Three Essays on International Macroeconomics

by

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Abstract

This thesis is comprised of three essays on international macroeconomics. The first chapter examines empirically both the long-run and short-run impacts of the exchange rate volatility on manufacturing sector and bilateral exports during the sample period of 1999-2010 in five major ASEAN countries. A set of autoregressive distributed lag bounds tests are applied to examine the long-run level relationships among the variables, and long-run impacts of exchange rate volatility on exports. Seemingly unrelated regressions models with error corrections are estimated to capture short-run dynamics. Significant and negative impacts of exchange rate volatility on exports are widely observed, which suggests risk averse exporters shift resources away from exporting to reduce exposure to higher exchange rate risk.

The second chapter employs the economic policy uncertainty index (EPU) developed by Baker et al. (2013) to empirically examine its effect on economic growth across both advanced and emerging countries over 1985-2006. In addition, this study aims to identify the channels through which the EPU affects economic growth. A series of Kiviet's estimators are utilized for this dynamic panel data analysis. The results confirm that higher economic policy uncertainty reduces economic growth and the three channels of economic growth, physical capital accumulation, human capital accumulation, and total factor productivity (TFP) for both country groups.

The third chapter develops a set of two-country open economy dynamic stochastic general equilibrium models to explore cross-country correlations among real variables.

One contribution to the literature is to incorporate available features of modelling in the literature into the models. The other contribution is to seek features of modeling that affect international comovements among real variables. I find that these models are capable of resolving the existing international comovement puzzles even without the additive habit formations or special preference functions and retaining the key statistical characteristics of real variables in accordance to the data. Quantitative results indicate that spillovers between monetary policies and TFPs, price stickiness and capital utilization are the four major factors that drive international comovements. This finding overturns the conclusion by Dmitriev and Krznar (2012) that internal habit formation is the main driver for international comovements.

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and to our lovely son, David,

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Chapter 1

The Impact of Exchange Rate Volatility on ASEAN-5 Exports

1.1 Introduction

The collapse of the Bretton-Woods system in 1973 opened up a new era of flexible exchange rate regimes. Since then, both real and nominal exchange rates have exhibited significant fluctuations in both developed and developing countries. A key concern to economists and policy-makers is to understand to what extent such exchange rate volatility would affect exports. The conventional hypothesis tested in this area of research involves the negative impacts of exchange rate volatility on exports. The early theory predicts that volatile exchange rate movement would lead to higher uncertainties regarding the realization of the future exchange rate and expected profits. This in turn may affect the behaviour of exporters who could shift their available resources away from exporting to reduce exposure to the exchange rate risk. Some later theoretical studies, on the other hand, propose a positive relationship between the exchange rate volatility and exports, and interpret it as the dominance of the income effect over substitution effect or adjustment costs.

Few of the existing empirical studies examine the effects of exchange rate volatility on exports for Indonesia, Malaysia, Philippines, Singapore and Thailand (ASEAN-

5).[1] A significant connection between exchange rate volatility and exports can be potentially underlined based upon three facts of ASEAN-5. First, volatile exchange rate movements have been observed since the Asian financial crisis in 1997.[2] Secondly, the "export-oriented" economic development policy both spurred the "Asian economic miracle" and deepened the ASEAN-5's dependence on foreign export demands over the last four decades.[3] Thirdly, the U.S. dollar has remained the main invoicing currency in exports.[4]

This paper contributes to the empirical literature by examining both the long-run and short-run effects of exchange rate volatility on ASEAN-5 exports to the U.S. in three important aspects. First, both the manufacturing sector and bilateral data are employed. Unlike the previous literature which mainly focuses on investigating the effect of exchange rate volatility on exports by using bilateral and aggregate data, this paper, however, extends the analysis to the sector level to explore the specific effect.[5] Mckenzie (1998) summarizes the sector analysis findings as "limited

[1]The studies that focus on the Southeast Asian countries are Chit(2008), Chit et al. (2010) and Choong et al. (2005).

[2]Figures A.2 and A.6 in the Appendix A respectively demonstrate the CPI-based real exchange rates of ASEAN-5 against the U.S. dollar, and the three measures of real exchange rate volatility. We can see the volatile movements of real exchanger rates as well as the rise of exchange rate volatility during and after the Asian financial crisis in 1997.

[3]Figure A.1 in the Appendix A illustrates the share of exports over GDP in ASEAN-5.

[4]Kamps (2006) reports the U.S. dollar were the main invoicing currency for three ASEAN countries − Indonesia, Malaysia and Thailand during 1991-2004. For Indonesia, other than in 1995, the share of the U.S. dollar as invoicing currency was above 90 percent; for Malaysia, the share was was above 60 percent in the mid 1990s, and rose to 90 percent in the early 2000s; for Thailand, the share dropped from above 90 percent in the early 1990s to 84 percent in 2003. The recent data quoted from a research paper commissioned by the ASEAN Secretariat in 2010 indicate that share of the U.S. dollar as invoicing currency remained above 80 percent for Thailand by the end of 2008. Lai et al. (2014) report the share to be above 80 percent by the end of 2011. The same research paper commissioned by the ASEAN Secretariat (2010) reports 76 percent of export destinations of 15 Singapore-based traders are invoiced in the U.S. dollar based on results of a survey conducted for these traders. Although no data have been reported for the invoicing currency of the Philippines, it is reasonable to assume the U.S. dollar as the major invoicing currency given its history with the U.S. and similarity in economic development shared with other regional countries.

[5]An aggregate model employs trade/GDP weighted aggregate data, and a disaggregate model

evidence as to the impact of exchange rate volatility on trade flows" and "a subsequent examination of bilateral trade flows failed to generate any additional insights". The problem of an aggregate analysis is that it presumably assumes uniform effects of all explanatory variables on exports across countries, which wipes out the possibility of different country specific effects. The only variation among countries is captured by trade/GDP weights. Analogously, in a bilateral analysis, the assumption of uniform impacts on exports across all sectors still holds, which does not capture the specific effect of the exchange rate volatility on each sector. Thus, a comparison of the effects of manufacturing sector and bilateral analysis can provide direct evidence to this argument.

Secondly, a long-run export equation is estimated by the autoregressive distributed lag (ARDL) bounds test developed by Pesaran and Shin (1999) and Pesaran et al. (2001). The conventional Johansen cointegration test results will be unreliable if I(0) regressors are included in the long-run level equations. For that reason, I am applying a method to offer more accurate and reliable results in the existence of a mixture of I(1) and I(0) regressors.[6] Unlike the previous time series studies, the special feature of the ARDL bounds test is that it does not assume unity of integrated orders among the variables. Instead, it allows the series to be integrated in different orders, which reasonably fulfills the purpose of analyzing long-run level relationships in this paper.

Thirdly, the seemingly unrelated regressions (SUR) modeling technique is employed to estimate short-run dynamic equations system by including lagged level

uses either bilateral or sector data.

[6] I(d) represents a time series becomes stationary after d-th differencing, e.g., I(0) means stationarity in level, and I(1) implies stationarity after the first difference.

variables to capture the long-run level relationships. A common problem encountered in a panel analysis with a small dimension of cross-sections (N) data set, like the one used in this paper, is that the homoskedasticity assumption may not hold, which indeed is generally rejected in practice.[7] Meanwhile, the SUR model generates the cross-sectional specific estimates other than the pooling estimates obtained from the panel models. Therefore, the SUR model that allows cross-sectional heteroskedasticity can provide a better and more flexible way of estimating the short-run dynamic structure in a simultaneous equations system, and correct the potential contemporaneous cross-sectional interdependence at the same time.

Both the long-run and short-run effects of exchange rate volatility on exports of ASEAN-5 are examined by employing a quarterly panel data set for ASEAN-5 from 1999 to 2010 at the sector and bilateral levels. Three measures of exchange rate volatility are implemented.[8] The ARDL bounds tests confirm ten long-run level relationships among the real exports, real exchange rate, real U.S. GDP and exchange rate volatility for all ASEAN-5 countries. The results imply mixed effects (positive and/or negative coefficients) of exchange rate volatility on exports in both short-run and long-run. They also confirm that the U.S. demand is a major factor that drives ASEAN-5 exports, along with the distinct findings on the effects of exchange rate on exports among ASEAN-5.

The remainder of the paper is organized as follows. Section 1.2 reviews the theoretical models and summarizes the empirical findings. Section 1.3 briefly describes

[7] Tenreyro (2007) points out that if the unobserved characteristics of the data are omitted, even after implementing proper panel methodologies, the results would still be biased given a small N setup in nature.

[8] Detailed descriptions of the three measures will be presented in Section 1.3.

the specifications of the model, methodology applied and data sources. Sections 1.4 discusses the estimation strategies. Section 1.5 presents the results and discussions. Section 1.6 draws conclusions.

1.2 Literature Review

Several theoretical models outlining the impact of exchange rate volatility on international trade have been developed, but theoretical conclusions and empirical results have proven to be inconclusive.

1.2.1 Theoretical Models

Hooper and Kohlhagen (1978) set up a pioneer theoretical partial equilibrium model based on the fact that risk averse exporters mostly bear the exchange rate risk since international trade is mainly invoiced in exporter's currency.[9] Typically, the exchange rate is established by the parties at the time of the trade contract, but payment is not made until the future delivery actually takes place. They assume an exporter produces and exports competitively to a foreign market; both importers and exporters can hedge exchange rate risk in forward markets. Thus, if the exchange rate fluctuation becomes unpredictable, it will create uncertainties about the realization of the profits and reduce the benefits of international trade.[10] Medhora (1990) and Arize et al. (2000) follow Hooper and Kohlhagen's assumption on accessibility to forward markets,

[9]The Hooper and Kohlhagen model is present in the Appendix A.

[10]Exchange rates are indeed difficult to predict. Especially, during the Asian financial crisis, the ASEAN-5 countries switched from the fixed exchange rate regime to floating exchange rate regime, which inevitably caused higher unpredictability of exchange rates.

and suggest that the exchange rate risk for the less developed countries (LDCs) is generally not hedged due to the limitations of traders' accessibility to forward markets.

Economists have also developed models to show the possibility of a positive relationship between exchange rate volatility and exports. De Grauwe (1988) proposes a model where producers are free to allocate resources in producing and selling goods and services domestically or internationally.[11] He argues that a positive effect of exchange rate volatility on exports would be observable if the income effect dominates the substitution effect, which depends on the degree of risk aversion and convexity or concavity assumption on the utility function in exchange rate.[12]

Franke (1991) introduces entry and exit costs into the risk neutral firms' decision making on maximizing the expected cash flows. He shows that a firm would benefit from increased exchange rate volatility if the present value of cash flow grows faster than that of entry or exit costs under a sufficient condition that the cash flow function is convex in the exchange rate.

Broll and Eckwert (1999) develop a model where given the probability distribution of the standard deviation of exchange rate, a firm makes ex-ante decisions on the expected utility of profit by choosing production, and makes ex-post decisions on product allocation after observing the exchange rate. Their results imply that a

[11] This model relaxes the assumption of constant absolute risk aversion made in the Hooper and Kohlhagen (1978) model.

[12] De Grawe shows that the net effect of exchange rate volatility on exports is determined by the signs of $R(1-R)+R'\tilde{Y}_f$, where R is the constant relative risk aversion (CRRA), $R(1-R)$ represents the substitute effect and $R'\tilde{Y}_f$ stands for the income effect. If an exporter has higher risk aversion $R>1$, higher exchange rate volatility increases exports, and vice versa for an exporter with less risk aversion $R<1$. More generally, once CRRA is relaxed, $R'<0$ is a necessary condition for a positive connection between exchange rate volatility and exports, which implies the domination of income effect over substitution effect. The details of De Grauwe model are presented in the Appendix A.

firm maximizes its profits by exporting all its products under a depreciation of the domestic currency or selling domestically if an appreciation is observed. Thus, Broll and Eckwert put forth the possibility of a positive connection between exports and exchange rate volatility which depends on the degree of relative risk aversion.

To sum up, the results of theoretical analysis depend on the assumed degree of risk aversion, forms of utility function, adjustment costs and existence of forward markets for risk hedging. Therefore, the effects of exchange rate volatility on exports are not theoretically determined.

1.2.2 Empirical Evidence

Mckensie (1998) summarizes the findings in previous studies, and more importantly points out some fundamental issues on empirical research which include what countries to study, whether to employ nominal or real exchange rate, which explanatory variables and model estimation techniques to use. Due to data availability, early studies all focus on developed countries; but since the early 1990s, economists have extended their analysis to developing countries and set up mixed data sets to include both developed and developing countries in panel studies.

Empirical estimations of export demand equation have evolved with the development of new econometric techniques during the last three decades. In general, the studies prior to the late 1980s do not overcome the stationarity issue which could cause spurious effects. Since then, econometricians have developed a number of unit root and cointegration tests for time series analysis and extended them to panel analysis

in the early 1990s.

Both positive and negative effects of exchange rate volatility on exports have been reported in literature. On the one hand, purely negative effects of exchange rate volatility on exports have been widely observed in time series studies (see Chowdhury 1993, Arize 1997, Doroodian 1999, Fang and Lai 2009) and in panel studies (see Baak 2004, Chit et al. 2010); on the other hand, mixed effects have been confirmed in time series studies (see Arize et al. 2000, Aurangzeb et al. 2005, De Vita and Abbott 2004) and in panel studies (see Bohara and Sauer 2001, Clark et al. 2004, Hondroyiannis et al. 2008). Thus, the effects of exchange rate volatility on exports are undetermined in the empirical investigations.

Economists have so far provided evidence that significant lagged effects of explanatory variables − exports, exchange rate, foreign demand and exchange rate volatility − exist after estimating short-run dynamic equations in time series analysis. Unlike these time series studies, the recent panel studies all focus on estimating the contemporaneous effects of exchange rate volatility on exports. In this paper, I extend dynamic analysis to panel studies.

