	20	9	20	9	20	9	14	0
	No Alarm	1	68	1	68	1	68	7	77
	% Correct	95.24	88.31	95.24	88.31	95.24	88.31	66.67	100.00
	% Incorrect	4.76	11.69	4.76	11.69	4.76	11.69	33.33	0.00
	λ Noise-to-signal	0.1227		0.1227		0.1227		0.0000	
	ϕ False-to-True	0.0896		0.0896		0.0896		0.2000	
	Ω Risk Aversion	0.1496		0.1496		0.1496		0.4047	
	θ Loss Function	0.0265		0.0265		0.0265		0.0571	

Table 3.03. (continues)

		Min θ		Min Ω		Min ϕ		Min λ	
		Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis
CN	Threshold	p=0.32-0.35		p=0.32-0.35		p=0.32-0.35		p=0.62-0.63	
	Alarm	19	6	19	6	19	6	15	0
	No Alarm	3	112	3	112	3	112	7	118
	% Correct	86.36	94.92	86.36	94.92	86.36	94.92	68.18	100.00
	% Incorrect	13.64	5.08	13.64	5.08	13.64	5.08	31.82	0.00
	λ Noise-to-signal	0.0588		0.0588		0.0588		0.0000	
	ϕ False-to-True	0.1033		0.1033		0.1033		0.1892	
	Ω Risk Aversion	0.2007		0.2007		0.2007		0.3682	
CZ	θ Loss Function	0.0257		0.0257		0.0257		0.0400	
	Threshold	p=0.14-0.18		p=0.14-0.18		p=0.40		p=0.73-0.89	
	Alarm	23	7	23	7	23	7	15	0
	No Alarm	0	58	0	58	0	58	8	65
	% Correct	100.00	89.23	100.00	89.23	100.00	89.23	65.22	100.00
	% Incorrect	0.00	10.77	0.00	10.77	0.00	10.77	34.78	0.00
	λ Noise-to-signal	0.1077		0.1077		0.1077		0.0000	
	ϕ False-to-True	0.0569		0.0569		0.0569		0.2105	
DK	Ω Risk Aversion	0.0795		0.0795		0.0795		0.4387	
	θ Loss Function	0.0159		0.0159		0.0159		0.0727	
	Threshold	p=0.24		p=0.24		p=0.30-0.31		p=0.89-0.90	
	Alarm	54	26	54	26	54	26	22	0
	No Alarm	2	57	2	57	2	57	34	83
	% Correct	96.43	68.67	96.43	68.67	96.43	68.67	39.29	100.00
	% Incorrect	3.57	31.33	3.57	31.33	3.57	31.33	60.71	0.00
	λ Noise-to-signal	0.3249		0.3249		0.2778		0.0000	
ES	ϕ False-to-True	0.2114		0.2114		0.2065		0.4359	
	Ω Risk Aversion	0.2371		0.2371		0.2764		0.8517	
	θ Loss Function	0.0489		0.0489		0.059		0.1957	
	Threshold	p=0.26		p=0.26		p=0.26		p=0.89	
	Alarm	35	13	35	13	35	13	16	0
	No Alarm	2	90	2	90	2	90	21	103
	% Correct	94.59	87.38	94.59	87.38	94.59	87.38	43.24	100.00
	% Incorrect	5.41	12.62	5.41	12.62	5.41	12.62	56.76	0.00
FN	λ Noise-to-signal	0.1334		0.1334		0.1334		0.0000	
	ϕ False-to-True	0.0991		0.0991		0.0991		0.3963	
	Ω Risk Aversion	0.1612		0.1612		0.1612		0.7176	
	θ Loss Function	0.0300		0.0300		0.0300		0.1200	
	Threshold	p=0.11		p=0.11		p=0.18-0.21		p=0.92	
	Alarm	42	20	42	20	42	20	20	0
	No Alarm	1	76	1	76	1	76	23	96
	% Correct	97.67	79.17	97.67	79.17	97.67	79.17	46.51	100.00
FR	% Incorrect	2.33	20.83	2.33	20.83	2.33	20.83	53.49	0.00
	λ Noise-to-signal	0.2133		0.2133		0.1748		0.0000	
	ϕ False-to-True	0.1310		0.1310		0.1193		0.3651	
	Ω Risk Aversion	0.1744		0.1744		0.1760		0.7004	
	θ Loss Function	0.0345		0.0345		0.0345		0.1324	
	Threshold	p=0.35-0.38		p=0.17-0.22		p=0.17-0.22		p=0.77-0.78	
	Alarm	17	4	18	9	17	4	11	0
	No Alarm	3	114	2	109	3	114	9	118
GR	% Correct	85.00	96.61	90.00	92.37	85.00	96.61	55.00	100.00
	% Incorrect	15.00	3.39	10.00	7.63	15.00	3.39	45.00	0.00
	λ Noise-to-signal	0.0399		0.0848		0.0848		0.0000	
	ϕ False-to-True	0.1013		0.0967		0.0967		0.2903	
	Ω Risk Aversion	0.2007		0.1797		0.1797		0.5152	
	θ Loss Function	0.0232		0.0246		0.0246		0.0522	
	Threshold	p=0.36-0.37		p=0.36-0.37		p=0.36-0.37		p=0.94	
	Alarm	55	12	55	12	55	12	19	0
	No Alarm	3	68	3	68	3	68	39	80
	% Correct	94.83	85.00	94.83	85.00	94.83	85.00	32.76	100.00
	% Incorrect	5.17	15.00	5.17	15.00	5.17	15.00	67.24	0.00
	λ Noise-to-signal	0.1582		0.1582		0.1582		0.0000	
	ϕ False-to-True	0.1122		0.1122		0.1122		0.5065	
	Ω Risk Aversion	0.1604		0.1604		0.1604		0.9550	
	θ Loss Function	0.0348		0.0348		0.0348		0.2261	

Table 3.03. (continues)

		Min θ		Min Ω		Min ϕ		Min λ	
		Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis
HN	Threshold	p=0.25		p=0.25		p=0.25		p=0.76-0.78	
	Alarm	22	7	22	7	22	7	13	0
	No Alarm	1	65	1	65	1	65	10	72
	% Correct	95.65	90.28	95.65	90.28	95.65	90.28	56.52	100.00
	% Incorrect	4.35	9.72	4.35	9.72	4.35	9.72	43.48	0.00
	λ Noise-to-signal	0.1016		0.1016		0.1016		0.0000	
	ϕ False-to-True	0.0757		0.0757		0.0757		0.2778	
	Ω Risk Aversion	0.1277		0.1277		0.1277		0.5401	
ID	θ Loss Function	0.0232		0.0232		0.0232		0.0842	
	Threshold	p=0.28-0.37		p=0.28-0.37		p=0.28-0.37		p=0.66-0.76	
	Alarm	28	4	28	4	28	4	25	0
	No Alarm	2	96	2	96	2	96	5	100
	% Correct	93.33	96.00	93.33	96.00	93.33	96.00	83.33	100.00
	% Incorrect	6.67	4.00	6.67	4.00	6.67	4.00	16.67	0.00
	λ Noise-to-signal	0.0429		0.0429		0.0429		0.0000	
	ϕ False-to-True	0.0564		0.0564		0.0564		0.0909	
IN	Ω Risk Aversion	0.1129		0.1129		0.1129		0.2052	
	θ Loss Function	0.0185		0.0185		0.0185		0.0308	
	Threshold	p=0.26-0.33		p=0.26-0.33		p=0.26-0.33		p=0.80	
	Alarm	25	6	25	6	25	6	19	0
	No Alarm	1	107	1	107	1	107	7	113
	% Correct	96.15	94.69	96.15	94.69	96.15	94.69	73.08	100.00
	% Incorrect	3.85	5.31	3.85	5.31	3.85	5.31	26.92	0.00
	λ Noise-to-signal	0.0552		0.0552		0.0552		0.0000	
IR	ϕ False-to-True	0.0480		0.0480		0.0480		0.1555	
	Ω Risk Aversion	0.0889		0.0889		0.0889		0.3196	
	θ Loss Function	0.0144		0.0144		0.0144		0.0403	
	Threshold	p=0.23		p=0.23		p=0.45		p=0.99	
	Alarm	44	15	44	15	44	15	5	0
	No Alarm	2	78	2	78	2	78	41	93
	% Correct	95.65	83.87	95.65	83.87	95.65	83.87	10.87	100.00
	% Incorrect	4.35	16.13	4.35	16.13	4.35	16.13	89.13	0.00
IT	λ Noise-to-signal	0.1686		0.1686		0.0619		0.0000	
	ϕ False-to-True	0.1141		0.1141		0.1014		0.8039	
	Ω Risk Aversion	0.1658		0.1658		0.2095		1.1863	
	θ Loss Function	0.0331		0.0331		0.0417		0.236	
	Threshold	p=0.23		p=0.23		p=0.23		p=0.88	
	Alarm	47	16	47	16	47	16	24	0
	No Alarm	2	73	2	73	2	73	25	89
	% Correct	95.92	82.02	95.92	82.02	95.92	82.02	48.98	100.00
JP	% Incorrect	4.08	17.98	4.08	17.98	4.08	17.98	51.02	0.00
	λ Noise-to-signal	0.1874		0.1874		0.1874		0.0000	
	ϕ False-to-True	0.1240		0.1240		0.1240		0.3425	
	Ω Risk Aversion	0.1712		0.1712		0.1712		0.6914	
	θ Loss Function	0.0348		0.0348		0.0348		0.1449	
	Threshold	p=0.13		p=0.15		p=0.29-0.30		p=0.95	
	Alarm	55	35	54	31	55	35	20	0
	No Alarm	0	49	1	53	0	49	35	84
KO	% Correct	100.00	58.33	98.18	63.10	100.00	58.33	36.36	100.00
	% Incorrect	0.00	41.67	1.82	36.90	0.00	41.67	63.64	0.00
	λ Noise-to-signal	0.4167		0.3758		0.2619		0.0000	
	ϕ False-to-True	0.2632		0.2401		0.1969		0.4667	
	Ω Risk Aversion	0.2518		0.2484		0.2708		0.8882	
	θ Loss Function	0.0504		0.0504		0.0576		0.2014	
	Threshold	p=0.16-0.24		p=0.16-0.24		p=0.16-0.24		p=0.78-0.98	
	Alarm	13	4	13	4	13	4	8	0
	No Alarm	0	121	0	121	0	121	5	125
	% Correct	100.00	96.80	100.00	96.80	100.00	96.80	61.54	100.00
	% Incorrect	0.00	3.20	0.00	3.20	0.00	3.20	38.46	0.00
	λ Noise-to-signal	0.0320		0.0320		0.0320		0.0000	
	ϕ False-to-True	0.0163		0.0163		0.0163		0.2381	
	Ω Risk Aversion	0.0290		0.0290		0.0290		0.4208	
	θ Loss Function	0.0058		0.0058		0.0058		0.0290	

Table 3.03. (continues)

		Min θ		Min Ω		Min ϕ		Min λ	
		Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis
MX	Threshold	<u>p=0.18-0.20</u>		<u>p=0.18-0.20</u>		<u>p=0.18-0.20</u>		<u>p=0.97</u>	
	Alarm	39	11	39	11	39	11	19	0
	No Alarm	0	88	0	88	0	88	20	99
	% Correct	100.00	88.89	100.00	88.89	100.00	88.89	48.72	100.00
	% Incorrect	0.00	11.11	0.00	11.11	0.00	11.11	51.28	0.00
	λ Noise-to-signal	0.1111		0.1111		0.1111		0.0000	
	ϕ False-to-True	0.0588		0.0588		0.0588		0.3448	
	Ω Risk Aversion	0.0797		0.0797		0.0797		0.6577	
MY	θ Loss Function	0.0159		0.0159		0.0159		0.1159	
	Threshold	<u>p=0.21</u>		<u>p=0.21</u>		<u>p=0.21</u>		<u>p=0.90-0.93</u>	
	Alarm	20	4	20	4	20	4	14	0
	No Alarm	0	99	0	99	0	99	6	103
	% Correct	100.00	96.12	100.00	96.12	100.00	96.12	70.00	100.00
	% Incorrect	0.00	3.88	0.00	3.88	0.00	3.88	30.00	0.00
	λ Noise-to-signal	0.0388		0.0388		0.0388		0.0000	
	ϕ False-to-True	0.0198		0.0198		0.0198		0.1765	
NL	Ω Risk Aversion	0.0325		0.0325		0.0325		0.3488	
	θ Loss Function	0.0065		0.0065		0.0065		0.039	
	Threshold	<u>p=0.11</u>		<u>p=0.11</u>		<u>p=0.28-0.34</u>		<u>p=0.90-0.91</u>	
	Alarm	36	25	36	25	36	25	10	0
	No Alarm	0	79	0	79	0	79	26	104
	% Correct	100.00	75.96	100.00	75.96	100.00	75.96	27.78	100.00
	% Incorrect	0.00	24.04	0.00	24.04	0.00	24.04	72.22	0.00
	λ Noise-to-signal	0.2404		0.2404		0.1005		0.0000	
NW	ϕ False-to-True	0.1366		0.1366		0.1270		0.5652	
	Ω Risk Aversion	0.1786		0.1786		0.2389		0.9079	
	θ Loss Function	0.0357		0.0357		0.0414		0.1486	
	Threshold	<u>p=0.09-0.11</u>		<u>p=0.09-0.11</u>		<u>p=0.50</u>		<u>p=0.93</u>	
	Alarm	47	36	47	36	47	36	9	0
	No Alarm	0	54	0	54	0	54	38	90
	% Correct	100.00	60.00	100.00	60.00	100.00	60.00	19.15	100.00
	% Incorrect	0.00	40.00	0.00	40.00	0.00	40.00	80.85	0.00
OE	λ Noise-to-signal	0.4000		0.4000		0.1194		0.0000	
	ϕ False-to-True	0.2500		0.2500		0.2079		0.6786	
	Ω Risk Aversion	0.2628		0.2628		0.4013		1.0859	
	θ Loss Function	0.0526		0.0526		0.0818		0.2219	
	Threshold	<u>p=0.24</u>		<u>p=0.24</u>		<u>p=0.24</u>		<u>p=0.94-0.95</u>	
	Alarm	33	14	33	14	33	14	10	0
	No Alarm	4	89	4	89	4	89	27	103
	% Correct	89.19	86.41	89.19	86.41	89.19	86.41	27.03	100.00
PH	% Incorrect	10.81	13.59	10.81	13.59	10.81	13.59	72.97	0.00
	λ Noise-to-signal	0.1524		0.1524		0.1524		0.0000	
	ϕ False-to-True	0.1390		0.1390		0.1390		0.5744	
	Ω Risk Aversion	0.2367		0.2367		0.2367		0.9226	
	θ Loss Function	0.0429		0.0429		0.0429		0.1543	
	Threshold	<u>p=0.30-0.77</u>		<u>p=0.30-0.77</u>		<u>p=0.30-0.77</u>		<u>p=0.30-0.77</u>	
	Alarm	19	0	19	0	19	0	19	0
	No Alarm	1	111	1	111	1	111	1	111
	% Correct	95.00	100.00	95.00	100.00	95.00	100.00	95.00	100.00
PO	% Incorrect	5.00	0.00	5.00	0.00	5.00	0.00	5.00	0.00
	λ Noise-to-signal	0.0000		0.0000		0.0000		0.0000	
	ϕ False-to-True	0.0256		0.0256		0.0256		0.0256	
	Ω Risk Aversion	0.0576		0.0576		0.0576		0.0576	
	θ Loss Function	0.0061		0.0061		0.0061		0.0061	
	Threshold	<u>p=0.08-0.12</u>		<u>p=0.08-0.12</u>		<u>p=0.08-0.12</u>		<u>p=0.88-0.96</u>	
	Alarm	22	13	22	13	22	13	12	0
	No Alarm	0	68	0	68	0	68	10	81
	% Correct	100.00	83.95	100.00	83.95	100.00	83.95	54.55	100.00
PO	% Incorrect	0.00	16.05	0.00	16.05	0.00	16.05	45.45	0.00
	λ Noise-to-signal	0.1605		0.1605		0.1605		0.0000	
	ϕ False-to-True	0.0873		0.0873		0.0873		0.2941	
	Ω Risk Aversion	0.1262		0.1262		0.1262		0.5516	
PO	θ Loss Function	0.0252		0.0252		0.0252		0.0777	

Table 3.03. (continues)

		Min θ		Min Ω		Min ϕ		Min λ	
		Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis
PT	Threshold	p=0.19-0.20		p=0.19-0.20		p=0.37		p=0.72	
	Alarm	32	13	32	13	32	13	23	0
	No Alarm	2	71	2	71	2	71	11	84
	% Correct	94.12	84.52	94.12	84.52	94.12	84.52	67.65	100.00
	% Incorrect	5.88	15.48	5.88	15.48	5.88	15.48	32.35	0.00
	λ Noise-to-signal	0.1645		0.1645		0.0674		0.0000	
	ϕ False-to-True	0.1196		0.1196		0.0972		0.1930	
	Ω Risk Aversion	0.1859		0.1859		0.1939		0.4167	
	θ Loss Function	0.0356		0.0356		0.0356		0.0746	
RM	Threshold	p=0.18-0.23		p=0.39-0.41		p=0.39-0.41		p=0.95-0.96	
	Alarm	37	10	36	6	37	10	20	0
	No Alarm	1	52	2	56	1	52	18	62
	% Correct	97.37	83.87	94.74	90.32	97.37	83.87	52.63	100.00
	% Incorrect	2.63	16.13	5.26	9.68	2.63	16.13	47.37	0.00
	λ Noise-to-signal	0.1657		0.1022		0.1022		0.0000	
	ϕ False-to-True	0.1035		0.0807		0.0807		0.3104	
	Ω Risk Aversion	0.1363		0.1326		0.1326		0.6537	
	θ Loss Function	0.0280		0.0280		0.0280		0.1440	
RS	Threshold	p=0.16-0.19		p=0.16-0.19		p=0.16-0.19		p=0.95	
	Alarm	32	9	32	9	32	9	13	0
	No Alarm	1	57	1	57	1	57	20	66
	% Correct	96.97	86.36	96.97	86.36	96.97	86.36	39.39	100.00
	% Incorrect	3.03	13.64	3.03	13.64	3.03	13.64	60.61	0.00
	λ Noise-to-signal	0.1407		0.1407		0.1407		0	
	ϕ False-to-True	0.0909		0.0909		0.0909		0.4348	
	Ω Risk Aversion	0.1313		0.1313		0.1313		0.8081	
	θ Loss Function	0.0263		0.0263		0.0263		0.1616	
SA	Threshold	p=0.51-0.53		p=0.15		p=0.51-0.53		p=0.51-0.53	
	Alarm	34	0	37	13	34	0	34	0
	No Alarm	4	100	1	87	4	100	4	100
	% Correct	89.47	100	97.37	87	89.47	100	89.47	100.00
	% Incorrect	10.53	0	2.63	13	10.53	0	10.53	0.00
	λ Noise-to-signal	0.0000		0.1335		0.0000		0.0000	
	ϕ False-to-True	0.0556		0.0848		0.0556		0.0556	
	Ω Risk Aversion	0.1343		0.1277		0.1343		0.1343	
	θ Loss Function	0.0232		0.0246		0.0232		0.0232	
SD	Threshold	p=0.14-0.17		p=0.14-0.17		p=0.44-0.50		p=0.97	
	Alarm	44	7	44	7	44	7	26	0
	No Alarm	0	89	0	89	0	89	18	96
	% Correct	100.00	92.71	100.00	92.71	100.00	92.71	59.09	100.00
	% Incorrect	0.00	7.29	0.00	7.29	0.00	7.29	40.91	0.00
	λ Noise-to-signal	0.0729		0.0729		0.0320		0.0000	
	ϕ False-to-True	0.0378		0.0378		0.0277		0.2572	
	Ω Risk Aversion	0.0500		0.0500		0.0513		0.5377	
	θ Loss Function	0.0100		0.0100		0.0100		0.1029	
SP	Threshold	p=0.30		p=0.30		p=0.30		p=0.78-0.84	
	Alarm	22	6	22	6	22	6	14	0
	No Alarm	1	110	1	110	1	110	9	116
	% Correct	95.65	94.83	95.65	94.83	95.65	94.83	60.87	100.00
	% Incorrect	4.35	5.17	4.35	5.17	4.35	5.17	39.13	0.00
	λ Noise-to-signal	0.0541		0.0541		0.0541		0.0000	
	ϕ False-to-True	0.0500		0.0500		0.0500		0.2432	
	Ω Risk Aversion	0.0939		0.0939		0.0939		0.456	
	θ Loss Function	0.0144		0.0144		0.0144		0.0518	
SW	Threshold	p=0.19-0.21		p=0.19-0.21		p=0.19-0.21		p=0.95-0.97	
	Alarm	30	14	30	14	30	14	4	0
	No Alarm	1	95	1	95	1	95	27	109
	% Correct	96.77	87.16	96.77	87.16	96.77	87.16	12.90	100.00
	% Incorrect	3.23	12.84	3.23	12.84	3.23	12.84	87.10	0.00
	λ Noise-to-signal	0.1327		0.1327		0.1327		0.0000	
	ϕ False-to-True	0.0874		0.0874		0.0874		0.7715	
	Ω Risk Aversion	0.1394		0.1394		0.1394		1.0639	
	θ Loss Function	0.0257		0.0257		0.0257		0.1543	