1.3 The Empirical Model and the Data

1.3.1 The Empirical Model

The traditional specification of the long-run equilibrium export demand is as follows:

$$ex_t = \alpha_0 + \alpha_1 y_t + \alpha_2 re_t + \alpha_3 V_t + \varepsilon_t, \tag{1.1}$$

where ex_t denotes volume of export, y_t is a measure of real foreign demand, re_t represents the real exchange rate and V_t measures the exchange rate volatility. Since the U.S. is the only anchored country in the analysis, any variable with subscript j represents a bilateral variable of ASEAN-5 country j with respect to the U.S. All variables are in logs.[13]

A volatility series (V_t) is usually stationary in nature, while other macroeconomic variables are I(1). Therefore, the coventional cointegration tests which require the variables to be integrated in the same order do not work in estimating the long-run export demand relationship. The ARDL bounds test proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) does not require any pre-tests of the regressors, which avoids the introduction of further uncertainties into the analysis; and examines the level relationship among variables, regardless of whether the regressors are purely I(0), purely I(1) or mutually integrated.

We start from the setup of a general conditional error correction model (ECM):

$$\Delta z_t = c_0 + c_1 t + \pi_z z_{t-1} + \pi_x' \mathbf{x}_{t-1} + \sum_{i=1}^{p-1} \psi_i \Delta z_{t-i} + \sum_{j=1}^{q-1} \gamma_j' \Delta \mathbf{x}_{t-j} + \omega' \Delta \mathbf{x}_t + \varepsilon_t, \qquad (1.2)$$

where t is the time trend, z_t is an I(1) variable and $\mathbf{x}_t$ is a vector of I(d) regressors, π_z and π_x' are the long-run coefficient matrices, and ε_t is a white noise residual.[14]

The long-run level relationship between z_t and $\mathbf{x}_t$ can be tested by a joint F-statistic of π_z and π_x', i.e., H_0: $\pi_z = \pi_x' = 0$. Pesaran et al. (2001) have shown

[13] An anchor country is a common bilateral trade partner of the countries studies in the analysis. In this study, the U.S. serves as the common bilateral trade partner of ASEAN-5.

[14] In Pesaran et al. (2001), d is either 0 or 1, i.e., $\mathbf{x}_t$ regressors are either purely I(0), purely I(1) or mutually integrated.

that the asymptotic distribution of the F-statistics under the null hypothesis is not standard regardless of integration order of the variables. Instead, they propose a testing procedure for significance of the lower and upper bounds of the F-statistics by constructing the critical values for I(0) and I(1) series, respectively.[15] If the critical value of the F-statistic exceeds the upper bounds value, a level relationship is confirmed. In contrast, no level relationship is identified if the critical value falls below the lower bounds value. The test results remain inconclusive when the critical value lies between the two bounds.

Another critical ingredient of the testing procedure involves performing the long-run forcing tests for $\mathbf{x}_t$ on z_t, which helps to identify the uniqueness of the level relationship between $\mathbf{x}_t$ and z_t.[16] The long-run forcing test is based on a variant ARDL model presented below:

$$\Delta\mathbf{x}_t = c_0 + c_1 + \Pi_z z_{t-1} + \Pi_x' \mathbf{x}_{t-1} + \sum_{i=1}^{p-1} \Psi_i \Delta\mathbf{x}_{t-i} + \sum_{j=1}^{q-1} \Gamma_j' \Delta z_{t-j} + \Omega\Delta z_t + \nu_t. \quad (1.3)$$

This test focuses on examining whether z_{t-1} affects $\Delta\mathbf{x}_t$, i.e., H_0: $\Pi_z = 0$. A unique long-run relationship between $\mathbf{x}_t$ and z_t exists if and only if the null hypothesis is not rejected. Since the absence of feedback from z_t on predicting $\mathbf{x}_t$ in the short-run implies a one-way long-run forcing effect of $\mathbf{x}_t$ on z_t, a unique long-run level relationship is thereafter determined. Similarly, Pesaran et al. (2001) have illustrated that the t-statistic does not follow a standard t distribution asymptotically. They

[15] Different sets of lower and upper bounds values are calculated upon the restricted assumptions on intercept and trend or both.

[16] Pesaran et al. (2001) examine the assumption for bargaining theory of wage determination by applying this test developed by Granger and Lin (1995) and Banerjee et al. (1998).

compute the lower and upper bounds with various restrictions on intercept and trend for the cases of I(0) and I(1), respectively. Analogously, the test result depends upon the comparison of the t-statistic with the corresponding bound. A higher t-statistic than the upper bound implies no long-run forcing effect of z_{t-1} on $\Delta \mathbf{x}_t$; a smaller t-statistic than the lower bound indicates a long-run forcing effect; and a t-statistic lying between the two bounds suggests an uncertain result on the long-run forcing effect.

In this paper, I employ the ARDL bounds test and set up an estimated equation as:

$$\begin{aligned}\Delta ex_{j,t} = {} & \gamma_{j,0} + \gamma_{j,1} t + \gamma_{j,2} ex_{j,t-1} + \gamma_{j,3} re_{j,t-1} + \gamma_{j,4} y_{j,t-1} + \gamma_{j,5} V_{j,t-1} \\ & + \sum_{i_0=1}^{d} \varphi_j Dummy_{j,i_0} + \sum_{i_1=1}^{p} a_j \Delta ex_{j,t-i_1} + \sum_{i_2=0}^{q} b_j \Delta y_{j,t-i_2} \\ & + \sum_{i_3=0}^{m} c_j \Delta re_{j,t-i_3} + \sum_{i_4=0}^{n} d_j \Delta V_{j,t-i_4} + e_{j,t}, \quad \forall j,\end{aligned} \tag{1.4}$$

where $Dummy_{j,i_0}$ represent the structural breaks which are discussed in the next section, $e_{j,t}$ is the residual, and other real variables follow the same definitions as in equation (2.1). Pesaran et al. (2001) discuss the consequences of including dummies in the ARDL bounds tests, and conclude that the asymptotic theory developed is not affected.[17]

SUR-ECM models as follows are estimated simultaneously for each set of volatility

[17] It is noteworthy that they further point out that both the asymptotic theory and critical values must be revised if the dummies have non-zero values in some periods, but the effects will be small.

measures of all ASEAN-5 countries:

$$\begin{aligned}\Delta\mathbf{ex}_{j,t} = {} & \Lambda_{j,0} + \Lambda_{j,1}t + \Lambda_{j,2}\mathbf{ex}_{j,t-1} + \Lambda_{j,3}\mathbf{re}_{j,t-1} + \Lambda_{j,4}\mathbf{y}_{j,t-1} + \Lambda_{j,5}\mathbf{V}_{j,t-1} \\ & + \sum_{i_0=1}^{d_j} \phi_j \mathbf{Dummy}_{j,i_0} + \sum_{i_1=1}^{p_j} A_j \Delta\mathbf{ex}_{j,t-i_1} + \sum_{i_2=0}^{q_j} B_j \Delta\mathbf{y}_{j,t-i_2} \\ & + \sum_{i_3=0}^{m_j} C_j \Delta\mathbf{re}_{j,t-i_3} + \sum_{i_4=0}^{n_j} D_j \Delta\mathbf{V}_{j,t-i_4} + \mathbf{e}_{j,t}, \quad \forall j.\end{aligned} \tag{1.5}$$

1.3.2 The Data

Monthly data for the period from 1996 to 2010 are obtained from the USA Trade *Online* of the Foreign Trade Division of the U.S. Census Bureau, the *International Financial Statistics* (IFS) and the *Direction of Trade Statistics* (DOTS) of the *International Monetary Fund* (IMF).[18] Quarterly and annual data from 1980 to 2010 are respectively retrieved from the IFS and DOTS of the IMF, and the *World Development Indicators* (WDI).[19,20]

The quarterly manufacturing sector and bilateral imports by the USA from ASEAN-5 are used to approximate the exports of ASEAN-5 to the USA. Both the manufacturing sector and bilateral volumes of exports are generated by deflating the U.S. imports by the import prices. The real U.S. GDP is employed as the measure of the real foreign demand across ASEAN-5. The real exchange rate is obtained from taking

[18]Because the manufacturing sectoral data are only available since 1996, the bilateral analysis follows the same range in order to make the results comparable.

[19]The data on annual GDP measured in constant 2000 US dollar are retrieved from the WDI. The weights of quarterly real GDP of ASEAN-5 are calculated by taking the shares of real GDP adjusted by GDP deflator in each quarter over the annual real GDP. The quarterly real GDP series in constant 2000 US dollar are the products of annual real GDP and quarterly weights.

[20]In this study, all monthly, quarterly and annual data employed covering a time period from 1999 to 2000. Detail discussions are reported in Subsection 1.4.1. In sum, there are 48 quarterly observations for each ASEAN-5 country in the regression analysis.

the product of the period-average nominal exchange rate and the relative CPIs based on the 2005 levels in both monthly and quarterly frequencies. Three measures of exchange rate volatility are employed in this paper. These include the standard deviations of the first difference of the log real exchange rate (SD) with twelve lags (SD12); the moving sample standard deviation of the log real exchange rate (MSSD); and the Generalized Autoregressive Conditional Heteroscedasticity of the first difference of the log real exchange rate (GARCH).

Compared with the more widely applied MSSD and GARCH methods, the SD method typically serves as the benchmark proxy for exchange rate volatility. Chit et al. (2010) point out that the SD assigns a greater weight to some large exchange rate volatility than does the MSSD. However, they also argue that the SD may not be capable of capturing the exchange rate volatility if the exchange rate follows a constant trend. This implies that the exchange rate would be anticipated accordingly, and hence little exchange risk. The formula of the SD approach is

$$V_{j,t}^{SD} = \sqrt{\frac{\sum_{k=1}^{m}(\Delta re_{j,t-k+1} - \Delta \bar{re}_{j,t-k+1})^2}{m-1}}, \tag{1.6}$$

where $\Delta re_{j,t}$ is the first difference of the log monthly exchange rate, and m is the number of lags.

Since the early stage of research, the MSSD has been extensively applied by economists. A feature distinguishes the MSSD from the SD is that it allows the highly persistent movements of the exchange rate. However, Arize (1997) points out two critical shortcomings of the MSSD. First, the order of the MSSD is chosen arbi-

trarily with no common standard; secondly, this method lacks defining information sets, which could lead to either underestimating or overestimating the volatility.[21] The MSSD is defined as

$$V_{j,t}^{MSSD} = \sqrt{\frac{\sum_{k=1}^{m} (re_{j,t-k+1} - re_{j,t-k})^2}{m}}, \tag{1.7}$$

where m is the order of the moving average.

The commonly chosen order of m in the literature of monthly data analysis in both MSSD and SD methods is twelve (e.g., Frey (2002), Fang and Lai (2003) and Fang et al. (2009)). The twelve-month lags allow us to catch uncertainty in the exchange rate movements.

Gotur (1985) argues that the exchange rate volatility should measure the unpredictable movements of the exchange rate rather than the systematic movements which are largely predictable. Since the early 1990s, economists have employed GARCH estimations on volatility. An advantage of GARCH method is that the estimation is based upon past available information where certain statistical standards determine the specific form by allowing the time-varying relationships to generate a volatility series. GARCH estimation utilizes available information to extract the unknown information behind the data. This measurement of volatility is also named as the exchange rate uncertainty. In this paper, an $ARIMA(P,1,Q)$-$GARCH(M,N)$ model

[21] In literature, this order varies from 4 up to 12.

is applied to generate the volatility of exchange rate:

$$\Delta re_{j,t} = \beta_{j,0} + \sum_{i=1}^{P} \beta_j \Delta re_{j,t-i} + \sum_{i=1}^{Q} \lambda_j \epsilon_{j,t-i} + \epsilon_{j,t}, \tag{1.8a}$$

$$where\ \epsilon_{j,t} = u_{j,t}\sqrt{V_{j,t}^{GARCH}},\ \ u_{j,t} \sim N(0,1), \tag{1.8b}$$

$$V_{j,t}^{GARCH} = \mu_{j,0} + \sum_{i=1}^{M} \mu_j V_{j,t-i}^{GARCH} + \sum_{i=1}^{N} \eta_j \epsilon_{j,t-i}^2. \tag{1.8c}$$

GARCH variances of each ASEAN-5 are derived by following proper time series techniques. Since the ARDL bounds tests do not require pre-tests for any series in the analysis, it is natural to perform ARIMA models for the level of the real exchange rate by including the dummies which incorporate the important economic events (e.g., Asian Financial crisis in 1997 and Great Recession in 2008). The estimated coefficients of the first autoregressive lag indicate near random walk processes of all ASEAN-5 exchange rates.[22] Thus, ARIMA models with first difference of the real exchange rate is appropriate for the GARCH modeling. Significant lags of PACF and ACF determine the lags of AR and MA; and the Akaike information criterion (AIC) serves as the selection criteria in searching for the best fit parsimonious ARIMA models.[23] The results confirm GARCH effects for all ASEAN-5 and are reported in Table A.1. The standard deviations of the GARCH variances generated from the

[22]The estimates vary from 0.981 to 1.002.

[23]PACF, ACF, AR and MA stand for the partial autocorrelation function, autocorrelation function, autocorrelation order and moving average order, respectively. $LB-Q$, $LB-Q^2$ and ARCH-LM represent the Ljung-Box Q-statistics, Ljung-Box Q-statistics for squared residuals and Lagrange multiplier statistics for ARCH errors. First, $LB-Q$, $LB-Q^2$ and ARCH-LM tests are performed for the residuals to detect any possible GARCH effects. Next, the GARCH estimation of variance is introduced to estimate the residual of the best fit ARIMA model, while the optimal lag length is determined by the AIC.

models are utilized as one of the measurements of exchange rate volatility.

The three exchange rate volatility measures are generated by using the monthly exchange rate data since higher frequency data capture more volatile and detailed exchange rate movements than lower frequency data. However, only the largest monthly standard deviation of each exchange rate volatility in each quarter is employed, in other words, a maximum weight is assigned to that month. This characterizes the model estimated in this paper as a special case of mixed-frequency data models in which no optimal function is specified for determining the weight of each monthly exchange rate volatility.

1.4 Estimation Strategies

1.4.1 Structural Breaks

Since 1996, a series of events have deeply impacted the ASEAN economic developments and reshaped the international trade environments surrounding ASEAN. Among these events, the Asian financial crisis which erupted in July, 1997 is believed to have the most significant impact.[24] Thus, in this paper, I employ data starting from 1999 to 2010 to avoid the potential large impacts from the Asian financial crisis, and use both intercept and time dummies to capture the moderate impact during the late 1990s and early 2000s.

[24] I also test the global financial crisis in 2008 as a break, however, weakly significant effects of this crisis is only obtained in the case of Singapore.

1.4.2 ARDL Bounds Tests and Long-run Level Relationships

The procedures for conducting and estimating the ARDL bounds tests are as follows. First, the proper lag length (P) of the ARDL model is determined on the basis of minimizing the AIC of the vector error correction model (VECM), which can rule out any potential unexplained serial correlation in the estimated residuals. I empirically calculate the information criteria for different lag orders, $P = 1, 2, \cdots, 8$, and use the Lagrange multiplier (LM) test for autocorrelation up to the fourth lag of the residual.[25] The lag lengths of all manufacturing sector and bilateral VECMs are within the range between four and eight, and the results are presented in Tables A.3 and A.4. Second, I apply the lag orders selected by the AIC in the VECMs to the ARDL models and search for the best fit models by minimizing the AIC. This approach is different from the Hendry's general to specific modeling technique since a final ARDL regression includes all lags of each regressor up to the chosen lag length, regardless of the significance of those coefficients. Thirdly, F-statistics are computed to test whether the lagged regressors are jointly different from zero in each ARDL regression.

In total, there are ten confirmed long-run level relationships among the possible sixty candidates, and six of them have significant deterministic trends.[26] In particular, long-run level relationships are found among the exports, exchange rate, U.S. GDP and exchange rate volatility for Indonesia in all cases, but no such relationships

[25] The Schwarz's Bayesian Information Criteria (SIC) are also reported in Tables A.3 and A.4.

[26] For each ASEAN-5, in all cases of the three measures of exchange rate volatility both at manufacturing sector and bileral levels, there is a possibility of including deterministic trend or not; hence a total of sixty long-run level relationships are required to examine.

are confirmed for Malaysia and Singapore. The results of the long-run forcing tests confirm that no long-run impacts on the contemporaneous change in real exports from other explanatory variables, and also reaffirm uniqueness of the ten identified long-run level relationships. Tables A.5 and A.6 respectively display the results of both F- and t-statistics for testing the existence of the long-run export demand relationships.

Finally, to determine the overall fitness of the ARDL regression, a series of tests − LM, Ramsey, and Jarque-Bera and Skewness-kurtosis − are performed respectively to detect serial correlation, miss-specification, and normality of the residuals. The results, reported in Tables A.7 through A.12, indicate that the regressions have fairly goodness-of-fit and pass most of the diagnostic tests. The residuals are normally distributed without serial correlations; but the non-rejections of the Ramsey tests in some occasional cases imply that some non-linearly higher order effects could possibly be left out.

1.5 Empirical Results

1.5.1 Manufacturing Sectoral Analysis VS Bilateral Analysis

An important extension of this paper is to employ the manufacturing sector data to empirically examine the impacts of exchange rate volatility on exports, and to compare the results to those obtained from the bilateral analysis at both the long-run and short-run levels. The aim is to highlight the similarities and differences, and to further provide insight into policy implications. All estimation results are reported in

Tables A.7 through A.13 in the Appendix A. For the long-run level estimations, the lagged level variables carry the consistent signs in most estimations. Sizable differences of estimates in sector and bilateral analysis are obtained, which could be due to the two different exports data in nature. One consistent finding is that exchange rate volatility tends to positively affect Indonesian exports in the long-run in all six long-run level estimations, another consistent finding is the largest estimates of the U.S. GDP among all long-run level estimations. In the short-run analysis, I observe similar dynamics of explanatory variables across the six SUR models, but the U.S. demand and exchange rate volatility on the contrary retain significant difference between the sector and bilateral analysis. The U.S. demand has the tendency to positively affect the manufacturing exports more than the bilateral exports, and analogously, the exchange rate volatility tends to imply adverse effects on bilateral exports than on manufacturing exports. These two findings indeed characterize some important features of ASEAN-5 international trade relationships with the U.S. On the one side, ASEAN-5 majorly export manufacturing goods to the U.S., which implies that the manufacturing exports highly depend on the U.S. demand; on the other side, such high dependence may generate certain level of non-substitutability of manufacturing goods but lead to the overall exports more vulnerable to exchange rate risks.[27] More discussions on the results of manufacturing sector and bilateral analysis in both the long-run and short-run will be presented in the following subsections.

[27]Manufacturing goods account for 85.6 percent of the total exports of ASEAN-5, which indicates the greater importance of manufacturing industry to the economic development of ASEAN-5.

1.5.2 Long-run Relationships

The normalized coefficients of these lagged level variables are transformed by taking ratios of coefficients of lagged real exchange rate, U.S. GDP and exchange rate volatility over that of lagged exports, and altering sings of these relative coefficients.[28] The statistics of the relative coefficients are derived by using the delta method. All normalized coefficients are reported in Table A.13.[29] Although only Indonesia, Philippines and Thailand exhibit confirmed long-run level relationships upon the ARDL bounds test results, yet the estimation results do not imply significant differences in terms of the signs and sizes of the coefficients for each country for most estimates.

Among the ten level estimations, the estimates on the real U.S. GDP are all significant and positive as expected, and have the largest effects compared to other lagged variables. These larger than unity coefficients imply elastic U.S. demands for ASEAN-5 exports, which clearly indicates that the U.S. demand has been the major driving force for ASEAN-5 exports during the past decade.[30] In the exception of manufacturing SUR model for the Philippines with GARCH volatility and all bilateral SUR models for Indonesia, all the other long-run estimates of real exchange rate carry the significant and positive signs.[31] This finding clearly corroborates the prediction in

[28] The derivation follows the error correction (EC) model setup. An EC term is a linear combination of independent variables at levels. In this study, the relationship is given as $EC_{t-1} = ex_{j,t-1} + \beta_{j,0} + \beta_{j,1}trend + \beta_{j,2}re_{j,t-1} + \beta_{j,3}y_{j,t-1} + \beta_{j,4}V_{j,t-1}$. Since $E(EC_t) = 0$ in the long-run, then $ex_{j,t-1} = -\beta_{j,0} - \beta_{j,1}trend - \beta_{j,2}re_{j,t-1} - \beta_{j,3}y_{j,t-1} - \beta_{j,4}V_{j,t-1}$, where $-\beta_{j,2}$, $-\beta_{j,3}$ and $-\beta_{j,4}$ capture the long-run effects on exports. We can find these normalized coefficients by using the coefficients in equation (1.4) such that $-\beta_{j,2} = -\frac{\gamma_{j,3}}{\gamma_{j,2}}$, $-\beta_{j,3} = -\frac{\gamma_{j,4}}{\gamma_{j,2}}$ and $-\beta_{j,4} = -\frac{\gamma_{j,5}}{\gamma_{j,2}}$.

[29] All lagged estimates for long-run level relationships are reported in Tables A.7 through A.12.

[30] The only exception is the long-run estimation with GARCH volatility for the Philippines, where the estimate of the U.S. GDP is less than unity.

[31] The estimate of real exchange rate in the bilateral SUR model with GARCH volatility for Indonesia is insignificant.

the international trade theory that depreciation of a currency leads to higher exports. An explanation lies on the fact that the ASEAN-intra and ASEAN-China trades have been vigorously prospering, which substitute a significant portion of ASEAN-5 exports to the advanced economies and offset some effects by the depreciation during the sample period examined.[32] In all long-run level relationships, the lagged level real exports all generate negative and significant effects which are reported in Tables A.7 through A.12 in the Appendix A.

Ambiguous results are obtained from the estimates of the volatility measures in terms of signs and magnitudes, which is consistent with most findings in the recent literature. All normalized estimates vary within the range [-0.164, 0.132] for the manufacturing exports, and [-0.082, 0.105] for bilateral exports, respectively. For one standard deviation increase in the exchange rate volatility (reported in Table A.2), the long-run effects are in the range of [-7.2%, 8.3%] for the manufacturing exports, and [-3.1%, 6.8%] for bilateral exports, respectively.[33,34] Thus, exchange rate volatility has larger impacts on manufacturing exports in the long-run.[35] Although Indonesia

[32]Figure A.3 in the Appendix A shows the trade shares of ASEAN with its four major trade partners and the ASEAN-intra trade. We can clearly see a pattern of increasing weights on ASEAN-intra and ASEAN-China trade accompanied by the graduate declines of shares of ASEAN trade with developed countries.

[33]The effect is calculated by taking the product of the standard deviation of the exchange rate volatility and estimate. Because estimates obtained from different volatility measures can be comparable by the same standard in this way.

[34]Another possible reason could be that these countries have been having better access to forward/option markets for risk hedging. The early works (Medhora 1990 and Arize et al. 2000) pointed out that developing countries lacked access to forward markets for hedging against risk. However, financial markets have developed significantly in developing world over the past decade, which indeed has improved the opportunities of hedging of exporters. Therefore, the difference in sensitivity of exchange rate volatility with respect to manufacturing sector and bilateral exports may partly be explained by this fact, but unavailability of such data makes it impossible to examine empirically. Additionally, the difference in the efficiency of using available financial instruments by exporters across sectors could potentially contribute to this difference in sensitivity of manufacturing and bilateral exports to exchange rate volatility, which could be examined if data become available.

[35]Ideally, it would be interesting to compute sector exchange rates of ASEAN-5 and to examine

is the only ASEAN-5 country in the study that has confirmed level relationships in all cases, I find that GARCH series produces the smallest effects among all three volatility measures at both the manufacturing sector and bilateral levels. The intuition is that all the MSSD and SD12 measures are the unconditional volatilities where both the explained and unexplained movements of exchange rate are inherited. However, in the GARCH estimations, exchange rate movements are partially explained by the ARIMA model, and the remaining unexplained movements are depicted by the GARCH volatility. Among the ten confirmed long-run level relationships, the six estimates for Indonesia are all positive and significant; the rest estimates for the Philippines and Thailand are all negative with two being significant. The results show that only Indonesian exports react positively to higher exchange rate volatility during the last twelve-year period. Theoretically, this could be interpreted as the dominance of income effect over the substitution effect; empirically, it could be due to the coincidence between exports growth and exchange rate volatility. Until now no other theoretical works have been developed beyond the income and substitution effects to explain positive effect of exchange rate volatility on exports. During the Asian financial crisis, both exchange rate and inflation rate of Indonesia exhibited the largest volatile movements among the ASEAN-5.[36] After the monetary authority failed to defend its currency in the late 1997, Indonesian exporters began to lose

the impacts of these exchange rates and associated volatility on sector exports. However, the index of exporting price at manufacturing sector levels of ASEAN-5 are not available, which makes it impossible to investigate such impacts.

[36]Figure A.5 in Appendix A shows the percentage change in nominal exchange rate and inflation rate over 1997-2010. Overall, nominal exchange rate and inflation rate indicate volatile movements, and are highly correlated during the transition from fixed exchange rate regime to floating exchange rate regime during 1997-1999.

confidence on the monetary authority, and chose the U.S. dollar as safe heaven and hedges. As a result, the Indonesian exporters increased exports even though the exchange rate movements were volatile. The economic fundamentals may have changed for the Indonesian exporters, but the existing literature has not addressed this issue. Thus, it is possible to incorporate switch of preferences by exporters under various economic conditions to provide another theoretical link to explain positive connection between exchange rate volatility and exports.

1.5.3 Short-run Dynamics

In total, six SUR models are estimated for the short-run manufacturing sector and bilateral export demands in the cases of all the three exchange rate volatilities. According to the estimates of the short-run dynamics reported in Tables A.7 through A.12, most explanatory variables are within five lags. Overall, the U.S. demand demonstrates the largest impact on exports, and most of the lagged real exchange rates as well as the lagged real exports positively affect the real exports. In consistency with the findings in recent time series literature, mixed effects of exchange rate volatility are observed.

The U.S. demand has the largest effects among all the explanatory variables. 60 percent of the estimates carry the expected positive sign, and most are significant and larger than unity, which implies that ASEAN-5 manufacturing/total exports to the USA are income elastic in the short-run.[37] However, some significant and negative

[37]In the short-run dynamic analysis, the estimates represent the elasticities between the growth rates of the dependent variable and regressors.

coefficients are consistently obtained in both the manufacturing sector and bilateral SUR models, where most of them are observed within 2-quarter. This could be the reason of seasonality of real GDP in nature.[38] Another finding is that contemporaneous effects of the U.S. demand are either negative or insignificantly positive in all bilateral and some manufacturing estimations, which contributes as a main factor to cause fewer positive effects in the bilateral analysis. This could be the reason that international trade contracts typically have time lags between the contract and actual delivery dates. Consistent with the long-run analysis, the results also confirm the fact that the U.S. demand is the major driving force for ASEAN-5 exports.

In all SUR estimations, the majority of the estimated coefficients of the lagged real exports are positive. Other than Indonesia and the Philippines in which only positive and significant estimates are obtained, I find mixed effects of lagged real exports in all other ASEAN-5 countries. The significant and negative estimates are mostly reported for lags 2 and 4 for Malaysia, Singapore and Thailand in all estimations. Even though the export data have been seasonally adjusted, the seasonal relationship between the raw GDP and exports still holds, which could lead to this alternating signs of effects over lags. The lagged effects of exports are found with similar magnitudes in most of the SUR models, and the coefficients are ranged from -0.882 to 0.938 in sector analysis, and from -0.634 to 0.803 in bilateral analysis, respectively.