Table 3.03. (continues)

		Min θ		Min Ω		Min ϕ		Min λ	
		Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis	Crisis	No Crisis
TH	Threshold	<u>p=0.22</u>		<u>p=0.22</u>		<u>p=0.22</u>		<u>p=0.97-0.98</u>	
	Alarm	29	10	29	10	29	10	7	0
	No Alarm	1	99	1	99	1	99	23	109
	% Correct	96.67	90.83	96.67	90.83	96.67	90.83	23.33	100.00
	% Incorrect	3.33	9.17	3.33	9.17	3.33	9.17	76.67	0.00
	λ Noise-to-signal	0.0949		0.0949		0.0949		0.0000	
	ϕ False-to-True	0.0667		0.0667		0.0667		0.6217	
	Ω Risk Aversion	0.1124		0.1124		0.1124		0.9322	
	θ Loss Function	0.0201		0.0201		0.0201		0.1324	
TK	Threshold	<u>p=0.32-0.49</u>		<u>p=0.32-0.49</u>		<u>p=0.32-0.49</u>		<u>p=0.62-0.72</u>	
	Alarm	29	4	29	4	29	4	27	1
	No Alarm	3	75	3	75	3	75	5	78
	% Correct	90.63	94.94	90.63	94.94	90.63	94.94	84.38	98.73
	% Incorrect	9.38	5.06	9.38	5.06	9.38	5.06	15.63	1.27
	λ Noise-to-signal	0.0558		0.0558		0.0558		0.0151	
	ϕ False-to-True	0.0778		0.0778		0.0778		0.0923	
	Ω Risk Aversion	0.1569		0.1569		0.1569		0.2104	
	θ Loss Function	0.0288		0.0288		0.0288		0.0378	
TW	Threshold	<u>p=0.14</u>		<u>p=0.14</u>		<u>p=0.26-0.28</u>		<u>p=0.79</u>	
	Alarm	26	16	26	16	26	16	15	0
	No Alarm	1	95	1	95	1	95	12	111
	% Correct	96.30	85.59	96.30	85.59	96.30	85.59	55.56	100.00
	% Incorrect	3.70	14.41	3.70	14.41	3.70	14.41	44.44	0.00
	λ Noise-to-signal	0.1496		0.1496		0.1070		0.0000	
	ϕ False-to-True	0.0996		0.0996		0.0948		0.2857	
	Ω Risk Aversion	0.1602		0.1602		0.1683		0.5314	
	θ Loss Function	0.0290		0.0290		0.0275		0.0696	
UK	Threshold	<u>p=0.12-0.16</u>		<u>p=0.12-0.16</u>		<u>p=0.12-0.16</u>		<u>p=0.64-0.68</u>	
	Alarm	13	7	13	7	13	7	11	0
	No Alarm	1	118	1	118	1	118	3	125
	% Correct	92.86	94.40	92.86	94.40	92.86	94.40	78.57	100.00
	% Incorrect	7.14	5.60	7.14	5.60	7.14	5.60	21.43	0.00
	λ Noise-to-signal	0.0603		0.0603		0.0603		0.0000	
	ϕ False-to-True	0.0680		0.0680		0.0680		0.1200	
	Ω Risk Aversion	0.1290		0.1290		0.1290		0.2359	
	θ Loss Function	0.0158		0.0158		0.0158		0.0173	
US	Threshold	<u>p=0.15-0.16</u>		<u>p=0.15-0.16</u>		<u>p=0.15-0.16</u>		<u>p=0.79-0.81</u>	
	Alarm	17	6	17	6	17	6	14	0
	No Alarm	0	117	0	117	0	117	3	123
	% Correct	100.00	95.12	100.00	95.12	100.00	95.12	82.35	100.00
	% Incorrect	0.00	4.88	0.00	4.88	0.00	4.88	17.65	0.00
	λ Noise-to-signal	0.0488		0.0488		0.0488		0.0000	
	ϕ False-to-True	0.0250		0.0250		0.0250		0.0968	
	Ω Risk Aversion	0.0429		0.0429		0.0429		0.1979	
	θ Loss Function	0.0086		0.0086		0.0086		0.0171	
VE	Threshold	<u>p=0.15-0.17</u>		<u>p=0.15-0.17</u>		<u>p=0.40</u>		<u>p=0.97</u>	
	Alarm	54	18	54	18	54	18	16	0
	No Alarm	1	66	1	66	1	66	39	84
	% Correct	98.18	78.57	98.18	78.57	98.18	78.57	29.09	100.00
	% Incorrect	1.82	21.43	1.82	21.43	1.82	21.43	70.91	0.00
	λ Noise-to-signal	0.2183		0.2183		0.1309		0.0000	
	ϕ False-to-True	0.1315		0.1315		0.1173		0.5493	
	Ω Risk Aversion	0.1549		0.1549		0.1988		0.9897	
	θ Loss Function	0.0317		0.0317		0.0432		0.2245	

Note: The first column of the table shows sampled 41 countries (for abbreviation please refer to Appendix table A1). The λ , ϕ , θ , and Ω represent threshold choosing technique mentioned in section 3.3.4 such as KLR's Noise-to-Signal ratio, False-to-True ratio, Loss Function, and Risk Aversion respectively. Underlined thresholds probabilities are derived by related threshold choosing techniques where shaded numbers indicate their minimums.

For Australian case, all methods, except λ , find optimal threshold level as 0.38-0.44 that successfully predicts 98.40% (123 out of 125 events) of tranquil and 93.33% (14 out of 15 events) of recessionary periods. The λ suggests 0.59-0.61 threshold that forecast 100% of tranquil and 86.67% (13 out of 15 events) of crisis periods.

In case of Chile, once again three techniques (ϕ , θ , and Ω) suggest 0.20 probability threshold which misses just one crisis (95.24%) and falsely sends 9 signals, while λ selects 0.66-0.69 threshold which accounts all tranquil events (100%) for the sake of missing 7 actual crisis events. Indeed, ϕ , θ , and Ω methods choose the same level of threshold in majority of countries (27 out of 41 countries). For instance, they suggest 0.32-0.35 probability threshold in Canada predicting 94.92% of tranquil and 86.36% of recessionary periods, while λ chooses 0.62-0.63 threshold level that accounts 100% of tranquil and 68.18% of crisis periods. For Czech Republic case, they find 0.14-0.18 probability threshold as optimal level that successfully forecasts 89.23% of tranquil and 100% of crisis events, while KLR's λ suggests 0.73-0.89 threshold level with 100% tranquil and 65.22% crisis prediction rate. Equally, in Brazilian case all threshold methods, except λ , select 0.30 probability as optimal level that correctly forecasts 87.67% of tranquil periods and 100% of recessionary periods in advance. Whereas, Brazilian λ suggests threshold level of 0.88-0.91 that has stronger tranquil period prediction (98.63%), but weaker crisis period prediction (41.38%).

Considering threshold level selected by the trio (ϕ - Ω - θ), EWS in Greece correctly forecasts 94.83% of crises (55 crises out of 58 total crisis events) generating only 15% of false signals (12 false alarms out of 80 tranquil periods). In Hungary, the model predicts 95.65% of crises (22 crises out of 23 total crisis events) issuing only 9.72% of false alarms. Likewise, the model also show fairly good fit in Indonesia (6.67% type I error and 4% type II error), India (3.85% type I error and 5.31% type II error), Italy (4.08% type I error and 17.98% type II error), Mexico (zero type I error and 11.11% type II error), Poland (zero type I error and 16.05% type II error), Russia (3.03% type I error and 13.64% type II error), Spain (5.41% type I error and 12.62% type II error), Singapore (4.35% type I error and 5.17% type II error), Switzerland (3.23% type I error and 12.84% type II error), Thailand (3.33%

type I error and 9.17% type II error), Turkey (9.38% type I error and 5.06% type II error), and United Kingdom (7.14% type I error and 5.60% type II error).

The threshold for Ireland is chosen as 0.23 by θ and Ω with 83.87% tranquil prediction and 95.65% crisis prediction rates, whereas ϕ finds optimal threshold level as 0.45 with 94.62% tranquil prediction and 86.96% crisis prediction rates, and λ suggests threshold level of 0.99 with 100% tranquil prediction and 10.87% crisis prediction rates. In other words, the λ prefers to undertake 35 more missed crisis costs for the sake of nulling false signal rate. This reveals how λ might derive "crazy" outcomes.

In case of Belgium, θ and ϕ suggest 0.14 probability threshold level that forecasts 93.04% of tranquil and 96% of crisis periods successfully, while λ and Ω urge 0.87-0.88 and 0.10 threshold levels. The λ predicts 100% of tranquil periods and 64% of recessionary periods, while Ω predicts 88.70% of tranquil periods and 100% of crisis periods.

Threshold methods point different cut-off probabilities in case of Finland. The Ω suggests 0.11 level that correctly forecasts 42 crises out of 43 total crisis events (97.67%) for the sake of issuing 20 false alarms during 96 tranquil periods. The ϕ sets the threshold at 0.18-0.21 level which accounts 41 crises, but issues 16 false signals. Seemingly, it opts to miss one more crisis for the sake of decreasing false alarms from 20 to 16. The θ remains indifferent between cut-off levels of Ω and ϕ . In both cases it gets loss function value of 0.0345.

Similar scenario repeats in Portugal and Sweden where θ remains indifferent between cut-off levels of Ω and ϕ deriving equal statistics. The Ω in Portugal selects 0.19-0.20 cut-off level that estimates 94.12% of crises for the sake of issuing 15.48% false signals, while ϕ sets threshold level at 0.37 that results with 88.24% of crisis prediction and 5.95% of wrong alarms. In Sweden, EWS works comparatively better than Portugal as it correctly forecasts 44 crises out of 44 total crisis events (100%) for the sake of 7 false signals during 96 tranquil periods on the basis of threshold chosen by Ω . The Swedish ϕ select 0.44-0.50 threshold level where false alarms are decreased from 7 to 3 for the sake of missing one more crisis.

In case of France, the θ determines threshold at 0.35-0.38 which predicts 17 crises out of 20 total crisis events (85%) and falsely signals only in 4 times during

118 tranquil periods. However, ϕ and Ω choose threshold level of 0.17-0.22 that correctly estimates 18 crisis and issues 9 false alarms. In other words, ϕ and Ω opt to take five more pre-emptive actions for the sake of accounting one more crisis event.

It is worth to note that the minimum coefficients for ϕ , θ , and Ω are recorded in South Korea with 0.0058, 0.0290, and 0.0163 respectively. This indicates that our EWS model generates the highest performance in South Korea with zero percentage type I and 3.2% type II errors at threshold probability level of 0.16-0.24. In other words, the EWS successfully forecasts 100% of crisis events while it predicts 96.80 of tranquil periods just falsely signaling 4 events out of 138 total events.

China also seems to be one of countries where our EWS model produces higher estimation accuracy. Here, all three techniques (ϕ , θ , and Ω) select 0.06-0.09 probability threshold that correctly accounts 94.53% of tranquil and 100% of crisis events. The λ recommends the threshold level of 0.52-0.60 which prefers 2-to-7 trade-off between type I and type II errors, thus, its prediction rate for tranquil periods increases up to 100%, while crisis prediction rate drops to 83.33%.

Indeed, threshold selection technique plays a crucial role in ranking performance of EWS models in sampled countries. For instance, statistics of ϕ and Ω rank Malaysia as second best performing country with zero type I (20 crises are correctly predicted out of 20 total crisis events) and 3.88% type II errors (99 tranquil periods are correctly predicted out of 103 total tranquil periods); United States as third best country with zero type I (17 crises are correctly predicted out of 17 total crisis events) and 4.88% type II errors (117 tranquil periods are correctly predicted out of 123 tranquil periods). Whereas if one utilizes θ threshold selection technique then, s/he will find Philippines as second best performing country with 5% type I (19 crises are correctly predicted out of 20 total crisis events) and zero type II errors (111 tranquil periods are correctly predicted out of 111 total tranquil periods), and Australia as third best performing country with 6.67% type I (14 crises are correctly predicted out of 15 total events) and 1.60% type II errors (123 tranquil periods are correctly predicted out of 125 total tranquil periods).

On the other hand, according to threshold metrics our EWS model show relatively lower performance in Germany, Norway, Japan, Denmark, and Austria. In Japan, it accounts 100% of crises (55 out of 55), but sends too frequently false signals which emerge 41.67% type II errors according θ that sets threshold at 0.13 level. The Ω chooses 0.15 cut-off level opting to miss to crisis for the sake of decreasing false signals down to 36.90%. The ϕ , in turn, selects threshold of 0.29-0.30 probability level where false signal rate decreases further to 23.81% for the cost of 9.09% type I error.

In case of Norway, Ω and θ find 0.09-0.11 probability level as an optimal cut-off threshold that produces zero type I and 40.00% type II errors. Whereas, ϕ sets the threshold at 0.50 level where type II errors are shrunken from 40% to 8.89% for the cost of increasing type I error from zero to 25.53%. For Danish case, θ and Ω choose 0.24 probability as cut-off levels that result with 3.57% of type I and 31.33% of type II errors, while ϕ and λ set threshold level as 0.26 and 0.89-0.90 probabilities which derive 8.93% of type I and 25.30% of type II errors and 60.71% type I and zero type II errors respectively.

In case of Austria, all thresholds metrics, expect λ , select 0.24 level as cut-off where type I and type II error are measured as 10.81% and 13.59% respectively. The λ once again deviates far from aim of EWS as it sets threshold very high at 0.94-0.95 which produces high level of type I error (72.97%) even though it effectively nulls the false signals.

Finally, the threshold for Germany is chosen as 0.13 by θ and Ω with 71.29% tranquil prediction and 94.87% crisis prediction rates, and as 0.60-0.67 by ϕ and λ with 100% tranquil prediction and 74.36% crisis prediction rates. The ϕ and λ minimize false alarms to zero percentage for the sake of undertaking 8 more missed alarms, while θ and Ω prefer to miss 8 crises less for the sake of undertaking 29 more false alarms.

To conclude, the ϕ threshold selection technique appears the best methodology in theoretical ground that derives maximum accuracy for EWS by minimizing overall incorrectness of the model disregarding cost weights of type I and type II errors. If we regard statistics of ϕ method, our EWS model, in general, successfully forecasts 92.34% of upcoming crises within 6 quarters, while sending

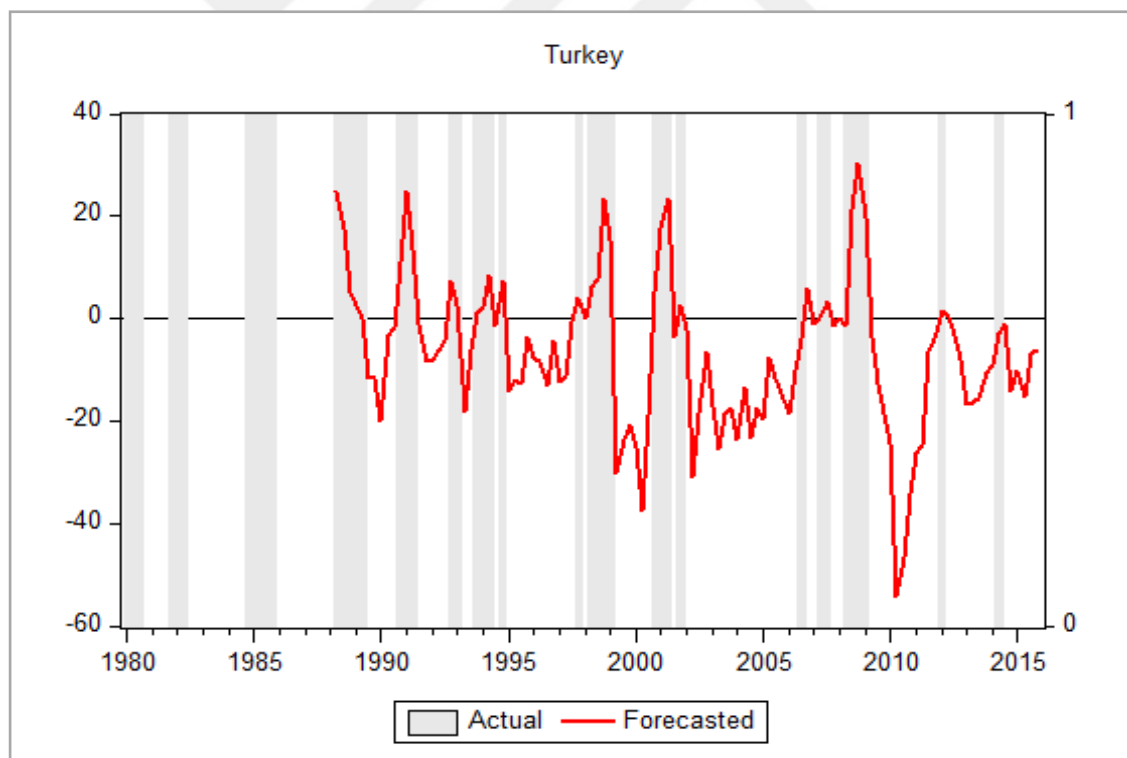
just 8.36% false signals during tranquil periods. In other words, the model correctly predicts 1218 crises out of 1319 total crisis events, while mistakenly signaling for 334 alarms during 3995 tranquil periods between 1980 and 2016 for 41 sampled countries. In addition, the high rate of crisis prediction demonstrates how efficiently the model accounts various types of economic and financial crisis. This also implies that the model is fairly generalized.

The study also offers evidence for stability of the model by testing it over 41 different countries. However, it comprises two limitations. First, unlike previous studies it does not carry out a panel analysis for a more generalized outlook. Because, each country has a different threshold and tolerance rate which might be associated with their economic strength, smoothness of macro-dynamics, foundation of financial markets, and etc. The tolerance rate indicates the degree and level of vulnerability of economic activities whose disturbance might cause a shrink in real output. This tolerance rate is latent in nature and its measurement might be very difficult. This research does not investigate measurement of tolerance rates of countries, thus, we simply cannot panelize the data and pursue panel analysis.