The evidence is inconclusive on how the exchange rate affects exports in the short-run. 77 percent of the estimates are positive as expected, which indicates that

[38]Quarterly GDP usually reaches the low in the first or second quarter and gradually rises to a peak in the fourth quarter.

ASEAN-5 exports generally are increasing as the currencies depreciate as what the trade theory predicts. In particular, for Malaysia, Singapore and Thailand, this exchange rate policy seems to work well for their export performances, which can be seen from the statistically significant and positive coefficients obtained from the SUR models. The significantly negative effects mixed with positive effects, on the contrary, are primarily reported in the cases of Indonesia and the Philippines. These results imply that a large depreciation of exchange rate could possibly generate a decrease in exports because of the lowered expected profits for exporters and the dampened consumer confidence in the economy, and indicate the less effectiveness of exchange rate policy for Indonesia and the Philippines. It could relate to the relatively healthier economic fundamentals and stronger resistance to volatile exchange rate movements of the other three ASEAN-5 countries since Asian financial crisis in 1997.

Significant negative effects of exchange rate volatility are observed and account for over 75 percent of the estimates in all SUR models, but are accompanied by some significant and positive estimates. Excluding the contemporaneous effects, lagged exchange rate volatility series exhibit purely negative effects for Indonesia, Malaysia and Philippines in the bilateral analysis, and even Singapore and Thailand mostly have negative effects; analogously, only Indonesia illustrate purely negative effects in lagged exchange rate volatility in the sector analysis. As a matter of fact, 80 percent of the bilateral estimates are negative compared to 71 percent of the sector estimates, which implies that mixed effects are more common in the manufacturing sector estimations. Additionally, the sector estimates are generally larger than those in the bilateral estimations except Malaysia. This finding is similar to that of the long-run analysis, and

indicates that the exchange rate volatility on average has larger effects on sector exports. The estimates of each ASEAN-5 country mostly have similar sizes in both the sector and bilateral analysis. The exchange rate volatility has much smaller effects on exports of Malaysia and the Philippines than of the other ASEAN-5 countries. In contrast, no consistent results are obtained for the contemporaneous effects in both sector and bilateral estimations. Only 40 percent of the contemporaneous estimates are statistically significant of which two thirds are negative. These contemporaneous estimates also turn out to be much smaller than the lagged estimates. Given a unit increase in standard deviation of the volatility, the magnitudes of changes of manufacturing sector and bilateral exports are within the range of [-5.2%, 6.9%], and [-7.9%, 4.6%], respectively. Among the three volatility measures, the GARCH method generates the largest negative impacts but smallest positive impacts mainly because of the much bigger standard deviations for the change of the GARCH volatility series.

The fact that exchange rate volatility negatively affects exports in the short-run implies that risk averse exporters are in favour of shifting resources into domestic market when facing higher exchange rate risk. This particularly fits the case of Indonesia where the volatile exchange rate movement leads to significant uncertainties, and later causes exporters to cut exports to reduce exposure to exchange rate volatility. However, in some ASEAN-5 countries, exporters sometimes tend to raise exports given higher exchange rate volatility. This behaviour provides the exact opposite implication for the effects of the exchange rate volatility on exports; and theoretically, this could be interpreted as the income effect dominating the substitution effect. At the sector and bilateral levels, mixed signs of the effects of exchange rate volatility

on exports are present in most ASEAN-5 countries (Malaysia, Philippines, Singapore and Thailand), which matches the empirical evidence derived in some recent literature. This mixture of the impacts implies that a complex decision making process is associated with the dynamics of the exchange rate fluctuation and exports.

1.6 Conclusion

This paper empirically examines both the long-run and short-run dynamic impacts of exchange rate volatility on ASEAN-5 exports at the manufacturing sector and bilateral levels in a quarterly panel data set over 1999-2010. One of the two main features of this study is to apply the ARDL bounds tests to identify possible long-run level relationships. The other is to use the SUR modeling technique to discover the short-run dynamics by controlling the cross-sectional interdependence. Three measures of exchange rate volatility are utilized in the study − the standard deviation method, the moving sample standard deviation method and the GARCH method.

By comparing the estimation results of the sector and bilateral analysis, similarities and differences emerge in both the long-run and short-run. Ten long-run level relationships are confirmed among real exports, real exchange rate, the U.S. GDP and exchange rate volatility. A mixture of positive and negative long-run effects of exchange rate volatility on exports is discovered, and particularly, purely positive effects are obtained for Indonesia. The real exchange rate and exchange rate volatility demonstrate larger effects in the manufacturing sector estimations than in the bilateral estimations; the exports and U.S. GDP show same signs and similar magnitude.

At both the manufacturing sector and bilateral levels, foreign demand is proven to be the crucial factor in driving ASEAN-5 long-run and short-run export demands. The exports exhibit close correlations with the seasonal shifts of the foreign demand in the short-run. The exchange rates significantly affect the exporting decisions but the signs are ambiguous, which implies the decision making by exporters is affected by a complex manner of dynamics in the short-run. Consistent with the recent literature, my results suggest significantly negative effects of the exchange rate volatility on the manufacturing as well as bilateral exports in the short-run, but are mixed with some positive impacts.

The negative impacts of exchange rate volatility on exports suggest that risk averse exporters reduce economic activities and adjust their resources away from exporting to reduce the exposure to exchange rate risk. However, it is possible that the positive effects indicate the exporters' different reactions to exchange rate risks in the long-run and short-run because of income effects' dominance over substitution effects. During the Asian financial crisis, the exchange rate uncertainty deeply impacted real sectors of the economy. It is therefore vitally important for trade policy-makers to be aware of the existing exchange rate volatility and recognize the potential impacts on trade and economy as a whole.

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Chapter 2

On The Effect of Economic Policy Uncertainty on Cross-country Growth

2.1 Introduction

Over the past 100 years, few major economic events have profoundly changed the world economic development than the Great Depression in 1929-1933 and Great Recession in 2007-2009. These two crises started in the U.S. and spread worldwide shortly after. Not only the U.S. economy but also other economies were severely damaged and took years for recovery. However, the then-prevailing idea that free market would automatically lead to full employment was practically rejected during the Great Depression, and was later replaced by a more practically successful theory developed by the British economist Keynes. Keynes and other Keynesian economists asserted that aggregate demand is the main driving force for an economy, and emphasized the importance of government intervention through public policies to achieve full employment and price stability. Therefore, the Great Depression has generally been regarded by economists as the beginning of economic policy activism. Since then, heavier government intervention, regulation and direction have been important factors that contribute to the economic development at both the aggregate and mi-

croeconomic levels.[1] Ironically, history has repeated itself for bringing another global crisis − Great Recession. Many economists believed the lack of regulation in financial system, sustained lower interest rates and huge capital inflow were the main causes to the housing bubbles and Great Recession. Thus, a new wave of policy reform was launched to stabilize and revive the economy. Starting from January, 2008, the Federal Reserve lowered the interest rates by 300 basis points in 9 months, and launched the first round of quantitative easing (QE) to purchase bank debt, mortgage-backed securities and the U.S. Treasury Notes in November 2008. Since then the Federal Reserve launched another two rounds of QE and has accumulated a total of $4.5 trillion assets by October 2014.[2] From late 2008 to early 2009, the Bush and Obama administrations passed a series of bailout and stimulus plans to prevent the U.S. economy from further contractions. However, higher uncertainty associated with on-going policy reform inevitably leads to a question on how this economic policy uncertainty would affect growth in the U.S. as well as in other countries. Baker et al. (2013) argue that this series of policy reform raised higher economic policy uncertainty than anytime before, and as a matter of fact slowed the economic recovery in the U.S.

After the release of the economic policy uncertainty index (EPU) by Baker et al. (2013), it is possible to empirically examine the impact of the EPU on growth.

[1] Figure B.2 in the Appendix B cited from Baker et al. (2013) shows the quarterly news based EPU during 1900-2013. We can see two periods with the most consistent and volatile EPU are those overlapping with the Great Depression and Great Recession.

[2] QE1 was launched in November 2008, and accumulated $2.1 trillion assets by June 2010. In November 2010, the Federal Reserve announced QE2 and purchased a total of $600 billion Treasury Securities by June 2011. The Federal Reserve launched the last QE3 in September 2012 to buy an additional $40 billion in mortgage-backed securities monthly. The purchase was increased to $85 billion per month in December 2012, and was halted in October 2014. The total accumulated asset reached $4.5 trillion.

Although they point out a negative correlation between the EPU and growth in the U.S. after the Great Recession, so far there is a clear gap in the understanding of the relationship between the U.S. EPU and cross-country economic growth since the existing works investigate either the effect of one aspect of economic uncertainty on growth or the effect of economic policy uncertainty on growth in only one country – the U.S.[3] Thus, the objective of this paper is to empirically examine the effect of the EPU on growth in both advanced and emerging countries over the period 1985-2006.

Figure 2.1: **Growth of GDP per Capita in Advanced and Emerging Countries, and Average US EPU 1985-2011**

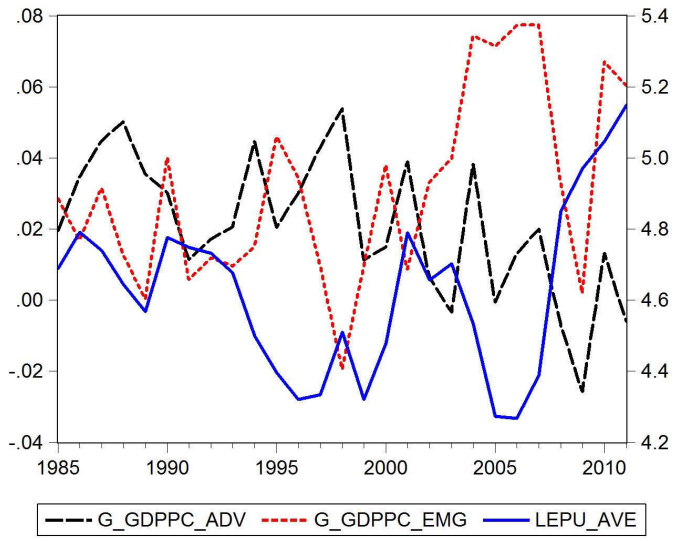


Figure 2.1 shows the relationship between the U.S. EPU and growth of GDP per capita in advanced and emerging countries for the period 1985-2011. During those years, the EPU has been very volatile and reached its historical highest levels since the start of the Great Recession.[4] Additionally, Figure 2.1 indicates that growth of GDP

[3]Other economic uncertainty includes government expenditure/revenue volatility, inflation rate volatility, exchange rate volatility, etc.

[4]This can be seen from Figures B.1 and B.2 in the Appendix B.

per capita in emerging countries is more volatile than that in advanced countries, and the EPU in general moves oppositely against growth. A positive growth comovement and negative correlations between the EPU and growth in the two country groups have become more apparent since the early 2000s. I further break the sample into 4 sub periods − 1985-1997, 1998-2001, 2002-2006 and 2007-2011, and report all correlations in Table 2.1. Relative to other sub periods, all these correlations start with low and negative values in the first sub period. During the second sub period, even though some important events happened, the EPU was relatively stable which implies that the U.S. economic policy making was not significantly affected. Emerging economies suffered most losses due to the Asian financial crisis and the subsequent Russian crisis, but advanced countries still experienced better economic growth. The results reported in the last two columns of Table 2.1 indicate high and positive growth correlation, and negative correlations between the EPU and growth. From the 9/11 terrorist attack in 2001 to the recent debt ceiling dispute in 2011, we can see in Figure 2.1 that emerging countries have outperformed advanced countries in growth, and spikes of most of these U.S. events reduced economic growth in advanced and emerging countries either within the same year or a few years afterward.[5] For instance, when the U.S. was close to debt ceiling in 2011, the vulnerable economic recovery in both country groups were suddenly hindered.

All these stylized facts point to a potential negative connection between the EPU

[5]In the early 2000s, some important events are believed to cause this outperformance in growth in emerging countries, for example, 9/11 terrorist attack in 2001, China's WTO membership acceptance in 2001, corporate fraud scandal in 2001, Afghanistan and the Iraq wars in 2001-2003, and rapid rise in commodity prices in 2000-2003.

Table 2.1: **Correlations among Growth of GDP per Capita and Average US EPU 1985-2011**

	1985-1997	1998-2001	2002-2006	2007-2011
Growth correlation between advanced and emerging countries	-0.078	-0.789	0.501	0.927
Correlation between EPU and growth in advanced countries	-0.224	0.522	-0.377	-0.528
Correlation between EPU and growth in emerging countries	-0.137	-0.072	-0.835	-0.582

and cross-country growth, but on the other hand, understanding the possible mechanisms of this negative correlation is also important. Bernanke (1983) first identifies the effect of economic uncertainty on development through irreversible investment. He argues that given irreversibility of investment on individual projects, the benefits gained from waiting for more information trade off the extra returns from early commitment, which could lead to a cut in investment and employment if the long-run perspective of the projects becomes uncertain. Bloom et al. (2007) reinvestigate the (partial) irreversibility and find that higher uncertainty reduces the responsiveness of investment to demand shocks. Bloom et al. (2012), Bachmann and Bayer (2013) and Baker et al. (2013) argue that economic uncertainty also affects consumption such that higher uncertainty induces less consumption but more work by households because of incentives for precautionary savings.

The effect of uncertainty on international trade has long time been documented in the literature. The exchange rate uncertainty is a common factor that affects trade. Given the fact that risk averse exporters mostly bear the exchange rate risk due to trade invoiced in exporter's currency, and the delay between trade contract

and payment, Hooper and Kohlhagen (1978) argue that when exchange rate fluctuation becomes unpredictable, it will create uncertainty about the realization of profits and reduce the benefits of international trade. Handley and Limão (2012) develop a theoretical model to explain export oriented firms' decisions on investment, and export entry and exit under both domestic and external trade policy uncertainty. They claim that an increase in policy uncertainty would reduce firms' incentives to enter and invest in foreign markets, which has been supported by their empirical studies on Portugal and China.