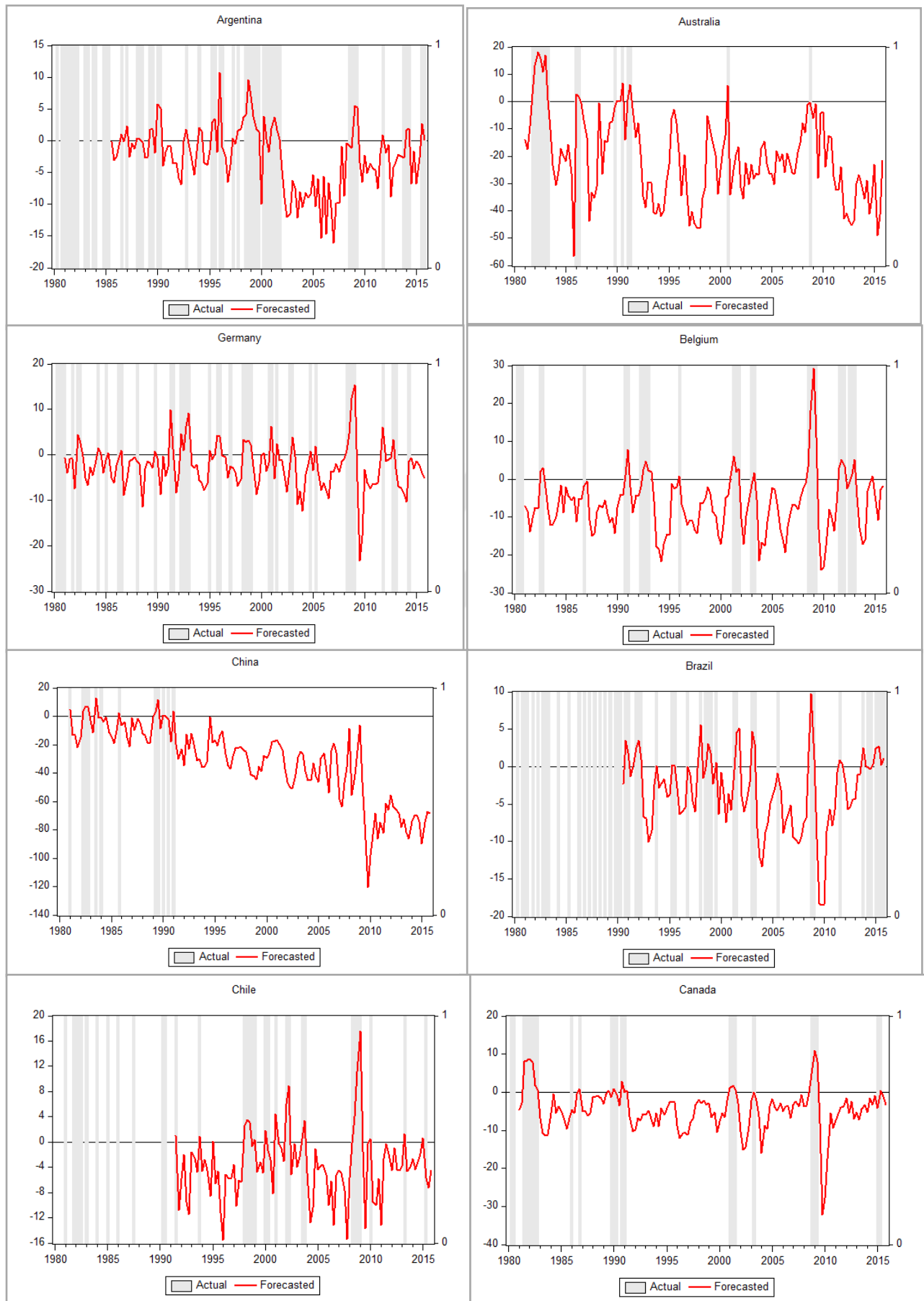
Due to its nature, the logit model estimation technique examines each explanatory variable separately and binarizes them by determining a certain level for each of them. In other words, if series exceeds the determined threshold level then it gets value of 1, and if otherwise it gets zero. This certain threshold indicates tolerance rate of each indicator and it varies across series as well as across countries. For instance, economy of Argentina and United States differs in many dimensions. A 100 bps increase in inflation rate (*CPI*) would emerge different reaction in Argentina and United States. Argentina might perceive this in tranquility as tolerable issue, while the United States might consider it as a serious issue. We represent these reactions as AG_{CPI}^{+100} and US_{CPI}^{+100} , where $AG_{CPI}^{+100} \neq US_{CPI}^{+100}$. In similar way, 200 bps decrease in balance-of-payment per GDP (*BOPY*) in these two country might generate different reactions and so consequences. So, $AG_{CPI}^{+100} \neq US_{CPI}^{+100} \neq AG_{BOPY}^{-100} \neq US_{BOPY}^{-100}$ is valid for this scenario. Taking into account these facts, if one still wants to panelize data in logit framework, then s/he should use dummy variables for each indicators as well as for the country itself in order to fix their within- and between-effects.

Second limitation is that this study does not carry out out-of sample analysis. However, our in-sample analysis derives one of the best performances among existing literature. The figures below display predictive strength of our model in graphical illustration where we depict actual (shaded area) and forecasted (red line) crises for each country. Figure 3.02 portrays goodness-of-fit of EWS model for Turkey where zero line is threshold. The data for Turkey starts in 1988, therefore, the in-sample forecasted red index line also starts in 1988. Notice that index line during crises periods (shaded area) is generally above the zero line and vice versa. The system correctly predicts majority of crisis events failing only in two cases. First, it falsely sends signal during Q4:2006-Q1:2007 where red index line is above zero, but no actual crisis event. Second, it fails to signal during Q1:2014 where crisis event takes place for one quarter.

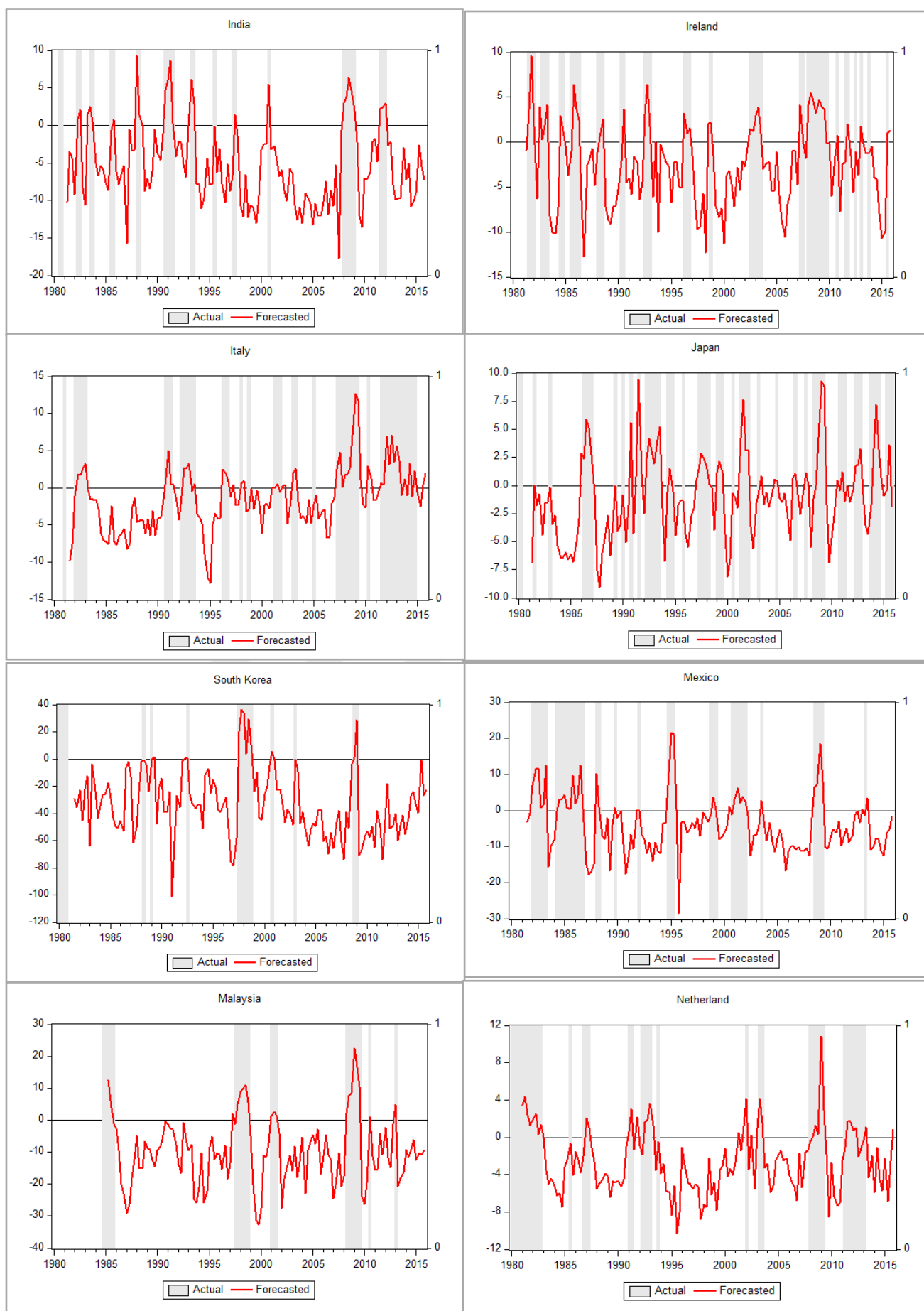
Figure 3.02. Goodness-of-fit Actual vs. Forecasted Crisis series

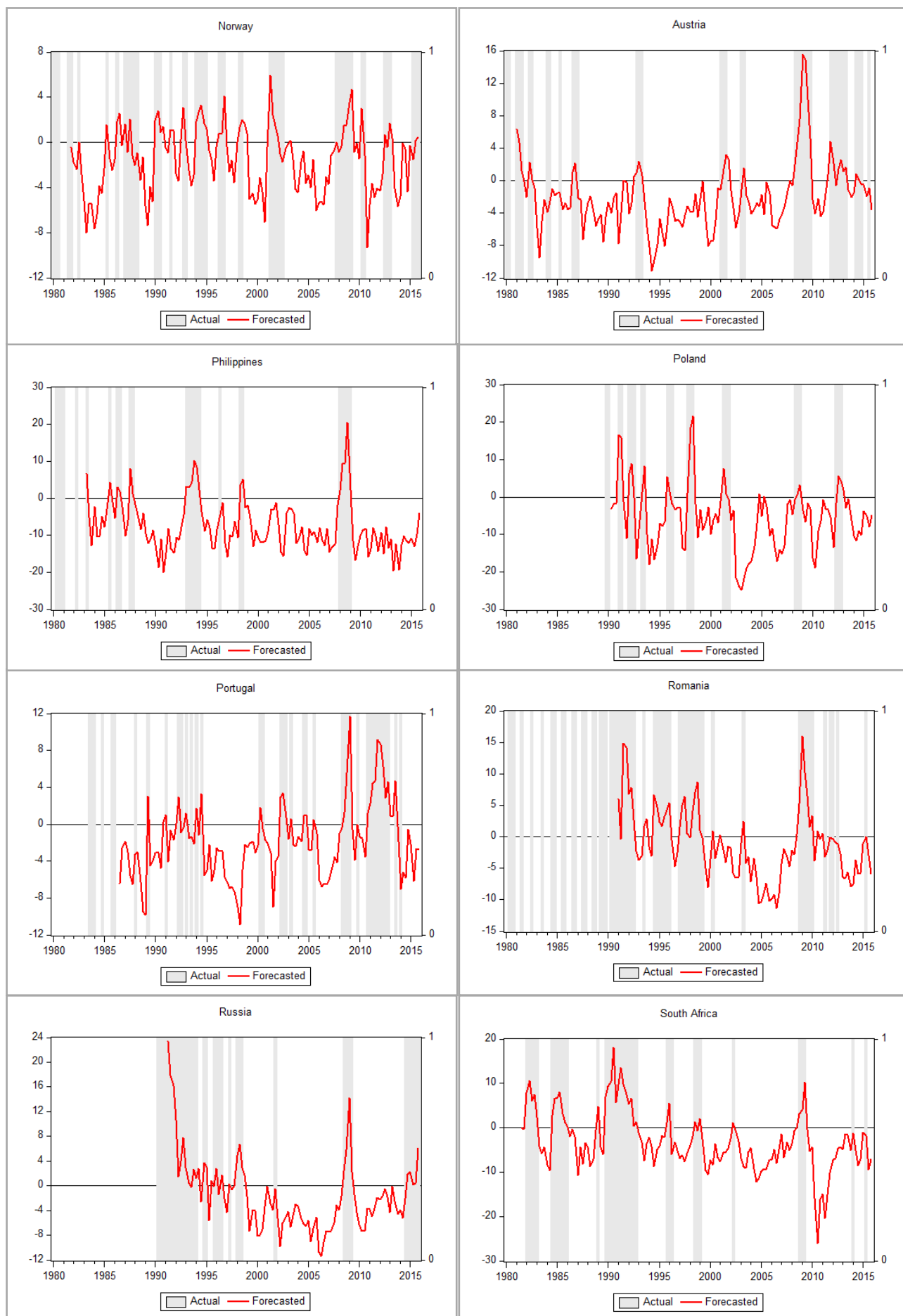


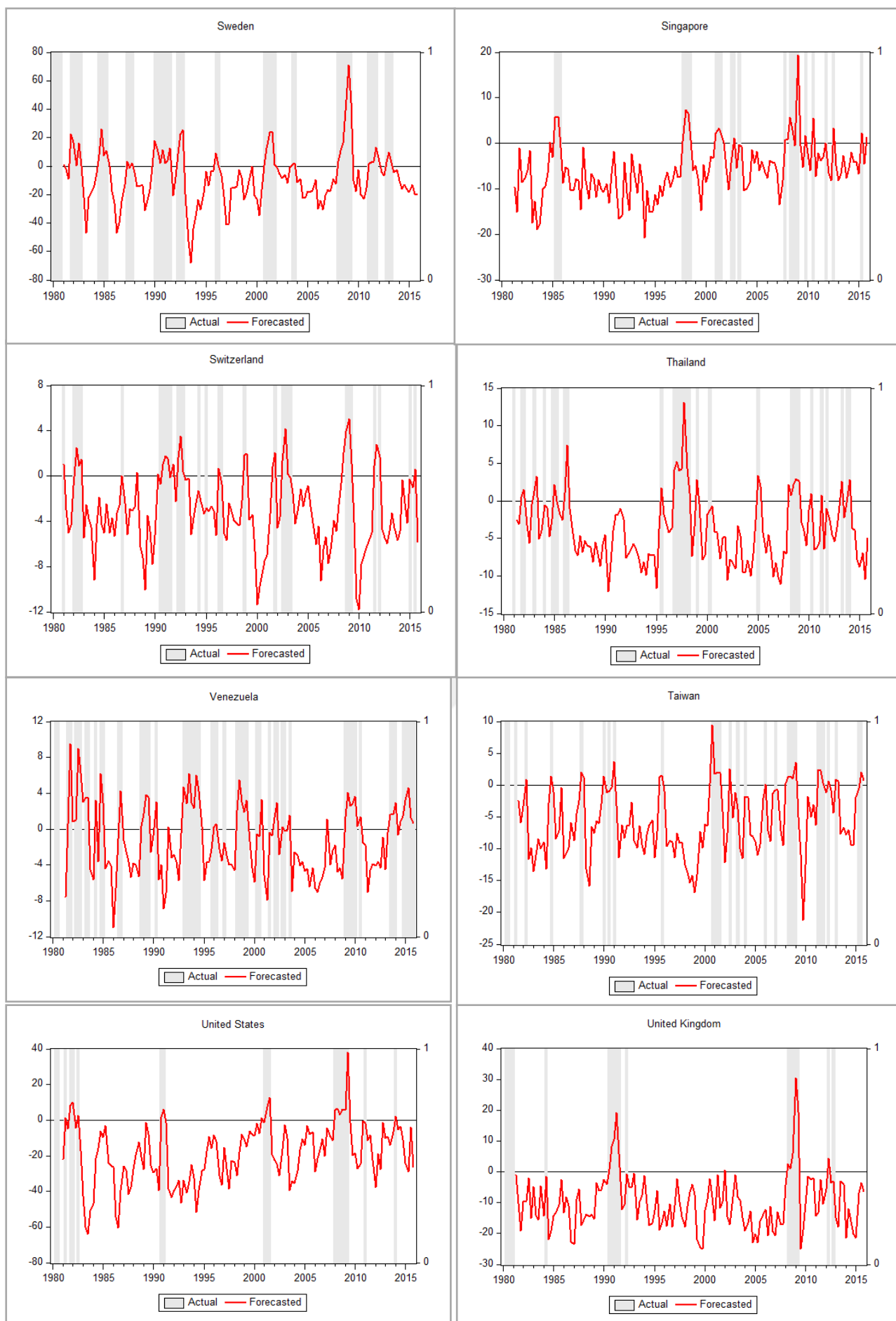
Source: Generated by the author in EViews software











3.5. Concluding remarks

This study contributes to existing literature in several patterns. First, it introduces a more generalized model that is capable of accounting various types of crisis and fairly stable over 41 different countries. Second, it introduces two new contagion proxy variables: Trade interdependence (interconnectedness) between countries (CON) and Speculative and Expectation pressure of the markets (SPEX). Third, it uses distributed Lag technique in Logit framework allowing lags to be dynamic ranging from 1 to 6. Fourth, it introduces two new optimal threshold selection techniques, namely, False-to-True ratio (ϕ) and Risk Aversion rate (Ω). The ϕ is an augmented version of KLR's Noise-to-Signal ratio and it is the best methodology in theoretical ground that derives maximum accuracy for EWS by minimizing overall incorrectness of the model disregarding cost weights of type I and type II errors. In turn, the Ω is the most secure and risk-averse technique that considers minimizing type II error as well as overall incorrectness of EWS model. The Ω derives quite similar estimates as Demirguc-Kunt and Detragiache (2000)'s Loss Function (θ) threshold selection technique. The main difference between two is θ requires ex-ante (predetermined) input weights based on decision maker's preference (degree of risk aversion) which might vary across countries and is quite difficult to find its optimum. On the other hand, Ω automatically finds the best trade-off weight between type I and type II errors that derives minimum incorrectness of the mode.

The empirical test of generalized DLL EWS model documents several plausible findings. First, fluctuations of composite leading indicator (CLI^c) around its long-run steady state have significant role in predicting upcoming crisis in all 41 countries without any exceptions.

Second, binary-transformed unemployment fluctuation (UD) seems to be the second best crisis indicator variable as it adds significant contribution in 39 countries out of 41, failing to be statistically significant only in Belgium and Austria. The average time lag between UD and upcoming crisis is measured as 2 quarters for our sample.

Third, all three contagion factors appears statistically significant within the model. Especially, newly designed CON variable improves the model remarkable by

playing a key role in forecasting upcoming crisis at 39 countries out of 41 total (fails only in Germany and India). The *CON* and *SPEX* indicators get positive coefficient, indicating an increase in these variables raises probability of crisis. The average time lag between *CON* and upcoming crisis events is measured as 2.54 quarters; whereas average time lag between *SPEX* and upcoming crisis events is computed as 2.90 quarters. This indicates that speculations and expectation in the market start to send signals before the trade interdependence factor. Indeed, *SPEX* appears as the earliest crisis indicator among other variables used in our EWS model. On the other hand, the estimated sign for *OIL* varies across countries and seemingly crude oil producer and exporter countries tend to have negative sign, while oil purchaser/importer countries tend to have positive sign. The time lag between *OIL* and upcoming crisis is measured as 2.39 quarters averagely.

Fourth, in line with existing literature, the study finds that overvaluation of real effective exchange rate (*REER*), fluctuations of inflation rate (*CPI*^c) around its long-run steady, high domestic credits to GDP (*CRDY*^c) add significant pressure on crisis probability. We measure the average time lag between *REEX* and upcoming crisis event as 2.33 quarters; whereas the time lags between *CPI*^c and crisis and between *CRDY*^c and crisis are averagely about 2.34 and 2.41 quarters respectively.

Fifth, fiscal balance per GDP (*BOPY*^c), government balance per GDP (*GOVY*^c), and foreign reserve coverage for import goods (*RESMON*) get negative sign in almost all countries, implying inverse relationship between these variables and crisis probability. Moreover, average time lag between these variable and crisis events appears as 2 quarters. This indicates that any increase in these indicators decreases probability of crisis occurrence within 2 quarters.

Finally, the study comparatively evaluates prediction performance of DLL EWS model under four different threshold selection techniques. It shows that performance of the model can be optimized with our new threshold selection techniques ϕ and Ω which derive better prediction rates comparing to Demirguc-Kunt and Detragiache (2000)'s Loss Function (θ) and KLR's methodology (λ). We observe that in nearly half of the sample θ , Ω , and ϕ finds the same cut-off probability level, while λ sets threshold at "crazy" levels. Averagely, θ , Ω , and ϕ correctly predict 96.13% (1258 crisis quarters), 96.36% (1271 crisis quarters), and 92.34% (1218 crisis quarters) of 1319 total crisis events (quarters) in advance, while

issuing 11.94% (477 tranquil quarters), 12.32% (492 tranquil quarters), and 8.36% (334 tranquil quarters) false signals during 3995 tranquil periods. The λ forecasts only 49.36% (651 crisis quarters) of total crisis (1319 quarters) with 0.05% (2 tranquil quarters) of false signal issued during tranquil periods between 1980 and 2016 for 41 sampled countries.



CONCLUSION

Summary of findings and contribution

Originality and contribution of the thesis into early crisis warning (EWS) literature are several-fold. First, this thesis offers a new generalized EWS framework that accounts various types of financial, economic, banking, and currency crises. Second, the research provides significant evidence for universality and capability the new EWS by considering the largest sample size in the literature by covering 41 countries from developed, emerging, and frontier markets over 1980-2016. While the existing literature mainly studies few developed countries such as the US, the UK, and the EU.

Third, the study takes into account most prominent leading indicators alongside with few new indicators that have not been used before. The selection of appropriate leading indicators of economic and financial turmoil also plays a crucial role in modelling EWS. However, the selection mainly depends on how the term “*crisis*” is defined. Unlike the related literature that often defines the crisis using self-built indexes, the study defines the “*crisis*” as shrinks in real output straightforwardly because of two reasons: (1) Real output is a real variable that attracts wide concern in both macroeconomics and finance. It is one of the primary indicators used to gauge the health of a country's economy as it summarizes aggregated demand and supply. Any shrinks in real output might negatively affect whole societies by generating dramatic consequences; (3) The main aim of the thesis is to construct more generalized and robust EWS that would capable of predicting various types of economic and financial imbalances. In this respect, a shrink in real output is an ideal definition of the crisis for the sake of achieving the main aim of the thesis.

Covering existing literature, we select 13 signalling indicators that add turmoil pressure on countries' economic and financial activities and eventually cause real output to shrink. These indicators are Inflationary (*CPI*) pressure, Unemployment (*UD*) pressure, Purchasing Managers' Index (*PMI*) fluctuations, Construction production index (*CONPI*) fluctuations, Industrial Production Index (*IPI*) fluctuations, Balance of payment (*BOPY*) pressure, Government Balance (*GOVY*) pressure, Liquidity and Foreign Reserves (*RESMON*) pressure, Real Effective Exchange rate (*REER*) pressure, Banking Credit (*CRDY*) bubble, World Oil Prices (*OIL*), Contagion

Effect (*CON*), Speculations and Expectations (*SPEX*). In order to mitigate collinearity issues between *PMI*, *CONPI*, and *IPI*, we composite these indexes into one as Composite Leading Index (*CLI*).

In addition, we also take into account speculations and expectations of the market that would be an ideal proxy for speculative contagion effects. Crediting Masson (1998), the thesis accounts contagion effect through three different channels: 1) Country-specific shocks; 2) Global resource-specific shocks; and 3) Speculation- or Expectation-motivated shocks. Considering reciprocal trade links and interconnectedness of countries, we introduce another brand-new contagion factor that would ideally reflect contagion effects caused by trade interdependence. We show how accurately this proxy measures country-specific spillover providing evidence for its overall significance.

Furthermore, the thesis utilizes joint frequencies of Google search trends and scientific research publications as a proxy for speculative and expectation based shocks. Although we detect a positive correlation between two contagiousness proxies (trade interconnectedness factor and speculation-expectation factor), we conclude that it remains weak to cause collinearity in the EWS model. For global shocks, we use proxy of changes in world crude oil prices. Unlike other two contagiousness proxies, the sign (direction of correlation) oil proxy varies across sampled countries. We observe that economies of oil exporter (producer) countries would negatively affected by price downfalls causing increase in probability of crisis outbreak, while other countries (mainly oil importers) would enjoy low oil prices which lead their crisis probability to decrease.

Fourth, the thesis also uses information gathered from empirical investigation of inflation and unemployment dynamics under Phillips Curve and Okun's Law frameworks respectively. Within this context, the thesis shows that inflation is mainly lagging variable and, thus, cannot be used in the EWS model. Instead, using expected inflation within the EWS model is more appropriate. Moreover, the thesis shows that inflation tend to behave differently during recessionary periods; thus dynamics of inflation changes. More specifically, we observe that degree of backwardness in shaping inflation expectations considerably increases during recessionary periods. Put differently, the agents in the market become less forward-

looking during crisis periods. This information is used as a leading indicator for our EWS model.

Similarly, the thesis also shows that unemployment is crucial indicator for upcoming crisis events. Unlike existing literature that largely neglects unemployment arguing that it is lagging variable of crisis, the thesis shows that unemployment and real output has bi-directional relationship. Thus, unemployment can be used as leading indicator of crisis as well. Moreover, the thesis observes that this relationship in Okun's framework considerably shrinks during recessionary periods. This yields valuable information to be used in the EWS model. These empirical investigations also shed light onto overall validity and stability of the macroeconomic relations that might be useful to in building EWS with their time lag interactions.

Fifth, this research introduces two new optimal threshold selection methods namely, False-to-True ratio (ϕ) and Risk Aversion rate (Ω), that help to evaluate predictive power of the EWS models more accurately. The ϕ is an augmented version of Kaminsky et al (1998)'s (KLR) Noise-to-Signal ratio and it appears as the best methodology in theoretical ground that derives maximum accuracy for EWS by minimizing overall incorrectness of the model disregarding cost weights of type I and type II errors. In turn, we find that the Ω is the most secure and risk-averse technique that considers minimizing type II error as well as overall incorrectness of EWS model. We comparatively evaluate prediction power our EWS models in 41 different countries with KLR's Noise-to-Signal (λ), Demirguc-Kunt and Detragiache (2000)'s Loss Function (θ), and with our two new threshold selection techniques. We observe that in nearly half of the sample θ , Ω , and ϕ finds the same cut-off probability level, while λ sets threshold at "crazy" levels.

Findings and contribution of analysis of inflation dynamics

The chapter one examines dynamics of inflation under empirically proven Phillips Curve (PC) framework testing its traditional, expectation-augmented classical, and hybrid new Keynesian versions distinguishing its validity and stability during tranquil and recessionary periods over 1980-2016 time span across 41 countries. As a result we document several findings. First, we find that forward-looking characteristic of inflation picks up weight after 1990's which indicates that

inflation became more sensitive to expected prices. We also observe that inflation in developed markets (with nearly 40%-60% backward- and forward-looking trade-off) is more forward-looking comparing to emerging (50%-50% BF trade-off) and frontier (60%-40% BF trade-off) markets. This indicates that developed markets dear forward-looking price expectations more than others. Plus, we believe that frontier and some of emerging economies do not seem to be working so smoothly, in practice, in terms of macroeconomic systems as developed markets do.

Second, we reveal that NKPC describes the dynamics of inflation the best. However, the hybrid version of NKPC need better proxy for real marginal costs. For this, we augment hybrid NKPC model with omitted fraction of real marginal costs, unit non-labor costs (*unlc*). And the augmented NKPC model seems to be working better capturing more variations in current inflation. For robustness, we also incorporate unit labor and non-labor costs into one total unit cost (*tuc*) factor, and we show that this variable is a better proxy for real marginal costs than using accounting only unit labor costs (*ulc*). In best specification, NKPC model shows that the Phillips relation (λ) varies across countries and markets. The model predicts that development markets have average *ulc* and *unlc* coefficients of 0.05 and 0.02 respectively, whereas emerging and frontier markets have average coefficients of 0.07-0.04 (*ulc- unlc*) and 0.09-0.03 (*ulc- unlc*).

Third, we observe that all versions of Phillips curve collapses during pure recessionary periods, except our unit non-labor cost augmented NKPC hybrid model. In this specification, unit labor cost factor loses its statistical significance, while unit non-labor costs factor preserve its significance at 5% level. Moreover, NKPC structural parameters analysis indicates that fraction decomposition factor of real marginal cost (ρ) is about 0.75 during growing periods and it increases to 0.86 during pure recessionary periods. This indicates that weight of unit labor costs in real marginal costs increases, while non-labor cost fraction shrinks as firms adjust their costs (mostly reducing non-labor costs as labor costs are rigid due to wage agreement and labor contracts) in response to shocks. Thus, unit labor costs remain irresponsive while unit non-labor cost picks up more sensitivity during recessionary periods. On the other hand, the decomposition factor ρ varies across countries. We observe that development markets tend to have higher ρ (the average is about 0.75) comparing to emerging and frontier markets ($\rho=0.60$). Majority of developed markets

has modernized labour markets where rights of employees protected by collective labour agreements and contracts that regulate the working conditions of unionized and non-unionized workers. Thus, nominal prices can be really persistent in these markets. However, the influence of labor unions and collective labour agreements is notably scant in developing (emerging and frontier) countries. In most cases employers directly cut wages in a response to negative shocks in these markets. Therefore, fraction of unit labor costs in real marginal costs often decreases concordantly ρ decrease further during recessionary periods.

Fourth, we find out that degree of backwardness (ω) ranges between 0.44-0.46 during growing (normal) periods, whereas it remarkably increases to 0.59-0.60 (almost 15 bps) during recessionary periods. This implies that firms tend to follow backward-looking rule of thumb in setting prices during recessionary periods. We believe that expectations on future prices flow smoothly and bidirectional between agents and market during growing economic periods, so agents benefit from all information available (past and expected) in the market. However, economic depression causes an uncertainty raising cloud of dust in the market, thus the smooth flow will be disrupted. Until the dust settles, agents mainly benefit from backward-looking information.

Fifth, although we observe very limited decrease in price stickiness (θ), we believe that it is quite stock-still during both normal and recessionary period. Newly set prices seem to remain for 4-5 quarters during growing economic periods, whereas it slightly decreases to 3.5-4.5 quarters during recessionary periods. On contrary, our country-based NKPC structural parameter analysis report that nominal rigidity varies across cross-section countries remarkably. Particularly, it is relatively higher in development markets than emerging and frontier ones. The average price duration in developed markets is about 5 quarters, while it is nearly 4 quarters in emerging and frontier markets.

To conclude, we believe that inflation is very effective tool that has a role in economic and financial stability. We examine its dynamics and explore how its parameters behave normal and recessionary periods. Our findings reveal that degree of backwardness increases, while subjective discount factor decreases and Phillips relation (where real marginal costs only proxied by unit labor costs) totally lose its significance during economic depression. Thus, we record these

observations as a recession signaling factors to be used in our main chapter where we set up an early crisis signaling framework for 41 sampled countries over 1980-2016.

Findings and contribution of analysis of unemployment dynamics

The chapter two examines dynamics of unemployment under Okun's law framework believing that it might yield valuable indications to be used in our EWS model. We pay focus on tranquil and recessionary periods separately using a broader country-time sample using up-to-date data over 1980-2016.

Although we gather different results from each country, our findings mainly refer universality of Okun's law as it appears statistically significant in most countries. Thus, we confirm overall validity of the Okun's law. In regard of stability of Okun's law, we find out that the Okun's coefficient is subjected to time-variation. Moreover, we also observe that the coefficient shrinks in absolute magnitude during recessionary periods. These results are in line with Owyang and Sepkhposyan (2012) and Grant (2017) who also document similar shrunk. Eventually, we believe that this information can be utilized as signalling indicator in an early crisis warning system.

More specifically, we find that developed markets have average Okun's coefficient of -0.42, while emerging, frontier, and unclassified markets have average coefficients of -0.21, -0.19, and -0.16 respectively. The lowest Okun's coefficients are documented in Luxembourg (-0.08), Austria (-0.16), Japan (-0.17), and Norway (-0.27) at 1% significance level. These results are in line with extant literature (Lee, 2000; Freeman, 2001; Perman and Tavera, 2005; Ball et al, 2012). The main driving force behind low Okun's coefficient is high institutional rigidity in labor markets; especially in Japan that "*lifetime employment*" tradition makes employers reluctant to dismiss employees.

On the other hand, we observe that the highest Okun's coefficients are estimated in Spain (-0.95), Netherlands (-0.59), and Australia (-0.57) at 1% significance level. Spanish coefficient is in line with most recent literature (Ball et al., 2012) that refers to extraordinarily high frequency of temporary (flexible) employee

contracts in Spain which offers firms an easy opportunity to amend their employment in response to output changes.

The main contribution of this study is that it measures Okun's coefficient during pure growing and pure recessionary periods. When we distinguish these two periods, we observe the Okun's coefficient preserves its statistical significance in both periods, but it is slightly higher during growing comparing to recessionary periods. To be more specifically, the coefficient during growing periods is -0.20 at 1% significance level, while it is -0.18 during recessionary periods preserving significance at 1% level even though its standard error increases twofold. Thus, we conclude that even though Okun's relation is valid over different time periods and economic environments, the variation exists in terms of its stability.

In addition, we also examine Okun's law under ARDL framework assessing its short- and long-run magnitudes. We find short-run Okun's coefficient as -0.06 and long-run coefficient as -0.16 both significant at 1% level. We document that these magnitudes remain stable (not changing in both magnitude and significance) during recessionary periods. This confirms overall stability of Okun's Law across time horizon including normal and abnormal economic periods. We detect speed of error correction as -0.0455 at 1% significance level which implies that the model converges towards equilibrium by correcting 4.55% of previous period's divergence from this equilibrium following a shock. Majority of extant literature generally finds low adjustment speed due to long memory of time series variables, government interventions by frequently changing policies, and impact of external factors, the convergence is gradually slow. Besides, we observe that speed of adjustment is fairly similar in countries that culturally akin each other such as Canada-United States, United Kingdom-Australia-Ireland, Japan-China, and Germany-France.

Lastly, we examine causality between real output and unemployment, to determine which is lagged and which is leading indicator. As a result, we document strong bidirectional causality. However, causality running from fluctuations in unemployment rate to movements in real output is stronger than vice versa causality during recessionary periods. This core finding indicates that movements in unemployment around its potential cause real output to fluctuate during recessionary periods, and impulse-response function shows response of real output to the shock in unemployment is strong negative that picks to maximum magnitude

during 2nd-3rd quarters where afterwards gradually slows down and approximately ends up in 7th quarter. Thus, in examination of crisis-prone countries it is better to use unemployment gap as explanatory variable for real output gap. But one should also account potential collinearity problem of using inflation and unemployment rates in the same model due to Phillips relation.

Findings and contribution of early crisis warning framework

In order to fulfil the main aim of the thesis, we establish a common EWS model that accounts various types of crisis (financial, economic, banking, and currency) and improves existing models in several patterns. First, we use broadest financial and economic indicators, however, to avoid collinearity problem (inflation-unemployment, inflation-interest rate, Purchasing Managers' Index, Construction production index, Industrial Production Index vs.) we re-structured some of these indicators combining them in to one index indicator.

One of the major contributions of this study is that it introduces two contagion proxy variables: trade interdependence based contagiousness (*CON*) and Speculative and Expectation pressure of the markets (*SPEX*). The *CON* accurately accounts contagion effects on the basis of between-country trade interdependences. Whereas *SPEX* is proxied by jointly Google search frequencies (trends) and academic researches. We attach great importance to these variables as one accounts shifts in investors' (market) sentiment and expectations significantly, while other accounts contagion effects through trade channels. We also introduce a brand-new technique for determining less-risky optimal threshold as following Risk Aversion rate and augment existing Noise-to-Signal ratio with False-to-True ratio.

Using Distributed Lag Logit Estimation technique, we document several plausible findings. First, fluctuations of composite leading indicator (CLI^c) around its long-run steady state have significant role in predicting upcoming crisis in all 41 countries without any exceptions. Its lag length varies between 1-3 quarters for all countries, indicating that the CLI^c starts to issue signal closer to the event time. Seconds, binary-transformed unemployment fluctuation (*UD*) seems to be the second best crisis indicator variable as it adds significant contribution in 39 countries out of 41, failing to be statistically significant only in Belgium and Austria. The signal

length of *UD* appears to be 1-4 quarters in majority of the sampled countries, indicating it starts to send signals maximum 4 quarters prior to crisis events. We measure the time lag between *UD* and upcoming crisis as 2 quarters averagely. Third, crediting Masson (1998)'s three reasons of contagion effects we included three indicators, namely, trade interdependence factor (*CON*), changes in world crude oil price (*OIL*), and market speculations and expectations (*SPEX*), that corresponds to three channel of contagiousness. We document that all three factors add significant contribution into our EWS model. Especially, our newly designed *CON* variable improves our model remarkable. This indicator fails to be statistically significant only in two countries: Germany and India. For remaining 39 sampled countries *CON* is highly significant factor in forecasting upcoming crises. Both *CON* and *SPEX* indicators gets positive coefficient, indicating an increase in these variables raises probability of crisis. The time lag between *CON* and upcoming crisis events is measured as 2.54 quarters averagely; whereas time lag between *SPEX* and upcoming crisis events is computed as 2.90 quarters averagely. This indicates that speculations and expectation in the market starts to send signals before the trade interdependence factor. Actually, we find that *SPEX* is the earliest indicator among other variables used in our EWS model. On the other hand, the estimated sign for *OIL* varies across countries and seemingly crude oil producer and exporter countries tend to have negative sign, while oil purchaser/importer countries tend to have positive sign. The time lag between *OIL* and upcoming crisis is measured as 2.39 quarters averagely.

Fourth, in line with existing literature we also find that overvaluation of real effective exchange rate (*REER*), fluctuations of inflation rate (*CPI*^c) around its long-run steady, high domestic credits to GDP (*CRDY*^c) add significant pressure on crisis probability. We measure the time lag between *REEX* and upcoming crisis event as 2.33 quarters averagely; whereas the time lags between *CPI*^c and crisis and between *CRDY*^c and crisis are averagely about 2.34 and 2.41 quarters respectively.