Since I find very low correlations of the U.S. EPU with respect to trade openness and international financial integration, it does not support the idea that the EPU affects economic growth through these two channels.[6] In literature, economists argue that the spillover effect of the EPU across countries is a theoretical link that connects the EPU and cross-country growth. Kim (2001) introduces the spillover effects of monetary policy uncertainty, and empirically finds significant effects of the U.S. monetary policy uncertainty on macroeconomic aggregates of the G6 countries.[7] The recent work by Colombo (2013) examines and concludes the significant effects of the U.S. EPU on the Euro area macroeconomic aggregates. Table 2.2 reports the correlations among the EPUs of the available countries and regions from Baker et al. (2013), and provides direct evidence that correlations among the EPUs are high. Most of the EPU correlations with the U.S. counterpart are greater than 95 percent.

[6] I check the correlations of trade openness and international financial integration with respect to the U.S. EPU for advanced and emerging countries, respectively. The correlations between the U.S. EPU and trade openness for the two country groups are 0.01 and 0.08; the correlations between the U.S. EPU and international financial integration for the two country groups are 0.02 and 0.06.

[7] The G6 countries are Canada, France, Germany, Italy, Japan and UK.

Such high EPU correlations suggest that any major economic policy changes in the U.S. could indirectly affect other countries in the short-run. Since the U.S. EPU is available over the longest time period, it is natural to employ and examine the effect of the U.S. EPU on cross-country growth.

Table 2.2: **Correlations Among Average EPUs 1985-2006**

	USA	EU	Canada	China	India
USA	1				
EU	0.9826	1			
Canada	0.9799	0.9656	1		
China	0.7614	0.7021	0.8068	1	
India	0.9551	0.9199	0.9560	0.8103	1

Note: 1. The EPUs of the USA, European Union (EU), Canada, China and India are available from 1985, 1997, 1990, 1995 and 2003, respectively.

2. The cross-country correlations of EPUs are calculated up to 2006.

3. The cross-country correlations of EPUs are restricted by the EPUs with shorter time dimensions.

However, the recent quantitative findings on the effects of economic uncertainty on the U.S. GDP, investment and employment at both aggregate and microeconomic levels are somewhat inconclusive. Bloom (2009), Bloom et al. (2012) and Baker et al. (2013) find larger impacts of policy uncertainty on the U.S. GDP growth at around 2%, while others report little or no impact at the microeconomic level (Bachmann and Bayer 2013, Bachmann et al. 2013). Born and Pfeifer (2013) examine the quantitative effects of monetary and fiscal policy uncertainty on the U.S. business cycle fluctuations by employing an estimated dynamic stochastic general equilibrium (DSGE) model at the aggregate level. They find that a joint two-standard deviation of policy shocks reduces output by 0.045 percent, which is far below those reported in other aggregate

level studies.

Since neither theoretical works nor empirical investigations have linked the economic policy uncertainty to cross-country growth, this paper tries to fill this gap and aims to answer two questions: first, whether higher economic policy uncertainty dampens economic growth across countries; second, what are the channels through which the EPU affects growth.

The results indicate that higher economic policy uncertainty in the U.S. reduces economic growth overall with larger effects obtained for emerging countries. Regarding the channels through which the EPU affects growth, I find that the EPU affects all three channels of economic growth, physical capital accumulation, human capital accumulation and total factor productivity (TFP). The evidence suggests that some other explanatory variables also significantly affect cross-country economic growth and the channels.

The remainder of the paper is organized as follows. Section 2.2 briefly describes the specifications of the model and data sources. Section 2.3 presents econometric methodology applied in the analysis. Section 2.4 discusses the empirical results. Section 2.5 concludes.

2.2 The Model and Data

2.2.1 The Model

The model estimated in this paper extends the dynamic panel data (DPD) model used in Vieira et al. (2013) by introducing the EPU and other explanatory variables, and is specified as:

$$g_{y,i,t} = \alpha + \rho g_{y,i,t-1} + \varrho yinitial_{i,t} + X_{i,t}\beta + \eta epu_t + \mu_i + u_{i,t}, \tag{2.1}$$

where i and t represent the spatial and time dimensions of all variables; $g_{y,i,t}$ denotes the growth rate of real GDP per capita and is measured in constant 2005 US dollars; $yinitial_{i,t}$ is natural logarithm of real GDP per capita of the first year in every five years starting from 1985; epu_t stands for natural logarithm of the U.S. EPU; $\mu_{i,t}$ is the country specific effect and $u_{i,t}$ is the residual. $X_{i,t}$ consists of the growth rate and natural logarithm of levels of the U.S. real GDP per capita, natural logarithms of human capital index and real effective exchange rate (REER), along with levels of share of government expenditure in GDP, trade openness, share of investment in GDP, population growth rate, depreciation rate, inflation rate, volatility of inflation rate, volatility of REER, volatility of ratio of government expenditure, net inflow of real foreign direct investment, flow of real net foreign assets, political instability and polity. Detailed description of the variables is provided in the "data" subsection.

Accordingly, the DPD estimations of the three channels of growth have very similar

formats as equation (2.1) but include different sets of explanatory variables. As in a typical setup of DPD models, first lags of the growth rates of the three channels are included as regressors. Common regressors in the three regressions contain the growth rates and natural logarithm of levels of the U.S. counterparts, natural logarithm of the U.S. EPU, share of government expenditure in GDP, openness of international trade, population growth, political instability and polity. In the regression of physical capital accumulation, depreciation rate and human capital accumulation are the extra regressors; in the human capital accumulation regression, share of investment in GDP is also included as a regressor; in the TFP growth regression, share of investment in GDP and human capital accumulation are the additional regressors.

2.2.2 The Data

Advanced and emerging countries are the two groups of countries analyzed in this paper. The categorization of advanced countries follows the definition of the *International Monetary Fund* (IMF), and that of emerging markets takes account the definitions of the IMF, *Emerging Market Bond Index Plus* (EMBI+) and *Morgan Stanley Capital International Index* (MSCI). The final data set consists of 27 advanced countries and 38 emerging markets.[8]

All data are at annual frequency covering the period from 1985 to 2006.[9] National account variables are collected from the *Penn World table* 8.0 (PWT8.0) and *World Development Indicators* (WDI). The REERs are directly utilized from the data set

[8]Table B.1 in the Appendix B contains details of each categorization.

[9]The U.S. EPU is only available starting from 1985. In addition, political instability is available up to 2006. Since political instability significantly affects economic growth, exclusion of this variable would result in omitted variable bias.

developed by Darvas.[10] The data for international financial integration are obtained from the *External Wealth of Nations Mark II database* developed and updated by Lane and Milesi-Ferretti. In this paper, I employ two measures of institutions, political instability and polity. I follow Aisen and Veiga (2013) to define political instability by using cabinet changes as a proxy, and adopt the polity scale which measures democracy from strongly autocratic (-10) to strongly democratic (10). The measure of political instability is retrieved from the *Cross-National Time-Series* (CNTS) data set. Polity is acquired from the *Polity IV: Regime Authority Characteristics and Transitions Datasets* (Polity IV).

The U.S. EPU is obtained from the database developed and maintained by Baker et al. (2013).[11] I take average of the monthly EPU indices for annual levels, and perform robustness checks for the maximum and end of period monthly EPU indices. The index is built on four main components − the news index which is constructed upon searching the ten major U.S. newspapers starting from January 1985 in regard to economic policy, political and global events, the tax expiration index that measures the number and size of federal tax code provisions with future expirations updated from the Congressional Budget Office, and the forecaster disagreement indices that capture the disagreements among economic forecasters in the Philadelphia Federal Reserve's Survey of Professional Forecasters on government purchases and CPI forecasts. The four components are given a weight of 1/2, 1/6, 1/6 and 1/6, respectively. All components are normalized with a standard deviation of 1, and the overall index

[10]Detailed description of the data is available in the following link: http://www.bruegel.org/publications/publication-detail/publication/716-real-effective-exchange-rates-for-178-countries-a-new-database/

[11]More information of this variable can be found at: http://www.policyuncertainty.com/

is normalized as 100 for the base year 2011.

2.3 Econometric Modeling

Among the most common problems encountered in DPD analysis, endogeneity and parameter heterogeneity are most frequently discussed in the literature. Econometricians have developed a number of estimators to cope with these problems. In this section, I briefly present the available estimators with their key elements, and discuss their properties in dealing with these common econometric problems. In addition, selecting an estimator that is capable of fitting the small sample property of the data set employed in this study is vitally important. Table 2.3 summarizes properties of the most common estimators that deal with these three econometric problems. Among all the estimators, random and fixed effects estimators cannot cope with any of these problems, Anderson-Hsiao IV and system and difference GMM estimators deal with endogeneity, mean group estimators deal with parameter heterogeneity, and Kiviet's estimators cope with both endogeneity and small sample problems.

Table 2.3: **Properties of DPD Estimators**

	Endogeneity	Parameter Heterogeneity	Small Sample
Random Effects Estimator			
Fixed Effects Estimator			
Anderson-Hsiao IV Estimator	✓		
Difference GMM Estimator	✓		
System GMM Estimator	✓		
Kiviet's Estimators	✓		✓
Mean Group Estimators		✓	

2.3.1 Conventional Estimators – Random and Fixed Effects Estimators

Random and fixed effects estimators have been commonly used by economists, but they both exhibit biases. In general, as long as the estimated model is correctly specified as non-linear, the random effects estimator is upward biased given the existence of the individual effects. Considering a simple DPD regression as follows:

$$y_{i,t} = \alpha + \rho y_{i,t-1} + X_{i,t}\beta + \mu_i + u_{i,t}, \tag{2.2}$$

where $y_{i,t}$ is the dependent variable, $X_{i,t}$ is a vector of independent variables, μ_i denotes the individual effects, and $u_{i,t}$ is the residual. The two dimensions of the data, "N" and "T", are respectively defined as the number of entities and time periods.

In general, macroeconomic variables are positively persistent, thus, I assume $corr(y_{i,t}, y_{i,t-1}) > 0$. We can derive a following relationship – $cov(y_{i,t-1}, \mu_i + u_{i,t}) = cov(\mu_i + u_{i,t-1}, \mu_i + u_{i,t}) = var(\mu_i) > 0$, and further conclude $corr(y_{i,t-1}, \mu_i) > 0$. This positive correlation leads to an upward bias in the estimate of ρ.[12]

Nickell (1981) shows that the least squares dummy variable (LSDV) estimator or fixed effects estimator is downward biased, and the bias persists even if N is large.

[12]The fundamental assumption of random effects estimator requires that explanatory variables are uncorrelated with the individual effects, however, the derivation shows a positive correlation between $y_{i,t-1}$ and μ_i in a DPD model. Assuming $W_{i,t} = (y_{i,t-1}\ X_{i,t})$ and $\lambda = (\rho\ \beta')$, as a result, $\widehat{\lambda}_{RE} = \left(W'\widehat{\Omega}^{-1}W\right)^{-1} W'\widehat{\Omega}^{-1}y = \lambda + \left(W'\widehat{\Omega}^{-1}W\right)^{-1} W'\widehat{\Omega}^{-1}\mu_i + \left(W'\widehat{\Omega}^{-1}W\right)^{-1} W'\widehat{\Omega}^{-1}u = \lambda + \left(W'\widehat{\Omega}^{-1}W\right)^{-1} W'\widehat{\Omega}^{-1}\mu_i$, where $\widehat{\Omega}^{-1}$ is the error covariance matrix. The last term of this equation represents the positive bias.

He proves the inconsistency of the estimates as $N \to \infty$ such that

$$\operatorname*{plim}_{N\to\infty}(\hat{\rho}-\rho) = -\frac{1+\rho}{T-1}\left[1-\frac{1}{T}\frac{1-\rho^T}{1-\rho}\right]\left\{1-\frac{2\rho}{(1-\rho)(T-1)}\left[1-\frac{1}{T}\frac{1-\rho^T}{1-\rho}\right]\right\} \simeq -\frac{1+\rho}{T-1}. \tag{2.3}$$

To show downward bias of the fixed effect estimator, we first remove the individual effects by demeaning equation (2.2) as

$$y_{i,t}-\bar{y}_{i,t} = \rho(y_{i,t-1}-\bar{y}_{i,t-1}) + (X_{i,t}-\bar{X}_{i,t})\beta + (u_{i,t}-\bar{u}_{i,t}). \tag{2.4}$$

Since $corr(y_{i,t-1}, u_{i,t}) = 0$ and $corr(y_{i,t}, u_{i,t}) > 0$, the sign of $corr[(y_{i,t-1}-\bar{y}_{i,t-1}), (u_{i,t}-\bar{u}_{i,t})]$ is determined by $corr\left(\frac{T-1-j}{T-j}y_{i,t-j}, -\frac{1}{T-j+1}u_{i,t-j}\right)$. Thus, a negative correlation between the residual and the lagged dependent variable $y_{i,t-1}$ is observed, and the estimate of ρ is downward biased.[13] The first difference estimator would not help to correct this bias since one can show that residual of the first difference equation is still negatively correlated with the difference of the lagged dependent variable.

2.3.2 Endogeneity

One major difficulty that the DPD models face is endogeneity, and particularly, many variables are indeed endogenous in macroeconomic analysis as discussed by Temple (1999). Therefore, econometricians develop instrumental variables (IV) methods to

[13] The bias of the fixed effect estimator is

$$\widehat{\rho}-\rho = \frac{\sum_{i=1}^{N}\sum_{t=1}^{T}\frac{(y_{i,t-1}-\bar{y}_{i,t-1})(u_{i,t}-\bar{u}_{i,t})}{NT}}{\sum_{i=1}^{N}\sum_{t=1}^{T}\frac{(y_{i,t-1}-\bar{y}_{i,t-1})^2}{NT}}.$$

cope with endogeneity.