Fifth, fiscal balance per GDP (*BOPY*^c), government balance per GDP (*GOVY*^c), and foreign reserve coverage for import goods (*RESMON*) get negative sign in almost all countries, implying inverse relationship between these variables and crisis probability. Moreover, we measured time lag between these variable and

crisis events averagely as 2 quarter. This indicates that any increase in these indicators decreases probability of crisis occurrence within 2 quarters.

Sixth, we introduce two new optimal threshold selection techniques, namely, False-to-True ratio (ϕ) and Risk Aversion rate (Ω). The ϕ is an augmented version of KLR's Noise-to-Signal ratio and it is the best methodology in theoretical ground that derives maximum accuracy for EWS by minimizing overall incorrectness of the model disregarding cost weights of type I and type II errors. In turn, the Ω is the most secure and risk-averse technique that considers minimizing type II error as well as overall incorrectness of EWS model. We comparatively evaluate prediction power our EWS models in 41 different countries with KLR's Noise-to-Signal (λ), Demirguc-Kunt and Detragiache (2000)'s Loss Function (θ), and with our two new threshold selection techniques. We observe that in nearly half of the sample θ , Ω , and ϕ finds the same cut-off probability level, while λ sets threshold at "crazy" levels. Averagely, θ , Ω , and ϕ correctly predict 96.13%, 96.36%, and 92.34% of total crisis events in advanced, while issuing 11.94%, 12.32%, and 8.36% false signals during tranquil periods. The λ forecasts only 49.36% of total crisis events with 0.05% of false signal issued during tranquil periods. In other words, if we regard statistics of ϕ method, the model successfully predicts 1218 crises out of 1319 total crisis events, while 334 times mistakenly sending signals during 3995 tranquil periods between 1980 and 2016 for 41 sampled countries.

Limitations and recommendation

As limitations of this study we can point three issues. First, unlike previous studies we have not carry out a panel analysis for a more generalized outlook. Because, each country has different threshold and tolerance rate which might be associated with their economic strength, smoothness of macro-dynamics, foundation of financial markets, and etc. With tolerance rate we actually mean the degree and level of vulnerability of economic activities whose disturbance might cause shrink in real output. This tolerance rate is latent in nature and its measurement might be very difficult. This research does not investigate measurement of tolerance rate of countries, thus, we simply cannot panelize the data and pursue panel analysis.

Due to its nature, the logit model estimation technique examines each explanatory variable separately and binarizes them by determining a certain level for each of them. In other words, if series exceeds the determined threshold level then it gets value of 1, and if otherwise it gets zero. This certain threshold indicates tolerance rate of each indicator and it varies across series as well as across countries. For instance, economy of Argentina and United States differs in many dimensions. A 100 bps increase in inflation rate (*CPI*) would emerge different reaction in Argentina and United States. Argentina might perceive this in tranquility as tolerable issue, while the United States might consider it as a serious issue. We represent these reactions as AG_{CPI}^{+100} and US_{CPI}^{+100} , where $AG_{CPI}^{+100} \neq US_{CPI}^{+100}$. In similar way, 200 bps decrease in balance-of-payment per GDP (*BOPY*) in these two country might generate different reactions and so consequences. So, $AG_{CPI}^{+100} \neq US_{CPI}^{+100} \neq AG_{BOPY}^{-100} \neq US_{BOPY}^{-100}$ is valid for this scenario. Taking into account these facts, if one still wants to panelize data in logit framework, then s/he should use dummy variables for each indicators used as explanatory variable as well as for the country itself in order to fix their within and between effects.

Second, due to binarization technique it would be difficult to measure magnitude of upcoming crisis. In other words, EWS will generate signal whenever crisis probability crosses critical threshold level, no matter how fold it exceeds. Thus, we cannot bring a straight-forward interpretation regarding magnitude of crisis, but only its probability.

Third, the probability of a crisis is a non-linear function of indicators in our EWS logit framework. Thus, we cannot bring a straight-forward interpretation of how much crisis probability would change following changes in indicators.

Fourth, we cannot determine tolerance rate (exact threshold level) for each indicator separately as it remains latent within EWS framework. In other words, our model won't give any information about indicator-specific threshold levels, but only country-specific threshold levels.

Fifth, our EWS model won't predict exact timing of a crisis, but it will show probability of occurrence of crisis within certain signal horizon or lag length time. This lag length or signal horizon is chosen by optimality through trade-off between two facts. First, economic disturbances tend to occur in a short time horizon rather

long-lasting weakening of economic fundamentals. One might expect that signaling of indicators will be significant, thus EWS model will issue better signals with high predictive accuracy as we approach closer to the actual time of crisis. Second, policy-makers would desire to have a considerable longer time length prior to the crisis in order to take significant preventive actions to fix the disturbance. In this respect, we define signalling horizon as 6 quarters. Although we bound the lags length with maximum -6 (past 6 quarters), we allow them to be dynamic for each indicator variables. Thus, the lag length dynamically varies between -1 quarter to -6 quarters across countries and indicator variables on the basis their significance in predicating crises.

Sixth, our EWS framework does not incorporate equity markets as proxy for contagion effects due to data limitation. This data is available only for few developed countries such as United States, United Kingdom, Germany, Canada, and Japan, but for majority of sampled countries the data lacks. However, we incorporate contagion effects into our EWS model by alternative three significant proxies: 1) Degree of trade interdependence between countries (*CON*); 2) Speculative and Expectation pressure of the markets (*SPEX*), and 3) World crude oil prices (*OIL*).

Lastly, this study does not carry out out-of sample analysis as data period is not sufficient for this analysis. But we believe that among existing literature our model performs better performance in in-sample analysis.

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APPENDICES

SECTION A1. Setup for NKPC Framework

The aggregate production of home economy can be present in CES function:

$$Y_t = \left[\int_0^1 Y_t(z)^{\frac{k-1}{k}} dz \right]^{\frac{k}{k-1}} \quad (A.01)$$

where k is elasticity between goods in the economy that are produced by z firms using inputs of labour, fixed capital, and other non-labour factors. Thus, the production function can be expressed as,

$$Y_t = \left[\alpha_L L_t(z)^{\frac{\gamma-1}{\gamma}} + \alpha_{H,NL} NL_{H,t}(z)^{\frac{\gamma-1}{\gamma}} + \alpha_{F,NL} NL_{F,t}(z)^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{(\gamma-1)\psi}} K^{\frac{\psi-1}{\psi}} \quad (A.02)$$

where $L_t(z)$, $NL_{H,t}(z)$, $NL_{F,t}(z)$, and K stand for labour, domestic non-labour, foreign non-labour, and fixed capital inputs in production process respectively. The parameter γ and ψ denote elasticity between inputs and weight of K in total production function. The total variable cost (TVC) function of z firms can be expressed as,

$$TVC_t(z) = W_t L_t(z) + P_{H,t} NL_{H,t}(z) + P_{F,t} NL_{F,t}(z) \quad (A.03)$$

where W , P_H , and P_F are wage cost paid for labour, domestic price of NL_H , and foreign price of NL_F respectively. In order to derive real total variable cost we deflate eq.(2.10) by consumer prices, P_t , as,

$$TVC_t(z) = \frac{W_t}{P_t} L_t(z) + \frac{P_{H,t}}{P_t} NL_{H,t}(z) + \frac{P_{F,t}}{P_t} NL_{F,t}(z) \quad (A.04)$$

Then, we use first order condition methodology and solve the cost minimization problem at (A.03) subject to the production constraint of (A.02).

$$L_t = Y_t(z)^\psi K^{1-\psi} \left[\alpha_L + \alpha_{H,NL} \left(\frac{\alpha_L P_{H,t}}{\alpha_{H,NL} W_t} \right)^{1-\gamma} + \alpha_{F,NL} \left(\frac{\alpha_L P_{F,t}}{\alpha_{F,NL} W_t} \right)^{1-\gamma} \right]^{\frac{\gamma}{(\gamma-1)}} \quad (A.05)$$

$$NL_{H,t} = Y_t(z)^\psi K^{1-\psi} \left[\alpha_{H,NL} + \alpha_L \left(\frac{\alpha_{H,NL} W_t}{\alpha_L P_{H,t}} \right)^{1-\gamma} + \alpha_{F,NL} \left(\frac{\alpha_{H,NL} P_{F,t}}{\alpha_{F,NL} P_{H,t}} \right)^{1-\gamma} \right]^{\frac{\gamma}{(\gamma-1)}} \quad (A.06)$$

$$NL_{F,t} = Y_t(z)^\psi K^{1-\psi} \left[\alpha_{F,NL} + \alpha_L \left(\frac{\alpha_{F,NL} W_t}{\alpha_L P_{F,t}} \right)^{1-\gamma} + \alpha_{H,NL} \left(\frac{\alpha_{F,NL} P_{H,t}}{\alpha_{H,NL} P_{F,t}} \right)^{1-\gamma} \right]^{\frac{\gamma}{(\gamma-1)}} \quad (A.07)$$

Putting eq.(A.05-07) into eq.(A.04) gives us real TVC,

$$\begin{aligned} TVC_t(z) = Y_t(z)^\psi K^{1-\psi} & \left[\frac{W_t}{P_t} \left(\alpha_L + \alpha_{H,NL} \left(\frac{\alpha_L P_{H,t}}{\alpha_{H,NL} W_t} \right)^{1-\gamma} + \alpha_{F,NL} \left(\frac{\alpha_L P_{F,t}}{\alpha_{F,NL} W_t} \right)^{1-\gamma} \right)^{\frac{\gamma}{(\gamma-1)}} \right. \\ & + \frac{P_{H,t}}{P_t} \left(\alpha_{H,NL} + \alpha_L \left(\frac{\alpha_{H,NL} W_t}{\alpha_L P_{H,t}} \right)^{1-\gamma} + \alpha_{F,NL} \left(\frac{\alpha_{H,NL} P_{F,t}}{\alpha_{F,NL} P_{H,t}} \right)^{1-\gamma} \right)^{\frac{\gamma}{(\gamma-1)}} \\ & \left. + \frac{P_{F,t}}{P_t} \left(\alpha_{F,NL} + \alpha_L \left(\frac{\alpha_{F,NL} W_t}{\alpha_L P_{F,t}} \right)^{1-\gamma} + \alpha_{H,NL} \left(\frac{\alpha_{F,NL} P_{H,t}}{\alpha_{H,NL} P_{F,t}} \right)^{1-\gamma} \right)^{\frac{\gamma}{(\gamma-1)}} \right] \\ TVC_t(z) = Y_t(z)^\psi \overline{MC}_t \quad (A.08) \end{aligned}$$

where $\overline{MC}_t$ is non-firm specific real marginal cost, and same for all z firms.

The firm specific real marginal cost can be derived by derivating real $TVC_t(z)$ with respect to firm's output, $Y_t(z)$.

$$MC_t(z) = \psi Y_t(z)^{\psi-1} \overline{MC}_t \quad (A.09)$$

The eq.(A.09) shows that firm-specific real marginal cost comprised of two components: firms' production output ($\psi Y_t(z)^{\psi-1}$) and non-firm specific real marginal cost ($\overline{MC}_t$). The second component, $\overline{MC}_t$, can be expressed as,

$$\overline{MC}_t = K^{1-\psi} \left[\alpha_N^\gamma \left(\frac{W_t}{P_t} \right)^{1-\gamma} + \alpha_H^\gamma \left(\frac{P_{H,t}}{P_t} \right)^{1-\gamma} + \alpha_F^\gamma \left(\frac{P_{F,t}}{P_t} \right)^{1-\gamma} \right]^{\frac{1}{1-\gamma}} \quad (A.10)$$

and can be further simplified by log-linearization as,

$$\overline{mc}_t = \frac{\frac{W^*}{P^*} w_t + \frac{P_H^*}{P^*} \left(\frac{\alpha_{H,NL} W^*}{\alpha_L P_H^*} \right)^\gamma p_{H,t} + \frac{P_F^*}{P^*} \left(\frac{\alpha_{F,NL} W^*}{\alpha_L P_F^*} \right)^\gamma p_{F,t}}{\frac{W^*}{P^*} + \frac{P_H^*}{P^*} \left(\frac{\alpha_{H,NL} W^*}{\alpha_L P_H^*} \right)^\gamma + \frac{P_F^*}{P^*} \left(\frac{\alpha_{F,NL} W^*}{\alpha_L P_F^*} \right)^\gamma} - p_t \quad (A.11)$$

where asterisk and lower case letters denote long-run level and deviations from long-run equilibrium respectively. Rewrite eq.(A.11) as,

$$\begin{aligned}\overline{mc}_t &= \frac{\frac{W^*}{P^*} w_t}{\frac{W^*}{P^*} + \frac{P_H^*}{P^*} \left(\frac{\alpha_{H,NL} W^*}{\alpha_L P_H^*} \right)^\gamma + \frac{P_F^*}{P^*} \left(\frac{\alpha_{F,NL} W^*}{\alpha_L P_F^*} \right)^\gamma} + \frac{\frac{P_H^*}{P^*} \left(\frac{\alpha_{H,NL} W^*}{\alpha_L P_H^*} \right)^\gamma p_{H,t}}{\frac{W^*}{P^*} + \frac{P_H^*}{P^*} \left(\frac{\alpha_{H,NL} W^*}{\alpha_L P_H^*} \right)^\gamma + \frac{P_F^*}{P^*} \left(\frac{\alpha_{F,NL} W^*}{\alpha_L P_F^*} \right)^\gamma} \\ &\quad + \frac{\frac{P_F^*}{P^*} \left(\frac{\alpha_{F,NL} W^*}{\alpha_L P_F^*} \right)^\gamma p_{F,t}}{\frac{W^*}{P^*} + \frac{P_H^*}{P^*} \left(\frac{\alpha_{H,NL} W^*}{\alpha_L P_H^*} \right)^\gamma + \frac{P_F^*}{P^*} \left(\frac{\alpha_{F,NL} W^*}{\alpha_L P_F^*} \right)^\gamma} - p_t \\ \overline{mc}_t &= \frac{\frac{W^*}{P^*} w_t}{\frac{W^*}{P^*} + \frac{P_H^*}{P^*} \frac{NL_{H,t}}{W_t} + \frac{P_F^*}{P^*} \frac{NL_{F,t}}{W_t}} + \frac{\frac{P_H^*}{P^*} \frac{NL_{H,t}}{W_t} p_{H,t}}{\frac{W^*}{P^*} + \frac{P_H^*}{P^*} \frac{NL_{H,t}}{W_t} + \frac{P_F^*}{P^*} \frac{NL_{F,t}}{W_t}} + \frac{\frac{P_F^*}{P^*} \frac{NL_{F,t}}{W_t} p_{F,t}}{\frac{W^*}{P^*} + \frac{P_H^*}{P^*} \frac{NL_{H,t}}{W_t} + \frac{P_F^*}{P^*} \frac{NL_{F,t}}{W_t}} - p_t \\ \overline{mc}_t &= \frac{W^* L^* w_t}{W^* L^* + P_H^* NL_{H,t}^* + P_F^* NL_{F,t}^*} + \frac{P_H^* NL_{H,t}^* p_{H,t}}{W^* L^* + P_H^* NL_{H,t}^* + P_F^* NL_{F,t}^*} \\ &\quad + \frac{P_F^* NL_{F,t}^* p_{F,t}}{W^* L^* + P_H^* NL_{H,t}^* + P_F^* NL_{F,t}^*} - p_t\end{aligned}$$

Then, divide both nominator and denominator by long-run real GDP , Y^* , and domestic prices, P_H , to get,

$$\begin{aligned}\overline{mc}_t &= \frac{\frac{W^* L^*}{P_H^* Y^*} w_t}{\frac{W^* L^*}{P_H^* Y^*} + \frac{P_H^* NL_{H,t}^*}{P_H^* Y^*} + \frac{P_F^* NL_{F,t}^*}{P_H^* Y^*}} + \frac{\frac{P_H^* NL_{H,t}^*}{P_H^* Y^*} p_{H,t}}{\frac{W^* L^*}{P_H^* Y^*} + \frac{P_H^* NL_{H,t}^*}{P_H^* Y^*} + \frac{P_F^* NL_{F,t}^*}{P_H^* Y^*}} + \frac{\frac{P_F^* NL_{F,t}^*}{P_H^* Y^*} p_{F,t}}{\frac{W^* L^*}{P_H^* Y^*} + \frac{P_H^* NL_{H,t}^*}{P_H^* Y^*} + \frac{P_F^* NL_{F,t}^*}{P_H^* Y^*}} - p_t \\ \overline{mc}_t &= \frac{s_L^* w_t}{s_L^* + s_{NL_H}^* + s_{NL_F}^*} + \frac{s_{NL_H}^* p_{H,t}}{s_L^* + s_{NL_H}^* + s_{NL_F}^*} + \frac{s_{NL_F}^* p_{F,t}}{s_L^* + s_{NL_H}^* + s_{NL_F}^*} - p_t\end{aligned}\tag{A.12}$$

where s_L^* , $s_{NL_H}^*$, and $s_{NL_F}^*$ are shares of domestic labour, domestic non-labour, and foreign non-labour costs in GDP respectively.

On the demand side, firms want to clear out all of their produced goods,

$$Y_t(z) = \mu P_t(z) Q_t(z)\tag{A.13}$$

where $P_t(z)$ and $Q_t(z)$ are price and demanded quantity for z at time t . Firm specific demanded quantity can be expressed as,

$$Q_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-k} Q_t \quad (A.14)$$

for all $z \in (0,1)$ where

$$P_t = \left(\int_{z=0}^1 P_t(z)^{1-k} dz \right)^{\frac{1}{1-k}} \quad (A.15)$$

Firms determine prices by Calvo (1983) rule where each firm update its new price, P_t^N , every period with a fixed probability of $(1-\theta)$. While θ fraction of firms keeps their prices unchanged. The aggregate price level in the economy becomes,

$$P_t = \theta P_{t-1} + (1 - \theta) P_t^N \quad (A.16)$$

Among Calvo price setters ω fraction of firms follow backward-looking rule of thumb in adjusting their prices taking into account only the past inflation. Remaining $(1-\omega)$ fraction of firms updates their prices optimally taking demand, cost conditions, as well as expectations into account. Thus, ω fraction of firms are called as backward -looking firms with new prices of P_t^b , while $(1-\omega)$ fraction of firms are called forward-looking firms with new prices of P_t^f . The new adjusted price level, P_t^N , is structured with these two prices as,

$$P_t^N = \omega P_t^b + (1 - \omega) P_t^f \quad (A.17)$$

where P_t^b can be expressed as,

$$P_t^b = P_{t-1}^N + \pi_{t-1} \quad (A.18)$$

The forward-looking firms optimize their price, P_t^f , in order to maximize their future real profits. The real profit of the firm at time t , $\dot{R}_t$, can be derived by subtracting real total variables costs from the real total production as,

$$\dot{R}_t(z) = \frac{P_t^f Y_t(z)}{P_t} - Y_t(z)^\psi \overline{MC}_t \quad (A.19)$$

As forward-looking firms consider all future real profits, we should discount all expected future $\dot{R}$.

$$\dot{R}_t(z) = E_t \sum_{i=0}^{\infty} \theta^i \beta^i \left(\frac{P_t^f Y_{t+i}(z)}{P_{t+i}} - Y_{t+i}(z)^\psi \overline{MC}_{t+i} \right) \quad (\text{A.20})$$

where β^i is subjective discount factor (between 0 and 1) at period i that forward-looking firms use to discount their future flows, and θ^i is probability that P_t^f is set at time t holding i periods ahead.