2.3.2.1 Anderson-Hsiao IV Estimator

Anderson and Hsiao (1982) (hereafter AH) first consider the possibility to include lags of both dependent and independent variables as instruments. To derive the AH estimator, they remove individual effects by differencing equation (2.2) to have the following equation,

$$\begin{aligned} y_{i,t} - y_{i,t-1} &= \rho(y_{i,t-1} - y_{i,t-2}) + (X_{i,t} - X_{i,t-1})\beta + (u_{i,t} - u_{i,t-1}) \; or \\ \Delta y_{i,t} &= \rho \Delta y_{i,t-1} + \Delta X_{i,t}\beta + \Delta u_{i,t}. \end{aligned} \tag{2.5}$$

Next, they identify the instrumental variables based upon the statistical properties of the variables included. They argue that a valid instrument should possess the following properties: first, it must correlate with the explanatory variables on the right hand side; second, it must not correlate with the residuals. Given the fact that it is very difficult to find external instruments in macroeconomic analysis, the natural choice would be to use lags of the included variables. Since macroeconomic variables are typically highly persistent, thus, $y_{i,t-2}$, $\Delta y_{i,t-2}$, $\Delta X_{i,t}$ or their higher order lags are valid instruments.[14] However, longer lags shrink the size of a finite sample, which trades off the efficiency with less available information. Arellano (1989) further points out that $y_{i,t-2}$ is a better instrument than $\Delta y_{i,t-2}$ in that one extra cross section data would be saved in the estimation.[15] The standard IV estimator with higher order

[14] $\Delta X_{i,t}$ can be valid instruments if and only if strong exogeneity assumption holds, otherwise, only higher order lags of $y_{i,t-j}$, $\Delta y_{i,t-j}$ are valid instruments.

[15] If $y_{i,t-2}$ is the instrument employed in the regression, the minimum number of time periods is

lagged variables as valid instruments generates a consistent estimator such that

$$\widehat{\lambda}_{IV} = (W'Z(Z'Z)Z'X)^{-1}W'Z(Z'Z)^{-1}Z'y, \tag{2.6}$$

where Z is the matrix of instruments, W is the vector of explanatory variables which contains both $\Delta y_{i,t-1}$ and $\Delta X_{i,t}$, and $\widehat{\lambda}_{IV} = (\widehat{\rho}\ \ \widehat{\beta}')'$.

2.3.2.2 Generalized Method of Moments Estimators

The generalized method of moments (GMM) estimators have been popularized in the DPD literature. AB (1991) argue that the AH estimator fails to take account of all possible orthogonality conditions internally, and alternatively develop the so called difference GMM. The main difference of this method from the AH estimator is that it includes more instruments by using all the possible lags of dependent and (or) independent variables. The moment conditions $E(\mathbf{Z}_i'\Delta u_i) = 0$ expand much more than that of the AH estimator, and the corresponding instrument matrix is defined as

$$\mathbf{Z} = \begin{bmatrix} 0 & 0 & \cdots & 0 \\ [y_{i,1}\ \ \Delta X_{i,3}{}'] & 0 & \cdots & 0 \\ 0 & [y_{i,2}\ \ y_{i,1}\ \ \Delta X_{i,4}{}'] & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \ldots & [y_{i,T-2}\ \ \cdots\ \ y_{i,1}\ \ \Delta X_{i,T}{}'] \end{bmatrix}. \tag{2.7}$$

2. For the case of using $\Delta y_{i,t-2}$ as the instrument, the minimum number of time periods is 3.

Blundell and Bond (1998) (hereafter BB) develop another GMM estimator that introduces both lagged levels and differences as instruments. They argue that lagged level variables are poor instruments for the differenced variables if the variables have unit roots. This GMM estimator is named as the system GMM estimator which simultaneously estimates level and difference equations with each being instrumented separately. The system GMM approach makes an additional assumption on the moment conditions, i.e., $E[\Delta y_{i,t-\tau}(\mu_i + u_{i,t})] = 0$ where $\tau = 1, \ldots T$.

The GMM estimator relies on both the vector of moment conditions, $\widehat{M}(\lambda)$, and weighting matrix, W, and minimizes

$$\widehat{\lambda_{1S}} = \underset{\lambda}{\operatorname{argmin}}[\widehat{M}(\lambda)' W \widehat{M}(\lambda)], \tag{2.8}$$

where W is determined by the inverse of the covariance matrix of the empirical moments $-$ $[E[M(\lambda)M(\lambda)']]^{-1}$.[16]

The above estimations are recognized as the one-step GMM estimators, but sometimes two-step GMM estimators are needed to gain more efficiency. In the two-step estimation, a new weighting matrix $\widehat{S}$ is estimated by incorporating the $\widehat{\lambda_{1S}}$ in the one-step estimation, and the two-step GMM estimator is determined by minimizing

$$\widehat{\lambda_{2S}} = \underset{\lambda}{\operatorname{argmin}}[\widehat{M}(\lambda)' \widehat{S} \widehat{M}(\lambda)].^{17} \tag{2.9}$$

[16] $\lambda_{1S} = (\rho, \beta')'$. Similar to the AH method, some regressors are allowed to be endogenous. Technical details can be found in Roodman (2009)

[17] In some cases, one can even extend the two-step estimator to k-step with a similar idea as extending from one-step to two-step estimators.

Windmeijer (2005) reports that the two-step GMM estimator generates downward bias in standard errors, and especially when the number of instruments is large. He argues the source of bias is due to the fact that the covariance of the GMM estimator is a function of the weighting matrix S which is regarded as constant and derived from the one-step estimator. He uses the Taylor series expansion of the GMM formula with respect to the weighting matrix to derive the covariance of the estimator. This correction is proven to improve estimation and has become popular in empirical research. Windmeijer (2005) and others argue that the count of instruments is a major concern regarding empirical application of the GMM estimators since many instruments overfit endogenous variables, and particularly this problem exaggerates when weak instruments are included. Windmeijer finds that a reduction in instruments could significantly decrease the bias in the two-step estimation. In a similar spirit, Roodman (2009) argues that a large number of instruments can also weaken the power of Sargen/Hansen tests and lead to unreliable results. He proposes several techniques to reduce count of instruments such as restricting lags and collapsing common instruments over different time periods.

2.3.2.3 Kiviet's Estimators

Roodman (2009) and others argue that an important prerequisite to apply the popular GMM estimators is that the finite sample should preserve a statistical property of large N and small T. So far very limited research has shown the performance of the GMM estimators under samples with both dimensions being small. The relative simple setup of the Monte Carlo simulation experiments has also revealed limited in-

formation regarding the performance of the GMM estimators when more complicated estimations are required. To overcome the problems in small finite sample estimations, economists have reconsidered the LSDV method. Kiviet (1995, 1999), and Bun and Kiviet (2001, 2003, 2006) have developed a series of bias corrected LSDV (LSDVC) estimators and have examined their performance in finite samples with different sizes. They report that LSDVC estimator outperforms all other estimators in small finite samples, which has later been confirmed by Judson and Owen (1999) and Bruno (2005). Bun and Kiviet (2003) extend the earlier work by Nickell (1981) and Kiviet (1995) to approximate the bias in three orders. I next briefly present the main steps in deriving the LSDVC estimator. Rewriting equation (2.2) as

$$y = W\lambda + D\mu + u, \tag{2.10}$$

where $W = [y_{-1}\ X]$, $\lambda = [\rho\ \beta']'$, D is the matrix of individual dummies with a dimension of $(NT \times N)$.[18]

The LSDV estimator is estimated by using the following formula

$$\lambda_{LSDV} = (W'AW)^{-1}W'Ay, \tag{2.11}$$

where $A = S(I - D(D'SD)^{-1}D')S$ is the within transformation that wipes out the individual effects, S is a block-diagonal matrix of dimension $(NT \times NT)$ consisting of individual diagonal matrix S_i which has a dimension of $(T \times T)$. The bias is given

[18]For simplicity, I add α into the coefficient vector β. The resulting X contains the constant term as well.

as

$$E[\lambda_{LSDV} - \lambda] = E[(W'AW)^{-1}W'Au]. \tag{2.12}$$

Bun and Kiviet (2003) approximate the bias as

$$E[\lambda_{LSDV} - \lambda] = c_1(T^{-1}) + c_2(N^{-1}T^{-1}) + c_3(N^{-1}T^{-2}) + O(N^{-2}T^{-2}), \tag{2.13}$$

and bias approximations with higher levels of accuracy are $B_1 = c_1(T^{-1})$, $B_2 = B_1 + c_2(N^{-1}T^{-1})$ and $B_3 = B_2 + c_3(N^{-1}T^{-2})$. The detail of bias approximation of the Kiviet's LSDV estimator is presented in the Appendix B.

The LSDVC estimators require the initial estimates to be consistent before adopting a bootstrap approach to estimate the covariance matrix, standard errors, t-statistics and confidence intervals.[19]

2.3.3 Parameter Heterogeneity – Mean Group Estimators

The previously discussed estimators do not take parameter heterogeneity into consideration. Pesaran and Smith (1995), Pesaran et al. (1999), Pesaran (2006) have developed a series of maximum likelihood estimators to capture parameter heterogeneity and allow homogeneity simultaneously in dynamic panels. This category of estimators is usually referred as the mean group (MG) estimators, which includes MG, pooled MG (PMG) and common correlated effects MG (CCEMG). By deviating from the conventional homogeneity assumption in DPD analysis, these estimators

[19]The three consistent estimators employed are the AH estimator, difference and system GMM estimators.

allow both short-run heterogeneity and long-run homogeneity in groups. As a result, an autoregressive distributed lag model (ARDL) is utilized to represent these short-run and long-run specifications, and for each individual group we have

$$y_{i,t} = \sum_{j=1}^{P} \rho_{ij} y_{i,t-j} + \sum_{j=0}^{Q} \lambda'_{ij} X_{i,t-j} + \mu_i + u_{i,t}. \tag{2.14}$$

Reparameterizing equation (2.14) gives us

$$y_{i,t} = \phi_i y_{i,t-1} + \beta'_i X_{i,t} + \sum_{j=1}^{P-1} \rho^*_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{Q-1} \lambda^*_{ij} \Delta X_{i,t-j} + \mu_i + u_{i,t}, \tag{2.15}$$

where $\phi_i = \sum_{j=1}^{P} \rho_{ij}$, $\beta_i = \sum_{j=0}^{Q} \lambda_{ij}$, $\rho^*_{ij} = -\sum_{m=j+1}^{P} \rho_{im}$, and $\lambda_{ij} = -\sum_{m=j+1}^{Q} \lambda_{im}$.

The panel representation is

$$\mathbf{y}_i = \phi_i \mathbf{y}_{i,-1} + \mathbf{X}_{i,t} \beta_i + \sum_{j=1}^{P-1} \rho^*_{ij} \Delta \mathbf{y}_{i,-j} + \sum_{j=0}^{Q-1} \Delta \mathbf{X}_{i,-j} \lambda^*_{ij} + \mu_i \iota + \mathbf{u}_i, \tag{2.16}$$

where $\iota = (1, \ldots, 1)'_{T \times 1}$.

The long-run relationship between $\mathbf{y}_{i,-1}$ and $\mathbf{X}_{i,t}$ is depicted as the error correction term, which is also the relationship estimated in DPD analysis by using other estimators. One advantage of the MG estimators is that they are consistent and asymptotically normal irregardless of the stationarity of the variables. The main difference between the MG and PMG estimators is that the MG estimator takes average of the long-run coefficients of each group, but the PMG estimator assumes a common long-run relationship among all groups. Pesaran (2006) later develops the CCEMG estimator to account for the error cross section dependence in panels. In an Monte

Carlo simulation experiment, Pesaran shows that all MG estimators have substantial bias when sample size is small, and the CCEMG estimator outperforms MG and PMG estimators with smaller bias and RMSE.

2.3.4 Estimation Strategies

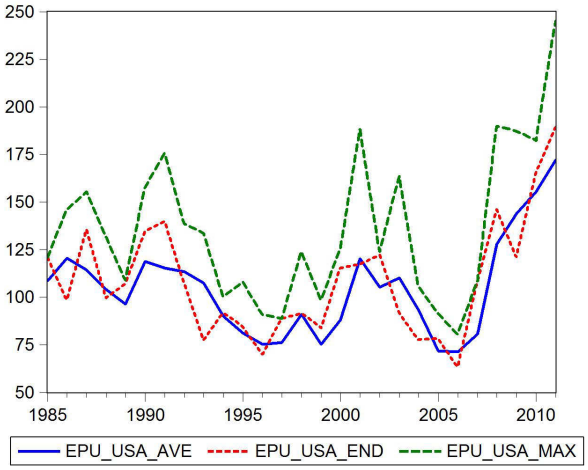
I next describe the estimation strategies that I follow in this paper. Generally, empirical estimations must stick to the properties of the data. The data set employed here is characterized as a small panel sample. Among available estimators, the Kiviet's estimators fulfill the small sample property better than others. Another important task is to prioritize the econometric issues in the analysis, which requires to choose between estimators that deal with endogeneity and those cope with parameter heterogeneity. The main concern is that leaving out endogeneity would lead to biased and inconsistent estimates, while the MG estimators that are capable of dealing with parameter heterogeneity do not deliver desirable results under small samples. Thus, I choose the Kiviet's estimators in this study.

The typical robustness check involves dividing sub-samples with shorter time periods or fewer variables. The robustness check in this study is based on the availability of data, and particularly, the EPU. The EPU is documented in monthly frequency starting from 1985, therefore, an optimal weighting method is necessary for annual frequency transformations. I adopt three optimal weighting methods, namely, the equal weighting (average), maximum weighting to maximum monthly index, and maximum weighting to end of year monthly index. This naturally leads to a set of robustness

checks on the three weighting methods. We can find close movements among these three EPUs plotted in Figure 2.2.

Although the data set is available from 1985 to 2011, the Great Recession in 2007-2009 represents a significant challenge. Economic events trigger changes in both the EPU and growth, thus, their relationship needs an empirical examination. However, given the scale of the impact of the Great Recession on global economy that has not seen since 1985, it may create an amplified negative correlation between the U.S. EPU and cross-country growth.[20] This paper aims to explore the effect of the U.S. EPU on cross-country growth during normalcy, thus, restricting the data set from 1985 to 2006 helps to prevent any impact or distortion by the Great Recession from introducing bias.