To solve firm's maximization problem, we shall use first-order condition methodology and differentiating eq.(A.20) with respect to P_t^f , then it is log-linearized as,

$$p_t^f = \left(\frac{1 - \theta\beta}{\psi} \right) E_t \sum_{i=0}^{\infty} \theta^i \beta^i (\overline{mc}_{t+i}) \quad (\text{A.21})$$

where small letters denote deviations from steady-state. We can rewrite eq.(A.21) in expectation form as,

$$p_t^f = \left(\frac{1 - \theta\beta}{\psi} \right) \overline{mc}_t + \left(\frac{1 - \theta\beta}{\psi} \right) E_t \sum_{i=1}^{\infty} \theta^i \beta^i (\overline{mc}_{t+i})$$

$$p_t^f = \left(\frac{1 - \theta\beta}{\psi} \right) \overline{mc}_t + E_t p_{t+1}^f \quad (\text{A.22})$$

The newly set price index, P_t^N , can be derived from eq.(A.16) as,

$$P_t^N = \frac{P_t - \theta P_{t-1}}{(1 - \theta)} \quad (\text{A.23})$$

and substitute it into eq.(A.17) as,

$$\frac{P_t - \theta P_{t-1}}{(1 - \theta)} = \omega P_t^b + (1 - \omega) P_t^f \quad (\text{A.24})$$

Substituting eq.(A.23) into eq.(A.18) we get,

$$P_t^b = \frac{P_{t-1} - \theta P_{t-2}}{(1 - \theta)} + \pi_{t-1} \quad (\text{A.25})$$

and we can rewrite eq.(A.24) as,

$$\frac{P_t - \theta P_{t-1}}{(1 - \theta)} = \omega \frac{P_{t-1} - \theta P_{t-2}}{(1 - \theta)} + \omega \pi_{t-1} + (1 - \omega) P_t^f \quad (\text{A.26})$$

From eq.(A.17) we can formulate P_t^f as,

$$P_t^f = \frac{(P_t^N - \omega P_t^b)}{1 - \omega} \quad (\text{A.27})$$

Thus, the expected P_t^f becomes,

$$E_t P_{t+1}^f = \frac{(E_t P_t^N - \omega E_t P_t^b)}{1 - \omega} \quad (\text{A.28})$$

Substituting eq.(A.18) and eq.(A.23) into eq.(A.28) gives us,

$$E_t P_{t+1}^f = \frac{1}{1 - \omega} \left[\frac{(E_t P_{t+1} - \theta P_t)}{1 - \theta} - \omega \left(\frac{P_t - P_{t-1}}{1 - \theta} + \pi_t \right) \right] \quad (\text{A.29})$$

and place eq.(A.29) into eq.(A.22) to get,

$$p_t^f = \left(\frac{1 - \theta\beta}{\psi} \right) \bar{m}\bar{c}_t + \frac{1}{1 - \omega} \left[\frac{(E_t P_{t+1} - \theta P_t)}{1 - \theta} - \omega \left(\frac{P_t - P_{t-1}}{1 - \theta} + \pi_t \right) \right] \quad (\text{A.30})$$

Eventually, place eq.(A.30) into eq.(A.26) to get final shape of hybrid NKPC framework,

$$\begin{aligned} \frac{P_t - \theta P_{t-1}}{(1 - \theta)} &= \omega \frac{P_{t-1} - \theta P_{t-2}}{(1 - \theta)} + \omega \pi_{t-1} + \left(\frac{(1 - \omega)(1 - \theta\beta)}{\psi} \right) \bar{m}\bar{c}_t \\ &+ \left[\frac{(E_t P_{t+1} - \theta P_t)}{1 - \theta} - \omega \left(\frac{P_t - P_{t-1}}{1 - \theta} + \pi_t \right) \right] \end{aligned} \quad (\text{A.31})$$

where price is formulized with only in its leads and lag as well as $\bar{m}\bar{c}$. With a little mathematical simplifications, eq.(A.31) can be rewritten as,

$$\pi_t = \frac{\omega}{\phi} \pi_{t-1} + \frac{\beta\theta}{\phi} E_t \pi_{t+1} + \frac{(1 - \omega)(1 - \theta)(1 - \theta\beta)}{\psi\phi} \bar{m}\bar{c}_t \quad (\text{A.32})$$

where $\phi = \theta + \omega[1 - \theta(1 - \beta)]$, and π_{t-1} , $E_t \pi_{t+1}$, and $\bar{m}\bar{c}_t$ are past period's inflation, expected next period's inflation, and real marginal cost in log-deviations respectively. Further, if we $\bar{m}\bar{c}_t$ can be separated into two components: labour-related costs and non-labour related costs as following.

$$\pi_t = \frac{\omega}{\phi} \pi_{t-1} + \frac{\beta\theta}{\phi} E_t \pi_{t+1} + \frac{(1-\omega)(1-\theta)(1-\theta\beta)}{\psi\phi} (\rho \overline{mc}_t^L + (1-\rho) \overline{mc}_t^{NL}) \quad (A.33)$$

where ρ indicates fraction of labour-related costs within the real marginal costs, while $1-\rho$ indicates fraction of non-labour related costs in the real marginal costs.

Table A1. Country Codes and Number of Recessions Different Time Periods

Country Name	Code	1980-1990	1990-2000	1980-2016	1990-2016	2000-2016
		40 quarters	40 quarters	145 quarters	105 quarters	65 quarters
Argentina	AG	22	17	55	33	16
Australia	AU	9	3	15	6	3
Germany	BD	13	13	42	29	16
Belgium	BG	6	6	23	17	11
Brazil	BR	19	16	51	32	16
Canada	CH	8	3	11	3	0
Chile	CL	10	8	32	22	14
China	CN	11	4	23	12	8
Czech Republic	CZ	-	13	24	24	11
Denmark	DK	15	11	50	35	24
Spain	ES	9	6	32	23	17
Finland	FN	5	15	43	38	23
France	FR	2	5	22	20	15
Greece	GR	21	14	75	54	40
Hungary	HN	-	17	27	27	10
Indonesia	ID	9	7	17	8	1
India	IN	10	9	24	14	5
Ireland	IR	15	11	47	32	21
Italy	IT	7	13	47	40	27
Japan	JP	6	16	46	40	24
South Korea	KO	4	4	11	7	3
Mexico	MX	16	4	31	15	11
Malaysia	MY	3	3	13	10	7
Netherlands	NL	11	3	31	20	17
Norway	NW	12	12	44	32	20
Austria	OE	10	2	32	22	20
Philippines	PH	11	7	21	10	3
Poland	PO	-	7	15	15	8
Portugal	PT	4	7	37	33	26
Romania	RM	19	23	56	37	14
Russia	RS	-	26	37	37	11
South Africa	SA	11	12	28	17	5
Sweden	SD	9	11	32	23	12
Singapore	SP	3	5	24	21	16
Switzerland	SW	6	13	31	25	12
Thailand	TH	10	8	29	19	11
Turkey	TK	19	18	47	28	10
Taiwan	TW	6	4	30	24	20
United Kingdom	UK	5	6	18	13	7
United States	US	6	2	18	12	10
Venezuela	VE	20	13	53	33	20

Notes: Numbers in the table show the quarter numbers with negative GDP growth (recession). The "-" denote missing data.

Table A2. Results of Unit Root Tests for Series of Traditional PC and EAPC

	ADF (intercept)			PP (intercept)		
	CPI	EI	U_U'	CPI	EI	U_U'
AG	0.0791 (L:2 N:126)	0.0508 (L:2 N:126)	0.0001 (L:0 N:144)	0.0000 (B:7 N:128)	0.0000 (B:7 N:128)	0.0000 (B:2 N:144)
AU	0.0008 (L:1 N:143)	0.0000 (L:0 N:144)	0.0010 (L:2 N:142)	0.0000 (B:8 N:144)	0.0000 (B:7 N:144)	0.0423 (B:6 N:144)
BD	0.1003 (L:3 N:141)	0.0355 (L:3 N:141)	0.0419 (L:4 N:140)	0.0000 (B:10 N:144)	0.0000 (B:10 N:144)	0.0008 (B:9 N:144)
BG	0.0000 (L:0 N:144)	0.0350 (L:1 N:143)	0.4779 (L:3 N:141)	0.0000 (B:9 N:144)	0.0001 (B:9 N:144)	0.0718 (B:3 N:144)
BR	0.2191 (L:2 N:103)	0.115 (L:3 N:103)	0.0000 (L:8 N:136)	0.0993 (B:1 N:105)	0.2073 (B:6 N:106)	0.0000 (B:8 N:144)
CH	0.0045 (L:4 N:140)	0.0040 (L:4 N:140)	0.0000 (L:1 N:143)	0.0000 (B:10 N:144)	0.0000 (B:10 N:144)	0.0172 (B:5 N:144)
CL	0.7175 (L:7 N:137)	0.7916 (L:7 N:137)	0.0002 (L:1 N:119)	0.0000 (B:8 N:144)	0.0001 (B:7 N:144)	0.0007 (B:4 N:120)
CN	0.0173 (L:3 N:141)	0.0106 (L:2 N:142)	0.0431 (L:0 N:144)	0.0000 (B:8 N:144)	0.0084 (B:4 N:144)	0.0241 (B:4 N:144)
CZ	0.0677 (L:3 N:96)	0.0002 (L:0 N:100)	0.0081 (L:5 N:87)	0.0000 (B:3 N:99)	0.0000 (B:17 N:100)	0.0509 (B:3 N:92)
DK	0.0361 (L:4 N:140)	0.0273 (L:3 N:141)	0.5460 (L:1 N:143)	0.0000 (B:10 N:144)	0.0000 (B:9 N:144)	0.2476 (B:7 N:144)
ES	0.3683 (L:7 N:137)	0.0393 (L:7 N:137)	0.6306 (L:1 N:143)	0.0000 (B:8 N:144)	0.0003 (B:10 N:144)	0.3053 (B:7 N:144)
FN	0.0154 (L:4 N:140)	0.0120 (L:4 N:140)	0.0001 (L:4 N:140)	0.0000 (B:10 N:144)	0.0001 (B:10 N:144)	0.0282 (B:9 N:144)
FR	0.0308 (L:11 N:133)	0.0239 (L:0 N:144)	0.0159 (L:1 N:143)	0.0055 (B:9 N:144)	0.0298 (B:12 N:144)	0.0371 (B:4 N:144)
GR	0.3312 (L:4 N:140)	0.5571 (L:4 N:140)	0.0000 (L:8 N:136)	0.0000 (B:10 N:144)	0.0000 (B:11 N:144)	0.036 (B:7 N:144)
HN	0.3649 (L:3 N:141)	0.4055 (L:6 N:138)	0.0098 (L:1 N:99)	0.0000 (B:10 N:144)	0.0000 (B:11 N:144)	0.0714 (B:0 N:100)
ID	0.0000 (L:0 N:144)	0.0000 (L:1 N:143)	0.0000 (L:4 N:140)	0.0000 (B:1 N:144)	0.0018 (B:9 N:144)	0.0015 (B:2 N:144)
IN	0.0031 (L:3 N:141)	0.0009 (L:4 N:140)	0.0000 (L:4 N:140)	0.0000 (B:9 N:144)	0.0000 (B:10 N:144)	0.0000 (B:10 N:144)
IR	0.0067 (L:4 N:140)	0.0011 (L:4 N:140)	0.1113 (L:2 N:142)	0.0000 (B:7 N:144)	0.0000 (B:3 N:144)	0.0652 (B:8 N:144)
IT	0.0061 (L:8 N:136)	0.0001 (L:9 N:135)	0.0024 (L:0 N:144)	0.0673 (B:9 N:144)	0.0881 (B:10 N:144)	0.0027 (B:6 N:144)
JP	0.0001 (L:1 N:143)	0.0086 (L:2 N:142)	0.6762 (L:0 N:144)	0.0000 (B:9 N:144)	0.0000 (B:8 N:144)	0.3394 (B:6 N:144)
KO	0.0001 (L:3 N:141)	0.0149 (L:2 N:142)	0.1671 (L:2 N:142)	0.0000 (B:8 N:144)	0.0000 (B:9 N:144)	0.0440 (B:5 N:144)
MX	0.0415 (L:0 N:144)	0.3655 (L:9 N:135)	0.0414 (L:4 N:140)	0.0672 (B:7 N:144)	0.0901 (B:6 N:144)	0.0567 (B:6 N:144)
MY	0.0000 (L:0 N:144)	0.0027 (L:1 N:143)	0.0006 (L:0 N:124)	0.0000 (B:4 N:144)	0.0000 (B:8 N:144)	0.001 (B:4 N:124)

Table A2. (continues)

	ADF (intercept)			PP (intercept)		
	CPI	EI	U_U'	CPI	EI	U_U'
NL	0.0274 (L:3 N:141)	0.0040 (L:4 N:140)	0.1580 (L:12 N:132)	0.0000 (B:10 N:144)	0.0000 (B:10 N:144)	0.0557 (B:5 N:144)
NW	0.0602 (L:3 N:141)	0.0000 (L:3 N:141)	0.2180 (L:0 N:144)	0.0000 (B:9 N:144)	0.0000 (B:10 N:144)	0.0848 (B:5 N:144)
OE	0.0059 (L:4 N:140)	0.0101 (L:3 N:141)	0.0842 (L:0 N:144)	0.0000 (B:9 N:144)	0.0000 (B:9 N:144)	0.1008 (B:1 N:144)
PH	0.0002 (L:2 N:142)	0.0005 (L:2 N:142)	0.0001 (L:4 N:140)	0.0000 (B:7 N:144)	0.0000 (B:7 N:144)	0.0000 (B:9 N:144)
PO	0.0964 (L:9 N:108)	0.2312 (L:6 N:112)	0.0066 (L:2 N:106)	0.0001 (B:3 N:117)	0.0076 (B:3 N:118)	0.0768 (B:6 N:108)
PT	0.5028 (L:7 N:137)	0.3723 (L:7 N:137)	0.1767 (L:1 N:143)	0.0000 (B:10 N:144)	0.0005 (B:10 N:144)	0.0000 (B:9 N:144)
RM	0.0000 (L:0 N:101)	0.0000 (L:0 N:102)	0.0001 (L:4 N:108)	0.0000 (B:8 N:101)	0.0000 (B:8 N:102)	0.0022 (B:7 N:112)
RS	0.1050 (L:2 N:97)	0.1158 (L:1 N:99)	0.0004 (L:4 N:100)	0.0002 (B:3 N:99)	0.0410 (B:2 N:100)	0.0006 (B:7 N:104)
SA	0.0364 (L:2 N:142)	0.2099 (L:2 N:142)	0.0000 (L:5 N:139)	0.0000 (B:7 N:144)	0.0007 (B:9 N:144)	0.0000 (B:10 N:144)
SD	0.1198 (L:3 N:141)	0.0463 (L:3 N:141)	0.1913 (L:1 N:143)	0.0000 (B:9 N:144)	0.0002 (B:9 N:144)	0.1991 (B:7 N:144)
SP	0.0000 (L:0 N:144)	0.0035 (L:3 N:141)	0.0000 (L:1 N:143)	0.0000 (B:4 N:144)	0.0000 (B:3 N:144)	0.0159 (B:10 N:144)
SW	0.0496 (L:4 N:140)	0.1493 (L:3 N:141)	0.0000 (L:1 N:143)	0.0000 (B:10 N:144)	0.0000 (B:9 N:144)	0.0228 (B:7 N:144)
TH	0.0000 (L:0 N:144)	0.0003 (L:1 N:143)	0.0000 (L:4 N:140)	0.0000 (B:7 N:144)	0.0000 (B:6 N:144)	0.0002 (B:1 N:144)
TK	0.5735 (L:3 N:141)	0.6090 (L:2 N:142)	0.0000 (L:8 N:136)	0.0000 (B:9 N:144)	0.0099 (B:7 N:144)	0.0000 (B:10 N:144)
TW	0.0000 (L:3 N:141)	0.0042 (L:6 N:138)	0.1369 (L:5 N:139)	0.0000 (B:7 N:144)	0.0000 (B:6 N:144)	0.1121 (B:9 N:144)
UK	0.0117 (L:4 N:140)	0.0089 (L:4 N:140)	0.0413 (L:2 N:142)	0.0000 (B:10 N:144)	0.0000 (B:9 N:144)	0.0064 (B:8 N:144)
US	0.0002 (L:2 N:142)	0.0000 (L:4 N:140)	0.0295 (L:5 N:139)	0.0000 (B:7 N:144)	0.0000 (B:3 N:144)	0.0022 (B:6 N:144)
VE	0.0074 (L:0 N:143)	0.4144 (L:0 N:111)	0.0000 (L:4 N:140)	0.0095 (B:8 N:143)	0.2463 (B:2 N:111)	0.0000 (B:9 N:144)

Notes: The numbers in the table are rejection probabilities of the null hypotheses of ADF and PP tests including intercept. Probabilities below 0.10 denote rejection of these null hypotheses, thus, confirm stationarity of the CPI (inflation), EI (expected inflation), and U_U' (unemployment gap) series of related countries. The lag and observation parameters are presented in the parentheses where "L", "B", and "N" denote lag length, Newey-West bandwidth using Bartlett kernel, and observation number respectively. The lag length is determined by Schwarz Information Criterion (SIC) under maximum lag length specification of 13.

Table A3. Results of ADF Unit Root Test for NKPC Series

	ADF (intercept)					
	DEF	IP	IR	ULC_C	WI	Y_C
AG	0.0354 (L:2 N:123)	0.0150 (L:2 N:122)	0.1414 (L:4 N:139)	0.0005 (L:5 N:110)	0.0557 (L:10 N:93)	0.0000 (L:3 N:140)
AU	0.0009 (L:1 N:141)	0.0000 (L:0 N:140)	0.7244 (L:8 N:135)	0.0000 (L:7 N:136)	0.0000 (L:0 N:142)	0.0043 (L:0 N:143)
BD	0.0732 (L:3 N:139)	0.0000 (L:3 N:137)	0.0679 (L:1 N:142)	0.0007 (L:0 N:143)	0.0000 (L:0 N:142)	0.0024 (L:0 N:143)
BG	0.0000 (L:0 N:142)	0.0000 (L:0 N:141)	0.0679 (L:1 N:142)	0.0001 (L:2 N:140)	0.0000 (L:1 N:141)	0.0000 (L:2 N:141)
BR	0.0000 (L:0 N:103)	0.0000 (L:0 N:140)	0.0001 (L:1 N:142)	0.0055 (L:10 N:76)	0.0001 (L:3 N:84)	0.0008 (L:8 N:135)
CH	0.0000 (L:0 N:142)	0.0000 (L:0 N:141)	0.9141 (L:0 N:143)	0.0000 (L:5 N:137)	0.0008 (L:0 N:142)	0.0005 (L:2 N:141)
CL	0.0000 (L:1 N:141)	0.0000 (L:0 N:141)	0.0228 (L:1 N:142)	0.0023 (L:1 N:141)	0.0000 (L:0 N:118)	0.0005 (L:0 N:143)
CN	0.0000 (L:0 N:142)	0.0000 (L:0 N:140)	0.3951 (L:1 N:142)	0.0002 (L:0 N:143)	0.0020 (L:2 N:140)	0.0001 (L:1 N:142)
CZ	0.0000 (L:0 N:90)	0.0000 (L:0 N:90)	0.0002 (L:0 N:91)	0.0009 (L:0 N:91)	0.0005 (L:0 N:82)	0.0028 (L:4 N:87)
DK	0.0000 (L:0 N:142)	0.0000 (L:0 N:141)	0.1131 (L:0 N:143)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0000 (L:0 N:143)
ES	0.0105 (L:4 N:138)	0.0000 (L:0 N:140)	0.0679 (L:1 N:142)	0.0001 (L:0 N:142)	0.0403 (L:2 N:140)	0.0002 (L:3 N:140)
FN	0.0096 (L:3 N:139)	0.0000 (L:0 N:141)	0.0679 (L:1 N:142)	0.0000 (L:0 N:143)	0.0011 (L:2 N:140)	0.0000 (L:3 N:140)
FR	0.0464 (L:1 N:141)	0.0000 (L:0 N:141)	0.0679 (L:1 N:142)	0.0000 (L:0 N:143)	0.0001 (L:1 N:141)	0.0000 (L:2 N:141)
GR	0.0935 (L:2 N:140)	0.0203 (L:3 N:137)	0.0679 (L:1 N:142)	0.0000 (L:0 N:142)	0.0000 (L:0 N:82)	0.0006 (L:5 N:138)
HN	0.0000 (L:0 N:98)	0.0069 (L:3 N:94)	0.8147 (L:1 N:98)	0.0001 (L:1 N:90)	0.0231 (L:4 N:63)	0.0036 (L:1 N:98)
ID	0.0000 (L:0 N:142)	0.0007 (L:3 N:126)	0.0018 (L:1 N:142)	0.0000 (L:5 N:137)	0.0000 (L:4 N:138)	0.0011 (L:0 N:143)
IN	0.0000 (L:4 N:138)	0.0000 (L:1 N:140)	0.7940 (L:0 N:143)	0.0000 (L:2 N:140)	0.0001 (L:0 N:142)	0.0000 (L:4 N:139)
IR	0.0001 (L:1 N:141)	0.0000 (L:0 N:138)	0.0679 (L:1 N:142)	0.0000 (L:0 N:143)	0.0000 (L:1 N:141)	0.0001 (L:3 N:140)
IT	0.0270 (L:3 N:139)	0.0000 (L:0 N:141)	0.0679 (L:1 N:142)	0.0000 (L:4 N:139)	0.0019 (L:1 N:141)	0.0000 (L:3 N:140)
JP	0.0004 (L:2 N:140)	0.0000 (L:2 N:138)	0.2304 (L:3 N:140)	0.0000 (L:0 N:143)	0.0000 (L:0 N:142)	0.0003 (L:0 N:143)
KO	0.0000 (L:1 N:141)	0.0000 (L:0 N:140)	0.3219 (L:4 N:139)	0.0000 (L:0 N:143)	0.0256 (L:4 N:138)	0.0000 (L:3 N:140)
MX	0.0755 (L:0 N:142)	0.0000 (L:0 N:140)	0.0034 (L:10 N:65)	0.0002 (L:0 N:142)	0.0558 (L:4 N:138)	0.0000 (L:1 N:142)
MY	0.0000 (L:1 N:141)	0.0000 (L:1 N:140)	0.0683 (L:2 N:141)	0.0304 (L:3 N:115)	0.0142 (L:8 N:114)	0.0000 (L:1 N:142)

Table A3. (continues)

	ADF (intercept)					
	DEF	IP	IR	ULC_C	WI	Y_C
NL	0.0000 (L:0 N:142)	0.0000 (L:0 N:141)	0.0679 (L:1 N:142)	0.0000 (L:1 N:142)	0.0000 (L:1 N:141)	0.0012 (L:0 N:143)
NW	0.0000 (L:0 N:142)	0.0000 (L:0 N:140)	0.1932 (L:1 N:142)	0.0012 (L:1 N:141)	0.0000 (L:0 N:142)	0.0005 (L:1 N:142)
OE	0.0000 (L:0 N:142)	0.0000 (L:0 N:141)	0.0679 (L:1 N:142)	0.0000 (L:2 N:141)	0.0000 (L:1 N:141)	0.0004 (L:1 N:142)
PH	0.0313 (L:0 N:138)	0.0004 (L:3 N:138)	0.0684 (L:0 N:143)	0.0003 (L:0 N:118)	0.0230 (L:0 N:142)	0.0002 (L:0 N:143)
PO	0.0003 (L:0 N:106)	0.0000 (L:0 N:105)	0.1022 (L:8 N:99)	0.0052 (L:4 N:138)	0.0000 (L:2 N:104)	0.0000 (L:0 N:107)
PT	0.0008 (L:0 N:119)	0.0003 (L:0 N:141)	0.0679 (L:1 N:142)	0.0015 (L:0 N:142)	0.0562 (L:4 N:138)	0.0016 (L:0 N:143)
RM	0.0216 (L:5 N:98)	0.0115 (L:8 N:94)	0.6255 (L:1 N:102)	0.0036 (L:0 N:106)	0.0922 (L:0 N:86)	0.0004 (L:4 N:139)
RS	0.0817 (L:0 N:102)	0.0106 (L:4 N:97)	0.2493 (L:1 N:102)	0.0812 (L:0 N:102)	0.0000 (L:0 N:86)	0.0005 (L:3 N:100)
SA	0.0000 (L:0 N:142)	0.0000 (L:0 N:139)	0.1131 (L:1 N:142)	0.0016 (L:0 N:142)	0.0399 (L:4 N:138)	0.0000 (L:2 N:141)
SD	0.0364 (L:4 N:138)	0.0000 (L:0 N:141)	0.4902 (L:8 N:135)	0.0000 (L:0 N:143)	0.0000 (L:1 N:141)	0.0000 (L:3 N:140)
SP	0.0000 (L:0 N:140)	0.0000 (L:1 N:139)	0.0168 (L:3 N:140)	0.0000 (L:0 N:142)	0.0760 (L:4 N:66)	0.0000 (L:3 N:140)
SW	0.0620 (L:3 N:139)	0.0001 (L:3 N:137)	0.1276 (L:2 N:141)	0.0000 (L:4 N:139)	0.0000 (L:0 N:142)	0.0002 (L:1 N:142)
TH	0.0000 (L:0 N:142)	0.0000 (L:8 N:133)	0.0239 (L:4 N:139)	0.0001 (L:1 N:109)	0.0003 (L:5 N:137)	0.0001 (L:4 N:139)
TK	0.0874 (L:11 N:131)	0.0000 (L:1 N:140)	0.7452 (L:4 N:139)	0.0000 (L:0 N:110)	0.0044 (L:1 N:102)	0.0002 (L:8 N:135)
TW	0.0613 (L:3 N:137)	0.0000 (L:0 N:140)	0.1726 (L:2 N:141)	0.0001 (L:1 N:109)	0.0047 (L:1 N:141)	0.0000 (L:0 N:143)
UK	0.0000 (L:3 N:139)	0.0000 (L:0 N:140)	0.2764 (L:1 N:142)	0.0000 (L:0 N:143)	0.0000 (L:1 N:141)	0.0001 (L:2 N:141)
US	0.0016 (L:1 N:141)	0.0000 (L:1 N:139)	0.3550 (L:1 N:142)	0.0013 (L:1 N:142)	0.0000 (L:0 N:142)	0.0003 (L:2 N:141)
VE	0.0042 (L:4 N:138)	0.0000 (L:4 N:137)	0.1070 (L:4 N:139)	0.0000 (L:0 N:110)	0.0000 (L:0 N:102)	0.0002 (L:8 N:135)

Notes: The numbers in the table are rejection probabilities of the null hypothesis of ADF test including intercept. Probabilities below 0.10 denote rejection of the null hypothesis, thus, confirm stationarity of the DEF (inflation), IP (import prices), IR (interest rate), ULC_C (marginal labor cost gap), WI (wage inflation), and Y_C (output gap) series of related countries. The lag and observation parameters are presented in the parentheses where "L" and "N" denote lag length and observation number respectively. The lag length is determined by Schwarz Information Criterion (SIC) under maximum lag length specification of 13.

Table A4. Results of PP Unit Root Test for NKPC Series

	PP (intercept)					
	DEF	IP	IR	ULC_C	WI	Y_C
AG	0.0000 (B:7 N:125)	0.0000 (B:8 N:124)	0.0166 (B:4 N:143)	0.0282 (B:1 N:115)	0.0000 (B:5 N:103)	0.0014 (B:3 N:143)
AU	0.0000 (B:5 N:142)	0.0000 (B:10 N:140)	0.5640 (B:6 N:143)	0.0004 (B:4 N:143)	0.0000 (B:4 N:142)	0.0007 (B:4 N:143)
BD	0.0000 (B:8 N:142)	0.0000 (B:7 N:140)	0.5143 (B:7 N:143)	0.0001 (B:5 N:143)	0.0000 (B:6 N:142)	0.0004 (B:5 N:143)
BG	0.0000 (B:4 N:142)	0.0000 (B:5 N:141)	0.5143 (B:7 N:143)	0.0016 (B:4 N:142)	0.0000 (B:3 N:142)	0.0003 (B:4 N:143)
BR	0.0000 (B:6 N:103)	0.0000 (B:1 N:140)	0.0009 (B:6 N:143)	0.0039 (B:3 N:86)	0.0001 (B:28 N:87)	0.0000 (B:9 N:143)
CH	0.0000 (B:5 N:142)	0.0000 (B:4 N:141)	0.8413 (B:5 N:143)	0.0019 (B:2 N:142)	0.0006 (B:5 N:142)	0.0000 (B:2 N:143)
CL	0.0000 (B:8 N:142)	0.0000 (B:4 N:141)	0.0265 (B:12 N:143)	0.0151 (B:3 N:142)	0.0000 (B:1 N:118)	0.0001 (B:7 N:143)
CN	0.0000 (B:13 N:142)	0.0000 (B:5 N:140)	0.4000 (B:3 N:143)	0.0001 (B:3 N:143)	0.0000 (B:6 N:142)	0.0043 (B:2 N:143)
CZ	0.0000 (B:4 N:90)	0.0000 (B:1 N:90)	0.0007 (B:1 N:91)	0.0006 (B:3 N:91)	0.0004 (B:2 N:82)	0.0035 (B:3 N:91)
DK	0.0000 (B:5 N:142)	0.0000 (B:4 N:141)	0.1134 (B:1 N:143)	0.0000 (B:1 N:142)	0.0000 (B:7 N:142)	0.0000 (B:6 N:143)
ES	0.0011 (B:1 N:142)	0.0000 (B:6 N:140)	0.5143 (B:7 N:143)	0.0001 (B:2 N:142)	0.0000 (B:7 N:142)	0.0227 (B:4 N:143)
FN	0.0000 (B:8 N:142)	0.0000 (B:2 N:141)	0.5143 (B:7 N:143)	0.0000 (B:8 N:143)	0.0000 (B:7 N:142)	0.0034 (B:6 N:143)
FR	0.0319 (B:15 N:142)	0.0000 (B:5 N:141)	0.5143 (B:7 N:143)	0.0000 (B:6 N:143)	0.0000 (B:5 N:142)	0.0032 (B:4 N:143)
GR	0.0000 (B:7 N:142)	0.0000 (B:8 N:140)	0.5143 (B:7 N:143)	0.0000 (B:5 N:142)	0.0000 (B:4 N:82)	0.0000 (B:8 N:143)
HN	0.0000 (B:3 N:98)	0.0000 (B:11 N:97)	0.8488 (B:5 N:99)	0.0040 (B:2 N:91)	0.0347 (B:4 N:67)	0.0174 (B:1 N:99)
ID	0.0000 (B:4 N:142)	0.0000 (B:9 N:129)	0.0077 (B:1 N:143)	0.0039 (B:5 N:142)	0.0000 (B:11 N:142)	0.0011 (B:0 N:143)
IN	0.0000 (B:8 N:142)	0.0000 (B:6 N:141)	0.8055 (B:3 N:143)	0.0132 (B:0 N:142)	0.0002 (B:3 N:142)	0.0000 (B:8 N:143)
IR	0.0000 (B:7 N:142)	0.0000 (B:4 N:138)	0.5143 (B:7 N:143)	0.0000 (B:2 N:143)	0.0000 (B:6 N:142)	0.0017 (B:3 N:143)
IT	0.0000 (B:9 N:142)	0.0000 (B:5 N:141)	0.5143 (B:7 N:143)	0.0000 (B:7 N:143)	0.0000 (B:5 N:142)	0.005 (B:1 N:143)
JP	0.0000 (B:8 N:142)	0.0000 (B:2 N:140)	0.2348 (B:3 N:143)	0.0000 (B:4 N:143)	0.0000 (B:6 N:142)	0.0001 (B:4 N:143)
KO	0.0000 (B:7 N:142)	0.0000 (B:13 N:140)	0.0114 (B:6 N:143)	0.0000 (B:6 N:143)	0.0000 (B:6 N:142)	0.0000 (B:1 N:143)
MX	0.0117 (B:2 N:142)	0.0000 (B:8 N:140)	0.3937 (B:5 N:75)	0.0002 (B:3 N:142)	0.0001 (B:9 N:142)	0.0004 (B:2 N:143)
MY	0.0000 (B:11 N:142)	0.0000 (B:2 N:141)	0.0538 (B:1 N:143)	0.0000 (B:7 N:118)	0.0001 (B:15 N:122)	0.0012 (B:5 N:143)

Table A4. (continues)

	PP (intercept)					
	DEF	IP	IR	ULC_C	WI	Y_C
NL	0.0000 (B:7 N:142)	0.0000 (B:0 N:141)	0.5143 (B:7 N:143)	0.0000 (B:5 N:143)	0.0000 (B:6 N:142)	0.0005 (B:3 N:143)
NW	0.0000 (B:4 N:142)	0.0000 (B:3 N:140)	0.5136 (B:4 N:143)	0.0011 (B:3 N:142)	0.0000 (B:8 N:142)	0.0000 (B:6 N:143)
OE	0.0000 (B:7 N:142)	0.0000 (B:5 N:141)	0.5143 (B:7 N:143)	0.0000 (B:4 N:143)	0.0000 (B:6 N:142)	0.0002 (B:2 N:143)
PH	0.0177 (B:4 N:138)	0.0000 (B:10 N:141)	0.0748 (B:3 N:143)	0.0002 (B:5 N:118)	0.0100 (B:3 N:142)	0.0001 (B:5 N:143)
PO	0.0003 (B:6 N:106)	0.0000 (B:8 N:105)	0.1188 (B:53 N:107)	0.0076 (B:8 N:142)	0.0000 (B:0 N:106)	0.0000 (B:8 N:107)
PT	0.0008 (B:0 N:119)	0.0004 (B:4 N:141)	0.5143 (B:7 N:143)	0.0031 (B:6 N:142)	0.0000 (B:11 N:142)	0.0006 (B:6 N:143)
RM	0.0000 (B:6 N:103)	0.0000 (B:8 N:102)	0.5642 (B:5 N:103)	0.0036 (B:0 N:106)	0.0819 (B:4 N:86)	0.0027 (B:7 N:143)
RS	0.0674 (B:6 N:102)	0.0000 (B:8 N:101)	0.3292 (B:5 N:103)	0.0820 (B:2 N:102)	0.0000 (B:3 N:86)	0.0002 (B:3 N:103)
SA	0.0000 (B:0 N:142)	0.0000 (B:3 N:139)	0.0171 (B:7 N:143)	0.0014 (B:1 N:142)	0.0094 (B:15 N:142)	0.0007 (B:3 N:143)
SD	0.0000 (B:6 N:142)	0.0000 (B:4 N:141)	0.7433 (B:11 N:143)	0.0000 (B:6 N:143)	0.0000 (B:6 N:142)	0.0000 (B:5 N:143)
SP	0.0000 (B:2 N:140)	0.0000 (B:5 N:140)	0.1684 (B:9 N:143)	0.0000 (B:1 N:142)	0.0054 (B:3 N:70)	0.0013 (B:1 N:143)
SW	0.0000 (B:7 N:142)	0.0000 (B:2 N:140)	0.2909 (B:6 N:143)	0.0003 (B:4 N:143)	0.0000 (B:6 N:142)	0.0099 (B:1 N:143)
TH	0.0000 (B:5 N:142)	0.0000 (B:9 N:141)	0.0601 (B:10 N:143)	0.0012 (B:8 N:110)	0.0015 (B:23 N:142)	0.0000 (B:8 N:143)
TK	0.0000 (B:10 N:142)	0.0000 (B:7 N:141)	0.1614 (B:5 N:143)	0.0000 (B:3 N:110)	0.0000 (B:6 N:103)	0.0000 (B:10 N:143)
TW	0.0000 (B:9 N:140)	0.0000 (B:7 N:140)	0.2682 (B:5 N:143)	0.0000 (B:6 N:110)	0.0009 (B:4 N:142)	0.0000 (B:1 N:143)
UK	0.0000 (B:8 N:142)	0.0000 (B:0 N:140)	0.3167 (B:4 N:143)	0.0000 (B:2 N:143)	0.0000 (B:5 N:142)	0.0003 (B:5 N:143)
US	0.0024 (B:5 N:142)	0.0000 (B:8 N:140)	0.1835 (B:5 N:143)	0.0000 (B:6 N:143)	0.0000 (B:6 N:142)	0.0005 (B:3 N:143)
VE	0.0000 (B:9 N:142)	0.0000 (B:5 N:141)	0.0547 (B:6 N:143)	0.0000 (B:3 N:110)	0.0000 (B:3 N:102)	0.0000 (B:9 N:143)

Notes: The numbers in the table are rejection probabilities of the null hypothesis of PP test including intercept. Probabilities below 0.10 denote rejection of the null hypothesis, thus, confirm stationarity of the DEF (inflation), IP (import prices), IR (interest rate), ULC_C (marginal labor cost gap), WI (wage inflation), and Y_C (output gap) series of related countries. The lag and observation parameters are presented in the parentheses where "B" and "N" denote Newey-West bandwidth using Bartlett kernel and observation number respectively.