Figure 2.2: **Economic Policy Uncertainty Indices of the USA 1985-2011**



Another estimation strategy is to include the growth rate and levels of the real

[20]Figure 2.2 shows that the EPU was at its lowest level in 2006, and it did not rise dramatically until the breakout of the Great Recession. Further evidence could be found from the last column in Table 2.1 which indicates that the growth correlation between the two country groups, and correlation between the EPU and growth in advanced countries were at the highest levels since 1985. Although the correlation between the EPU and growth in emerging countries was lower than the one reported during 2002-2006, it still remained much higher than those calculated prior to 2002.

U.S. GDP per capita as independent regressors in estimations. Since Baker et al. (2013) have confirmed a significant and negative impact of the EPU on economic growth in the U.S., given the fact that the U.S. economic growth generally correlates with foreign growth positively, the U.S. EPU would negatively affect foreign growth even if no causal relationship exists. Thus, including the growth rate and levels of the U.S. GDP per capita as additional regressors help to explore this hypothesis, verify robustness of the estimations and possibly avoid omitted variable bias.

2.4 Empirical Results

Tables 2.4-2.7 report all estimation results. Results of the three Kiviet's estimators are displayed in each table, and three columns for each Kiviet's estimator are included. The first column presents the results for pooling both advanced and emerging countries; the second column reports the results for advanced countries; the third column contains the results for emerging countries. Most explanatory variables exhibit the expected signs, and distinct estimates are observed for advanced and emerging countries. The U.S. EPU significantly and negatively affects economic growth, and all three channels, physical capital accumulation, human capital accumulation and TFP. The robustness check supports that the three EPU indices produce similar estimates in magnitude and signs.

2.4.1 Growth Estimation

2.4.1.1 Economic Policy Uncertainty

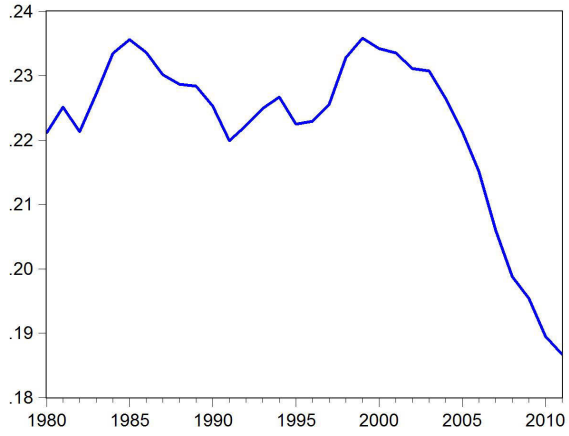
As the largest economy in the world for over a century, the U.S. economy has deeply affected the global economic development, thus, a natural question to ask would be how the economic policy uncertainty in the U.S. alone would affect the growth of the world economy. Figure 2.3 shows that before the mid 2000s, the U.S. economy as a share in the world economy has fluctuated between 22 and 24 percent, and declined to near 18 percent in 2011. After 1985, sharp declines of this share happened twice. One was the economic recession triggered by the "Black Monday" in late 1987 and lasted until the early 1990s, and the other started in 2002 after the "9/11" attacks. Figure 2.4 displays the logarithmic average EPU, and the business cycles of the U.S., advanced and emerging economies.[21] I find a strong negative correlated movement between the EPU and business cycles of the U.S. and advanced countries, but such a strong negative relationship could only be observable for the emerging countries after the mid 1990s.

The estimation results further provide evidence to support the hypothesis on the adverse effect of the EPU on growth. The EPU has shown negative impacts on economic growth in all three Kiviet's estimations. In Table 2.4, the three columns of each Kiviet's estimator report the results for pooling, advanced and emerging countries regressions, respectively. The results suggest that a 1 percent increase in the U.S. EPU

[21] The GDP data are generated by using Hodrick-Prescott (HP) filter, and the parameter λ is 6.25. The group of advanced countries reported in Figure 2.4 excludes the U.S.

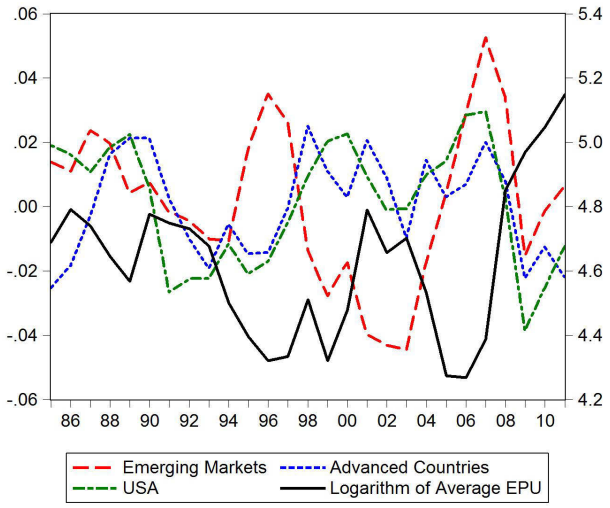
would significantly reduce the economic growth in advanced countries around 0.028 percent, 0.035 percent in emerging countries, and 0.031 percent across all countries. Analogously, a 1 standard deviation (22.8 percent) increase in the U.S. EPU would significantly reduce the economic growth by 0.638 percent, 0.798 percent and 0.707 in advanced countries, emerging countries and all countries. In general, one would expect that the U.S. EPU has a negative impact on economic growth in advanced countries. Since a negative correlation between the EPU and economic growth has been observed for the U.S. in the literature, it would imply a negative correlation between the U.S. EPU and economic growth in advanced countries given the fact that they have high economic integrations with the U.S. However, it is surprising to find a significant and adverse impact of the U.S. EPU on economic growth in emerging countries.[22]

Figure 2.3: **Ratio of the USA GDP over the World GDP 1980-2011**



[22]Since the late 1990s, especially since the Asian financial crisis in 1997, Russian crisis in 1998, Turkish crisis in 2001 and Argentine depression in 1998-2002, many emerging markets started to implement structural economic reform that involved liberalization of trade and international capital flows (China's acquisition of WTO membership in 2001, a series of FTAs signed by ASEAN with other major trade partners, etc.).

Figure 2.4: **Average US EPU and Business Cycles of US, Advanced and Emerging Countries 1985-2011**

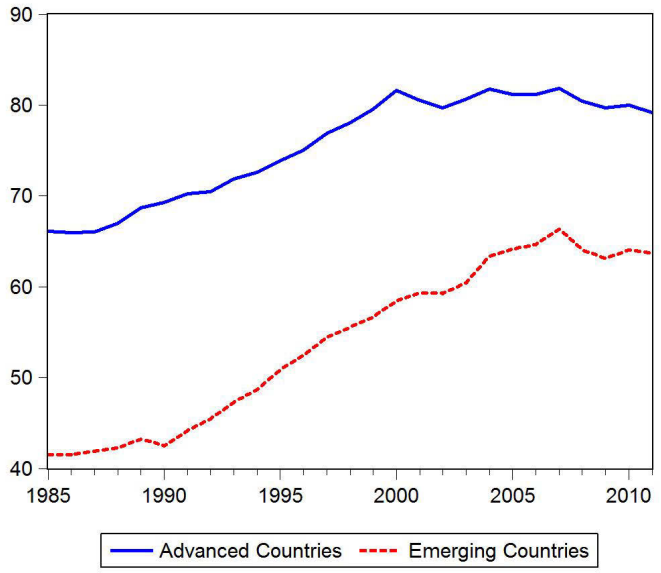


Advanced countries have integrated more into the globalization economically. Figure 2.5 displays the indices of economic globalization for the two country groups.[23] The economic globalization in advanced countries was about 60 percent higher than that in emerging countries in 1985. Since the 1990s, these two country groups have exhibited similar development paths to economic globalization, but advanced countries still demonstrated a much higher level of economic globalization than emerging countries. The economic globalization in advanced countries has been flat since 2000, while a similar pattern has not been observable in emerging countries until the breakout of the Great Recession. Furthermore, advanced countries have more mature and larger capital and financial markets, in which capital flows across countries to seek better investment opportunities with fewer barriers. The less integrated economic globalization in emerging countries should imply that they are less responsive to the

[23]The economic globalization indices are part of the KOF index of globalization developed by Dreher (2006).

U.S. EPU changes than advanced countries. Evidence also shows that some emerging countries have experienced faster and stronger economic growth over the last two decades. Figure 2.6 demonstrates the share of the four largest emerging countries – Brazil, India, Russia and China (BRIC) in 1990-2011. After the slightly decline in the share during the 1990s, the BRIC recovered from the Asian and Russian crises in the late 1990s and was en route to a steady and fast growth path. As a consequence of becoming stronger economic powers, the BRIC and other emerging countries started to influence the global markets such as driving up fossil fuel demands and commodity prices. The estimation results, however, suggest that the U.S. EPU has a slightly larger effect on growth in emerging countries even after controlling all the other factors.

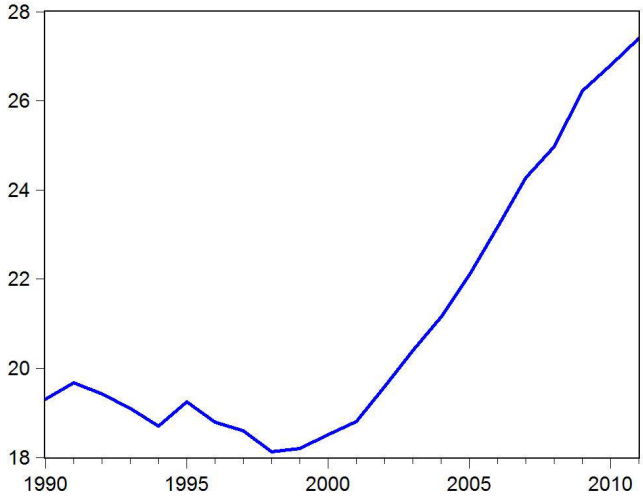
Figure 2.5: **Economic Globalization of Advanced and Emerging Countries 1985-2011**



In this study, since the EPU employed is an aggregate index, we could only un-

derstand whether the EPU affects cross-country growth and sign of the effect. As a result, it remains a challenge to provide policy recommendations due to the lack of information about the individual effect of each EPU component on cross-country growth. On the other hand, this could be the focus of future research. Once the data on individual EPU component become available, relationships between growth and these EPU components would be revealed and serve as milestones for policy making.

Figure 2.6: **BRIC Share of World GDP 1990-2011**



2.4.1.2 Neoclassical Growth Variables

All estimates can be found under the category of "Neoclassical Variables" in Table 2.4. The significant and less than unity coefficients of the lagged growth rate of real GDP per capita indicate the persistency but at low levels for both country groups. Even though the emerging countries have higher persistence levels, the past growth rate of real GDP per capita can only account for 30 percent of change in current growth rate. The significant and negative estimates of the initial GDP per capita