Table B1. Sample of Quarterly Okun's Law Analysis

N	COUNTRY	CODE	S&P	N	COUNTRY	CODE	S&P
1	Argentina	AG	F	29	Lithuania	LN	F
2	Australia	AU	D	30	Latvia	LV	F
3	Germany	BD	D	31	Luxembourg	LX	D
4	Belgium	BG	D	32	Mexico	MX	E
5	Bulgaria	BL	F	33	Malaysia	MY	E
6	Brazil	BR	E	34	Netherlands	NL	D
7	China	CH	E	35	Norway	NW	D
8	Chile	CL	E	36	New Zealand	NZ	D
9	Canada	CN	D	37	Austria	OE	D
10	Cyprus	CP	F	38	Philippines	PH	E
11	Croatia	CT	F	39	Poland	PO	E
12	Czech	CZ	E	40	Portugal	PT	D
13	Denmark	DK	D	41	Romania	RM	F
14	Estonia	EO	F	42	Russia	RS	E
15	Spain	ES	D	43	South Africa	SA	E
16	Finland	FN	D	44	Sweden	SD	D
17	France	FR	D	45	Slovenia	SJ	F
18	Greece	GR	E	46	Singapore	SP	D
19	Hungary	HN	E	47	Switzerland	SW	D
20	Iceland	IC	NA	48	Slovakia	SX	NA
21	Indonesia	ID	E	49	Thailand	TH	E
22	India	IN	E	50	Turkey	TK	E
23	Iraq	IQ	NA	51	Trinidad & Tobago	TT	F
24	Ireland	IR	D	52	Taiwan	TW	E
25	Israel	IS	D	53	United Kingdom	UK	D
26	Italy	IT	D	54	United States	US	D
27	Japan	JP	D	55	Venezuela	VE	F
28	South Korea	KO	D				

Table B2. Results of ADF Unit Root Test for Okun's Law variables U and Y levels

COUNTRY	CODE	LEVEL		1st DIFFERENCE		1st DIFFERENCE	
		U	Y	ΔU	ΔY	U-U*	Y-Y*
Argentina	AG	0.3364 (L:1 N:143)	0.9893 (L:0 N:143)	0.0000 (L:0 N:143)	0.0000 (L:0 N:142)	0.0009 (L:1 N:143)	0.0000 (L:3 N:140)
Australia	AU	0.1101 (L:2 N:141)	0.8890 (L:0 N:143)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0000 (L:2 N:141)	0.0043 (L:0 N:143)
Germany	BD	0.0796 (L:1 N:142)	0.7583 (L:0 N:143)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0003 (L:1 N:142)	0.0024 (L:0 N:143)
Belgium	BG	0.1585 (L:2 N:141)	0.8002 (L:1 N:142)	0.0000 (L:1 N:141)	0.0000 (L:0 N:142)	0.0055 (L:0 N:143)	0.0000 (L:2 N:141)
Bulgaria	BL	0.0092 (L:4 N:100)	0.8283 (L:4 N:140)	0.0026 (L:5 N:98)	0.0123 (L:3 N:140)	0.0000 (L:4 N:100)	0.0001 (L:4 N:140)
Brazil	BR	0.3356 (L:1 N:142)	0.9435 (L:0 N:143)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0006 (L:1 N:142)	0.0003 (L:1 N:142)
China	CH	0.1441 (L:1 N:142)	0.8263 (L:2 N:141)	0.053 (L:0 N:142)	0.0000 (L:1 N:141)	0.0000 (L:1 N:142)	0.0012 (L:0 N:143)
Chile	CL	0.1689 (L:1 N:118)	0.8788 (L:0 N:143)	0.0000 (L:0 N:118)	0.0000 (L:0 N:142)	0.0003 (L:1 N:118)	0.0005 (L:0 N:143)
Canada	CN	0.1495 (L:1 N:142)	0.8086 (L:1 N:142)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0001 (L:1 N:142)	0.0001 (L:1 N:142)
Cyprus	CP	0.8535 (L:4 N:99)	0.2699 (L:2 N:81)	0.0274 (L:4 N:98)	0.0548 (L:1 N:81)	0.0002 (L:4 N:99)	0.0054 (L:2 N:81)
Croatia	CT	0.2056 (L:1 N:99)	0.0991 (L:4 N:96)	0.0000 (L:0 N:99)	0.0017 (L:3 N:96)	0.0055 (L:1 N:99)	0.0033 (L:0 N:100)
Czech	CZ	0.3010 (L:5 N:86)	0.7146 (L:1 N:90)	0.0005 (L:4 N:86)	0.0000 (L:0 N:90)	0.0093 (L:5 N:86)	0.0026 (L:2 N:89)
Denmark	DK	0.4226 (L:1 N:142)	0.5087 (L:0 N:143)	0.0002 (L:0 N:142)	0.0000 (L:0 N:142)	0.0005 (L:1 N:142)	0.0000 (L:0 N:143)
Estonia	EO	0.0643 (L:2 N:105)	0.3139 (L:1 N:83)	0.0000 (L:0 N:106)	0.0462 (L:2 N:81)	0.0001 (L:3 N:104)	0.0005 (L:3 N:81)
Spain	ES	0.0819 (L:5 N:138)	0.6315 (L:3 N:140)	0.0402 (L:4 N:138)	0.0538 (L:2 N:140)	0.0000 (L:4 N:139)	0.0002 (L:3 N:140)
Finland	FN	0.0513 (L:2 N:141)	0.5456 (L:3 N:140)	0.0107 (L:3 N:139)	0.0042 (L:2 N:140)	0.0000 (L:3 N:140)	0.0000 (L:3 N:140)
France	FR	0.0477 (L:1 N:142)	0.2763 (L:1 N:142)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0000 (L:3 N:140)	0.0000 (L:2 N:141)
Greece	GR	0.7338 (L:1 N:142)	0.7503 (L:0 N:143)	0.0001 (L:0 N:142)	0.0000 (L:2 N:140)	0.0043 (L:1 N:142)	0.0011 (L:1 N:142)
Hungary	HN	0.5936 (L:1 N:98)	0.8706 (L:1 N:98)	0.0000 (L:0 N:98)	0.0000 (L:0 N:98)	0.0127 (L:1 N:98)	0.0036 (L:1 N:98)
Iceland	IC	0.2531 (L:1 N:98)	0.3961 (L:1 N:74)	0.0000 (L:0 N:98)	0.0001 (L:0 N:74)	0.0102 (L:1 N:98)	0.0632 (L:1 N:74)
Indonesia	ID	0.6576 (L:5 N:138)	0.6522 (L:0 N:143)	0.0000 (L:4 N:138)	0.0000 (L:0 N:142)	0.0000 (L:4 N:139)	0.0000 (L:2 N:141)
India	IN	0.8675 (L:2 N:141)	0.9999 (L:0 N:143)	0.0000 (L:1 N:141)	0.0000 (L:0 N:142)	0.0167 (L:1 N:142)	0.0001 (L:0 N:143)
Iraq	IQ	0.0132 (L:4 N:96)	0.9311 (L:5 N:132)	0.0010 (L:4 N:95)	0.0000 (L:4 N:132)	0.0000 (L:4 N:96)	0.0001 (L:5 N:132)

Table B2. (continues)

COUNTRY	CODE	LEVEL		1st DIFFERENCE		1st DIFFERENCE	
		U	Y	ΔU	ΔY	U-U*	Y-Y*
Ireland	IR	0.3161 (L:2 N:141)	0.8121 (L:2 N:141)	0.0028 (L:1 N:141)	0.0000 (L:1 N:141)	0.0005 (L:2 N:141)	0.0001 (L:3 N:140)
Israel	IS	0.3666 (L:1 N:111)	0.5174 (L:0 N:84)	0.0000 (L:0 N:111)	0.0000 (L:0 N:83)	0.0005 (L:1 N:111)	0.0053 (L:2 N:82)
Italy	IT	0.0779 (L:3 N:140)	0.1292 (L:1 N:142)	0.0071 (L:2 N:140)	0.0000 (L:0 N:142)	0.0000 (L:3 N:140)	0.0000 (L:3 N:140)
Japan	JP	0.5065 (L:1 N:142)	0.0004 (L:0 N:143)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0039 (L:1 N:142)	0.0003 (L:0 N:143)
South Korea	KO	0.0129 (L:1 N:132)	0.0004 (L:0 N:143)	0.0000 (L:0 N:132)	0.0000 (L:0 N:142)	0.0001 (L:1 N:132)	0.0000 (L:3 N:140)
Lithuania	LN	0.0857 (L:3 N:84)	0.4136 (L:0 N:83)	0.0000 (L:0 N:86)	0.0000 (L:0 N:82)	0.0914 (L:0 N:87)	0.0016 (L:3 N:80)
Latvia	LV	0.2353 (L:1 N:90)	0.3261 (L:2 N:81)	0.0000 (L:0 N:90)	0.0158 (L:1 N:81)	0.025 (L:1 N:90)	0.0018 (L:3 N:80)
Luxembourg	LX	0.8439 (L:1 N:130)	0.7230 (L:2 N:141)	0.0000 (L:0 N:130)	0.0000 (L:1 N:141)	0.0024 (L:1 N:130)	0.0000 (L:2 N:141)
Mexico	MX	0.1423 (L:1 N:142)	0.9271 (L:1 N:142)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0003 (L:1 N:142)	0.0000 (L:1 N:142)
Malaysia	MY	0.4532 (L:0 N:123)	0.7470 (L:1 N:142)	0.0000 (L:0 N:122)	0.0000 (L:0 N:142)	0.0000 (L:0 N:123)	0.0000 (L:1 N:142)
Netherlands	NL	0.0825 (L:9 N:134)	0.6572 (L:0 N:143)	0.0002 (L:7 N:135)	0.0000 (L:1 N:141)	0.0000 (L:3 N:140)	0.0012 (L:0 N:143)
Norway	NW	0.1718 (L:2 N:141)	0.4662 (L:1 N:142)	0.0000 (L:1 N:141)	0.0000 (L:0 N:142)	0.0145 (L:0 N:143)	0.0005 (L:1 N:142)
New Zealand	NZ	0.1913 (L:2 N:117)	0.9690 (L:0 N:114)	0.0012 (L:1 N:117)	0.0000 (L:0 N:113)	0.0024 (L:2 N:117)	0.0008 (L:0 N:114)
Austria	OE	0.0493 (L:4 N:139)	0.4609 (L:1 N:142)	0.0000 (L:3 N:139)	0.0000 (L:0 N:142)	0.0035 (L:4 N:139)	0.0004 (L:1 N:142)
Philippines	PH	0.2745 (L:1 N:142)	0.9999 (L:0 N:143)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0000 (L:0 N:143)	0.0002 (L:0 N:143)
Poland	PO	0.0014 (L:2 N:105)	0.9835 (L:0 N:107)	0.0888 (L:1 N:105)	0.0000 (L:0 N:106)	0.0056 (L:2 N:105)	0.0000 (L:0 N:107)
Portugal	PT	0.5188 (L:2 N:129)	0.0141 (L:0 N:131)	0.0008 (L:1 N:129)	0.0006 (L:2 N:128)	0.0186 (L:2 N:129)	0.0024 (L:0 N:131)
Romania	RM	0.1416 (L:2 N:109)	0.9216 (L:1 N:142)	0.0000 (L:0 N:110)	0.0000 (L:0 N:142)	0.0019 (L:2 N:109)	0.0041 (L:1 N:142)
Russia	RS	0.2411 (L:1 N:102)	0.7223 (L:3 N:100)	0.0000 (L:0 N:102)	0.0088 (L:2 N:100)	0.0050 (L:1 N:102)	0.0005 (L:3 N:100)
South Africa	SA	0.6414 (L:0 N:143)	0.9915 (L:1 N:142)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0007 (L:0 N:143)	0.0000 (L:2 N:141)
Sweden	SD	0.2576 (L:1 N:142)	0.9587 (L:0 N:143)	0.0000 (L:0 N:142)	0.0000 (L:1 N:141)	0.0017 (L:1 N:142)	0.0000 (L:3 N:140)
Slovenia	SJ	0.8203 (L:0 N:79)	0.2778 (L:1 N:82)	0.0000 (L:0 N:78)	0.0000 (L:0 N:82)	0.0976 (L:0 N:79)	0.0226 (L:1 N:82)
Singapore	SP	0.2966 (L:1 N:142)	0.2894 (L:0 N:143)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0000 (L:1 N:142)	0.0000 (L:3 N:140)

Table B2. (continues)

COUNTRY	CODE	LEVEL		1st DIFFERENCE		1st DIFFERENCE	
		U	Y	ΔU	ΔY	U-U*	Y-Y*
Switzerland	SW	0.1389 (L:2 N:141)	0.9128 (L:1 N:142)	0.0007 (L:1 N:141)	0.0000 (L:0 N:142)	0.0000 (L:1 N:142)	0.0002 (L:1 N:142)
Slovakia	SX	0.1612 (L:8 N:80)	0.5274 (L:0 N:92)	0.0081 (L:4 N:83)	0.0000 (L:0 N:91)	0.0160 (L:8 N:80)	0.0067 (L:0 N:92)
Thailand	TH	0.0004 (L:1 N:142)	0.0595 (L:0 N:143)	0.0000 (L:1 N:141)	0.0000 (L:0 N:142)	0.0000 (L:1 N:142)	0.0017 (L:0 N:143)
Turkey	TK	0.2426 (L:1 N:142)	0.8197 (L:0 N:143)	0.0000 (L:0 N:142)	0.0000 (L:3 N:139)	0.0002 (L:1 N:142)	0.0002 (L:0 N:143)
Trinidad & Tobago	TT	0.8336 (L:1 N:98)	0.8717 (L:1 N:136)	0.0001 (L:0 N:98)	0.0885 (L:0 N:136)	0.0000 (L:0 N:99)	0.0000 (L:1 N:136)
Taiwan	TW	0.3172 (L:1 N:142)	0.0434 (L:0 N:143)	0.0000 (L:0 N:142)	0.0000 (L:0 N:142)	0.0000 (L:1 N:142)	0.0000 (L:0 N:143)
United Kingdom	UK	0.1189 (L:1 N:142)	0.5365 (L:1 N:142)	0.0312 (L:0 N:142)	0.0000 (L:0 N:142)	0.0000 (L:1 N:142)	0.0001 (L:2 N:141)
United States	US	0.0568 (L:1 N:142)	0.2841 (L:2 N:141)	0.0000 (L:0 N:142)	0.0000 (L:1 N:141)	0.0006 (L:1 N:142)	0.0003 (L:2 N:141)
Venezuela	VE	0.1174 (L:2 N:141)	0.7805 (L:0 N:143)	0.0000 (L:1 N:141)	0.0000 (L:0 N:142)	0.0000 (L:2 N:141)	0.0000 (L:3 N:140)

Notes: The numbers in the table are rejection probabilities of the null hypothesis of ADF test including intercept. Probabilities below 0.10 denote rejection of the null hypothesis, thus, confirm stationarity of the U (unemployment), Y (real output), U-U* (unemployment gap), and Y-Y* (real output gap) series of related countries. The lag and observation parameters are presented in the parentheses where "L" and "N" denote lag length and observation number respectively. The lag length is determined by Schwarz Information Criterion (SIC) under maximum lag length specification of 13.

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3. **Russian** - advanced (Second Mother Tongue)
4. **Turkmen** - advanced (Mother Tongue)

GRANTS:

1. **Turkish Ministry of Education TCS Scholarship**, 2007-2011, (Fully Funded BA + Living Expenses)
2. **Fully Funded Ph.D. at Istanbul University**, 2014 - 2019.

3. **Silver Medal** - Young Turkmen Authors Competition, Turkmenistan, 2002.
4. **Golden Medal** - National Turkish Olympiads in Turkmenistan, 2003.
5. **Golden Medal** - Young Turkmen Authors Competition, Turkmenistan, 2003.
6. **Golden Medal** - Young Turkmen Poetry Competition, Turkmenistan, 2004.
7. **Golden Medal** - Turkmen Language & Literature Olympiads, Turkmenistan, 2004.
8. **5th place** - Math & IQ Olympiad of Turkmenistan, 2004.
9. **Distinction & Honours Degree** - DTTM High School, Turkmenistan, 2005.
10. **BADistinction & Honours Degree** - Marmara University, Turkey, 2011.
11. **MBA Distinction & Honours Degree** - Cardiff Metropolitan University, London, UK, 2013.
12. **Founder** of E-Dostluk Group – www.e-dostluk.com [The First Turkmen Social Platform]
13. **ALES: 80** – in October 2016
14. **Projects of Scientific Investigation (BAP), Grant: 28,500 TL** - "How Do Macroeconomic Indicators Interact? Figuring Out The Lag Between Nominal and Real Variables", Fatih University, Istanbul, Turkey, 2015.

ACADEMIC PUBLICATIONS:

1. Sovbetov, Y. (2018). "Factors Influencing Cryptocurrency Prices: Evidence from Bitcoin, Ethereum, Dash, Litecoin, and Monero", *Journal of Economics and Financial Analysis*, 2(2), pp. 1-27.
2. Sovbetov, Y. & Saka, H. (2018). "Does it take two to tango: Interaction between Credit Default Swaps and National Stock Indices", *Journal of Economics and Financial Analysis*, 2(1), pp. 129-149.
3. Sovbetov, Y. & Moussa, M. (2017). "Interaction of Economic Freedom and Foreign Direct Investment Globally: Special Cases from Neglected Regions", *Journal of Economics and Financial Analysis*, 1(1), pp. 59-80.
4. Sovbetov, Y. (2016). "Impact of Brand Dynamics on Insurance Premiums in Turkey", *Turkish Economic Review*, 3 (3), pp. 453-465.
5. Sovbetov, Y. (2015). "How IFRS Affects Value Relevance and Key Financial Indicators? Evidence from the UK", *International Review of Accounting, Banking, and Finance*, 7(1), pp. 73-96.
6. Sovbetov, Y. "Financial Price of Sin in Religious Context", *Spanish Journal of Accounting and Finance* (under review).
7. Sovbetov, Y. (2018). "Impact of Digital Economy on Female Employment: Evidence from Turkey". *International Economic Journal*, 32(2), pp.256-270.
<https://doi.org/10.1080/10168737.2018.1478868>
8. Sovbetov, Y., Orhan, M. & Saka, H. "Contributions of Zakat to Poverty Alleviation and Income Inequality Reduction", *Journal of Economic Studies* (under review).
9. Sovbetov, Y., Orhan, M. & Saka, H. "Exercising the Impact of Zakat on Income Inequality and Poverty", *Managerial Finance* (under review).
10. Sovbetov, Y. "Does Employee Happiness Create a Value on Stocks?", *Review of Economic Perspectives* (under review)
11. Sovbetov, Y. "Performance of Brandstars in Global Markets: Measuring Unmeasurables", *Romanian Journal of Economic Forecasting* (under review)
12. Sovbetov, Y. "Macroeconomic Factors Influencing Cross-border M&As: A Negative Binomial Approach", *Global Business and Economics Review* (under review).

13. Sovbetov, Y. & Kaplan, M. (2019). "Empirical Examination of the Stability of Expectations-Augmented Phillips Curve for Developing and Developed countries". *Theoretical and Applied Economics*, 26(2), pp. 63-78.
14. Sovbetov, Y. & Kaplan, M. (2019). "Causes of Failure of the Phillips Curve: Does tranquillity of economic environment matters?". *The European Journal of Applied Economics*, 16(2).
15. Sovbetov, Y. (2019). Phillips Curve Estimation During Tranquil and Recessionary Periods: Evidence From Panel Analysis. *Istanbul Journal of Economics*, 69(1), pp.23-41. DOI: 10.26650/ISTJECON2019-0005
16. Sovbetov, Y. (2013). "Financial Markets and Investment Analysis", *International Political Economy: Investment & Finance eJournal*, 1.
17. Sovbetov, Y. (2013). "The Influence of Brand Dynamics on Insurance Premiums in Turkey: An analysis of data of Turkey Insurance Sector over 2007-2012", *Sustainability & Economics eJournal*, 3.
18. Sovbetov, Y. (2013). "Relationship between Capital Structure & Profitability: Evidence from UK Banking Industry Over the Period of 2007-2012", *European Finance eJournal*, 5.
19. Sovbetov, Y. (2013). "E-Dostluk: Local Social Network for Turkmenistan", *eBusiness & eCommerce eJournal*, 5.
20. Sovbetov, Y. (2013). "The Firm Valuations in Mergers & Acquisitions, and its Impacts on Key Financial Ratios: Evidence from Banking Industry in UK Over the Period of 2000-2013", *Banking & Insurance eJournal*, 6.

COMPUTER SKILLS:

1. **EViews** - Advanced Statistical & Econometric Analysis software
2. **SPSS** - Advanced Statistical & Econometric Analysis software
3. **STATA** - Advanced Statistical & Econometric Analysis software
4. **Adobe Photoshop** - developer level
5. **Adobe After Effects** - developer level
6. **MS Office** - advanced level (Word, Excel, Power Point)
7. **Sketch Up** - advanced level
8. **Corel Draw** - advanced level
9. **Web Design** - experienced
10. **PHP** - developer level
11. **HTML / HTML 5** - developer level
12. **Pascal** - intermediate level
13. **Macromedia Flash** - intermediate level

MENTAL SKILLS:

- ✓ Ability to work under high pressure
- ✓ Highly concentrated, Highly focused on every details
- ✓ Very easy-going, very social
- ✓ Very punctual & highly disciplined
- ✓ Team Leader
- ✓ Creative & Problem solver
- ✓ Self-motivated
- ✓ Enjoying Math, Finance & Good at Analytical Thinking