Table 2.4: **Growth Regression Results with Average EPU of the USA**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
eui_USA_t	−0.0307***	−0.0283**	−0.0333*	−0.0309***	−0.0277**	−0.0345**	−0.0323***	−0.0268**	−0.0368**
	(0.0118)	(0.0142)	(0.0198)	(0.01)	(0.0117)	(0.0162)	(0.0101)	(0.0116)	(0.0168)
Neoclassical Variables									
g_gdppc_{t-1}	0.2992***	0.2149***	0.2982***	0.2924***	0.2477***	0.2823***	0.3238***	0.3050***	0.3296***
	(0.033)	(0.0555)	(0.0409)	(0.0327)	(0.0509)	(0.0382)	(0.0332)	(0.058)	(0.0412)
$gdppc\_initial$	−0.1188***	−0.0745***	−0.1448***	−0.1082***	−0.0649***	−0.1316***	−0.1115***	−0.0632***	−0.1352***
	(0.0149)	(0.0198)	(0.0217)	(0.0122)	(0.016)	(0.0185)	(0.0125)	(0.0164)	(0.0191)
$g\_gdppc\_USA_t$	−0.211	0.5149***	−0.7386***	−0.201	0.5128***	−0.7277***	−0.198	0.5191***	−0.7069***
	(0.173)	(0.1754)	(0.2107)	(0.1455)	(0.1416)	(0.1761)	(0.1444)	(0.1369)	(0.1789)
$gdppc\_USA_t$	0.0195	0.0461	−0.0469	0.022	0.0279	−0.0303	0.0184	0.0164	−0.0411
	(0.0336)	(0.0415)	(0.0632)	(0.0273)	(0.0314)	(0.0511)	(0.0289)	(0.0349)	(0.0579)
inv_t	0.0256***	0.0323**	0.0329**	0.0294***	0.0307**	0.0369***	0.0293***	0.0305**	0.0356***
	(0.0086)	(0.016)	(0.0133)	(0.0072)	(0.0122)	(0.011)	(0.0073)	(0.0124)	(0.0112)
hc_t	−0.0197	−0.0139	−0.0065	−0.0364	−0.02	−0.0315	−0.0317	−0.0241	−0.0164
	(0.0716)	(0.0839)	(0.1027)	(0.0593)	(0.0598)	(0.0825)	(0.0626)	(0.0713)	(0.0923)
n_t	0.2865	−0.8518	−0.376	0.1434	−0.9161*	−0.2852	0.2418	−1.0255*	−0.1532
	(0.6304)	(0.6937)	(0.8239)	(0.5166)	(0.535)	(0.682)	(0.5625)	(0.6045)	(0.7703)
δ_t	0.456	0.4364	0.3474	0.5109	0.3706	0.4776	0.4253	0.328	0.3186
	(0.4314)	(0.4357)	(0.716)	(0.3565)	(0.2972)	(0.5784)	(0.3801)	(0.3154)	(0.6219)
Other Variables									
gov_t	−0.001	−0.0066	−0.0038	0.0031	−0.0112	0.004	0.0024	−0.0057	0.0026
	(0.0101)	(0.0235)	(0.0149)	(0.0083)	(0.0183)	(0.0119)	(0.0085)	(0.02)	(0.0125)
π_t	−0.0039***	0.2202***	−0.0041***	−0.0040***	0.2306***	−0.0043***	−0.0040***	0.2230***	−0.0042***
	(0.0012)	(0.0646)	(0.0014)	(0.001)	(0.0522)	(0.0012)	(0.001)	(0.0491)	(0.0012)
$reer_t$	−0.0049	−0.0486**	0.0008	−0.0046	−0.0454***	−0.0001	−0.0066	−0.0483***	−0.0013
	(0.0099)	(0.0201)	(0.0137)	(0.0083)	(0.0159)	(0.0112)	(0.0084)	(0.0154)	(0.0115)
$trade_t$	0.0288***	0.0149	0.0369***	0.0258***	0.0178	0.0319***	0.0268***	0.0216	0.0332***
	(0.008)	(0.0209)	(0.0121)	(0.0068)	(0.0157)	(0.0098)	(0.0071)	(0.0173)	(0.0104)
Volatility									
gov_vol_t	0.1003	0.129	0.0782	0.1233**	0.0894	0.1133	0.1174*	0.0788	0.1082
	(0.0751)	(0.2165)	(0.106)	(0.0616)	(0.1698)	(0.0866)	(0.063)	(0.16)	(0.0901)
π_vol_t	0.0001***	−0.6454	0.0001**	0.0001***	−0.7507	0.0001***	0.0001***	−0.6239	0.0001***
	(0)	(0.9616)	(0)	(0)	(0.8056)	(0)	(0)	(0.7777)	(0)
$reer\_vol_t$	−0.0017	−0.0017	−0.0018	−0.0016	−0.0015	−0.0018	−0.0016	−0.0016	−0.0017
	(0.0017)	(0.0016)	(0.003)	(0.0015)	(0.0014)	(0.0025)	(0.0014)	(0.0013)	(0.0026)
International Financial Integration									
fdi_t	0.0004	−0.012	0.3167	0.0005	−0.0106	0.3422	0.0043	−0.0057	0.3462
	(0.1132)	(0.0738)	(0.3959)	(0.095)	(0.0608)	(0.3293)	(0.0942)	(0.0575)	(0.3343)
nfa_t	0.0166	−0.0094	0.1347**	0.0128	−0.0119	0.1383**	0.0183	−0.0074	0.1468**
	(0.0186)	(0.014)	(0.0684)	(0.0156)	(0.0099)	(0.0575)	(0.0166)	(0.0093)	(0.0613)
Institution									
$poli\_inst_t$	−0.0053*	−0.0023	−0.0058	−0.0053**	−0.0024	−0.0058	−0.0053**	−0.0026	−0.0057
	(0.0029)	(0.0038)	(0.0043)	(0.0025)	(0.0031)	(0.0036)	(0.0025)	(0.003)	(0.0037)
$polity_t$	−0.0004	−0.0008	0.0001	−0.0003	−0.0007	0.0002	−0.0003	−0.0007	0.0001
	(0.0007)	(0.0011)	(0.001)	(0.0006)	(0.0008)	(0.0009)	(0.0006)	(0.0008)	(0.0009)
Sample	1179	481	650	1179	481	650	1179	481	650

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. Standard errors are reported in the parentheses under the coefficients.

clearly imply conditional convergence across both groups of countries. In particular, I find that the conditional speed of convergence of emerging markets is on average twice faster than that of advanced countries.[24] Distinct estimates on the effects of the growth rate of the U.S. GDP per capita are obtained for the two country groups. The growth rate of the U.S. GDP per capita significantly and positively affects that in the advanced countries, however, a significant and negative effect is found for the emerging countries. The higher economic integration among the advanced countries indeed leads to a procyclical movement between the growth in the U.S. and other advanced countries, however, it is surprised to find such a negative relationship between the U.S. growth rate and that of the emerging countries. Figure 2.4 shows a close movement between the business cycles of the U.S. and other advanced countries, but a clear dispersion can be found between those of the U.S. and emerging countries since the early 1990s. This finding suggests emerging countries are more vulnerable to economic uncertainties compared to the more matured advanced countries, as a result, they tend to suffer more losses and sluggish growth.[25] The levels of the U.S. GDP per capita does not affect economic growth in either groups of countries significantly.

As expected, higher investment ratio raises economic growth in both groups of countries, and its contribution to emerging countries is slightly higher than that to advanced countries. This result supports most findings in the literature, but these impacts are much smaller than those reported by Mankiw, Romer and Weil (1992) (hereafter MRW) since they assume exogenous growth and include fewer explana-

[24]The half way convergence roughly takes 5 years for emerging countries but 10 years for advanced countries.

[25]This can be seen from the impacts of a series of financial crises that mostly hit emerging countries from the late 1990s to early 2000s.

tory variables. Population growth shows the most ambiguous results. First of all, as indicated in most literature, population growth has the largest impact among all independent variables, however, only advanced countries experience adverse and significant impacts from higher population growth. This finding reflects the fact that advanced countries in the past few decades have experienced slow population growth in contrast to the relatively faster population growth in emerging countries, however, it also contradicts the prediction of the Solow model where lower population growth raises income.[26]

Unlike MRW (1992), I analyze the individual effect of depreciation rate on economic growth. The Solow type models predict that higher depreciation of physical capital leads to lower growth of capital and results in a slower economic growth. In contrast, my results suggest insignificant coefficients in all regressions. One possible reason might be due to the data generating process. The PWT 8.0 calculates the depreciation rate by first disaggregating physical capital stock up to 6 assets given constant depreciation rates of each asset across countries, and later aggregating over capital deflated depreciation rates among all possible assets. This procedure indeed allows variations in depreciation rates across countries, however, it still does not break down the assumption on exogenous depreciation rates at the disaggregate level.[27] Economists have investigated the impact of depreciation rate on growth at microeconomic level. Bu (2006) provides empirical evidence that developing countries including some emerging countries tend to have higher depreciation rate than

[26]Table B.2 in the Appendix B reports that the average population growth in advanced countries is 0.6 percent, while that in emerging countries it is 1.6 percent.

[27]In Table B.2, one can find that the average depreciation rate of advanced countries in only marginally 0.02 percent higher than that of emerging countries.

advanced countries at the firm level, which would lead to lower growth by reducing the effects of savings and investment. Apergis and Sorros (2013) argue that employing accounting depreciations at the firm level provides more reliable information than the uniform depreciation derived from economic theory, and report that higher fixed capital depreciations could increase TFP and economic growth in contrast to the predictions of theory after examining 4030 firms across 25 countries.[28]

The most surprising result found in this paper is that neither advanced countries nor emerging countries exhibit significant or positive effects of human capital accumulation on growth. The conventional measure of human capital is the school-enrollment rates (Barro 1991, MRW 1992), however, the PWT 8.0 has developed a human capital index that is based on diminishing marginal returns to higher education reported in the literature. Therefore, this measure of human capital does not result in a sizable comparison to other measures, however, one would still be expecting a positive connection. Other literature has also found evidence that human capital has no effect or even negative effect on growth (Benhabib and Spiegel 1994, Pritchett 2001). Pritchett (2001) summarizes three possible causes: poor institutional environment creates privately remunerative but socially wasteful skills through schooling; broad variation in demand of educated labour across countries leads to variation in return to education; years of schooling is not a proper measure of quality of education.

[28]Besides the 20 advanced OECD countries, five emerging countries – Brazil, China, Korea, Mexico and South Africa are included.

2.4.1.3 Institutions

The results of the effects of institutions are present under the block of "Institution" in Table 2.4. My finding of insignificant effect of political instability on growth for either country group contradicts the claim by Aisen and Veiga (2013) that political instability significantly and adversely affects growth. However, my finding of insignificant effect of polity on growth reaffirms what Acemoglu et al. (2008) have discovered. They report insignificant effect of democracy on growth, and no causal effect of income on democracy, either. They further explain the cause as "historical sources of variation in development paths are responsible for much of the statistical association between long-run economic and political changes".

2.4.1.4 International Financial Integration

In order to assess the role of international financial integration on economic growth, I employ two measures – foreign direct investment (FDI) and net foreign assets (NFA).[29] Table B.2 in the Appendix B reports that emerging markets are receivers of FDI while advanced countries are the main source, and both groups of countries are net lenders of assets. During the sample period examined in this study, some emerging countries had accumulated a large amount of foreign reserve through their export-oriented economic development policy (e.g., China, Russia and Southeast Asian countries), and reinvested in foreign assets in some advanced countries (e.g., U.S.). Consequently, they have become net lenders. All estimation results are

[29]Since FDI and NFA are sometimes negative for some countries, as a result, I use the PPP values of the two variables in trillion constant 2005 US dollars.

displayed in the block of "International Financial Integration" in Table 2.4. I find that NFA shows significant and positive effect on growth in emerging markets. A $1 trillion increase in NFA leads to an average 0.14 percent rise in growth. However, the finding of insignificant effect of FDI on growth fundamentally contradicts the theoretical work by Alfaro et al. (2010), in which they conclude that FDI would promote economic growth.[30]

2.4.1.5 Other Variables and Volatility

In this paper, I additionally include measures of the share of government expenditure in GDP, trade openness, inflation rate and REER along with volatility measures of the share of government expenditure in GDP, inflation rate and REER. The estimation results are reported under the blocks of "Other Variables" and "Volatility" in Table 2.4. Other than the share of government expenditure in GDP and its volatility, and volatility of REER, all other variables are found to significantly affect cross-country economic growth.

Due to data availability, I only examine the effects of aggregate government expenditure on growth for both country groups. Theoretically, economists argue that government size in advanced countries expands during the economic downturn and shrinks when the economy is growing, which creates a negative correlation between business cycles and government size. Empirically, most existing studies that focus on investigating advanced countries generally report a negative and significant connec-

[30]Particularly, they argue that if a country is financially developed and substitution effect between domestic products and those produced by multinational enterprises (MNE) is strong, the impact on growth is even larger.

tion between government expenditure and growth. However, the results in this paper indicate insignificant effects of government expenditure on growth. Even though a few exceptions are found, they do not support the idea that government expenditure and its volatility are important factors for growth. One explanation is that sample period examined does not include the Great Recession and post recession periods where much larger share of government expenditure in GDP was found. Second, this finding could be a problem of employing aggregate level data since some sectors of government expenditure may potentially have more significant effects than others. Direct evidence supporting this argument is reported by Afonso and Furceri (2010) who find negative and significant effects of government expenditure and its volatility on growth at disaggregate level for the OECD and EU countries.[31]

Trade openness has long time been employed to explain growth in the literature but empirical implications on its effects remain ambiguous (Temple 1999). Traditionally, one would expect a positive association between the two variables, however, the recent panel data studies report no impact or even negative impact by mixing developed and developing countries together (Aisen and Veiga 2013, and Vieira et al. 2013). In this study, I find positive and significant effects of trade openness on grow in both pooling and emerging countries regressions. On average a 1 percent increase in trade openness would raise economic growth across all countries by 0.028 percent and in emerging countries by 0.033 percent, respectively.

In theory, real exchange rate has been regarded as a key variable that directly

[31]They find negative relationships at the aggregate level but policy implication is proposed for disaggregate components.

affects trade and growth thereafter, and has been practically used as a policy tool to promote growth with the most recent "Abeconomics" as an example. My estimation results indicate solely significant and negative effects of REER on growth in advanced countries, but insignificant effects for emerging countries. This finding suggests that depreciation of real exchange rate has been a more effective policy tool for advanced countries to raise growth but not for emerging countries. It also implies that in spite of the fact that some emerging countries (Southeast Asian countries prior to 1997 Asian financial crisis) have adopted export-oriented growth policy or pegged their nominal exchange rate to some major currencies, they could not maintain lower inflation as advanced countries and hence had little or no success to achieve higher growth.[32] Moreover, emerging markets are more vulnerable to outside shocks, for instance, they have been struck by a series of crises in the 1990s. Economists have also examined the effects of second moment of real exchange rate − volatility − on growth, but consensus has not been reached. The results in this paper demonstrate negative but insignificant coefficients in all regressions, which contradicts the recent work by Vieira et al. (2013) who report significant and negative impacts of exchange rate volatility on economic growth.

Inflation characterized as a part of short-run macroeconomic management has been included in cross-country panel studies to examine its effect on economic growth. The association between inflation and growth is discussed by Bruno and Easterly (1998). They assume that a negative connection between inflation and growth is

[32]This has been supported by the findings that inflation rate positively and significantly affects growth in advanced countries, but negatively and significantly affects growth in emerging countries.

temporary and only observable when the inflation is high, but no effect is present when inflation is lower. Khan and Senhadji (2000) examine the threshold effects in the relationship between inflation and growth, and report that the threshold level of inflation rate is 1-3 percent for advanced countries and 11 percent for developing countries. If inflation rate falls below this level, inflation rate would significantly and positively affect growth, otherwise, significant and negative effect would be obtained. Kremer et al. (2013) investigate threshold effects in a dynamic panel model. They find that threshold level for advanced countries is 2.5 percent, and that for developing countries is 17.2 percent. My findings confirm their conclusion but further address the distinct effects for the two country groups. During the last few decades, advanced countries have experienced decades of much more stable inflation, whereas emerging countries have not done such a good job.[33] Thus, it would be an interesting exercise to investigate the impacts of both inflation rate and its volatility on economic growth. The estimation results show that a 1 percent increase in inflation significantly raises growth by an average of 0.22 percent in advanced countries, but the economic growth in emerging countries would be reduced by 0.004 percent on average. Meanwhile, volatility of inflation in emerging countries significantly and positively affects growth by 0.0001 percent for a given 1 percent increase in volatility. These findings draw a conclusion that economic growth could potentially benefit from a successive period of stable and low inflation, however, excessive inflation could result in lower economic growth. Additionally, consumers are less aware of and less sensitive to change in

[33]In Table B.2, we can read that the average inflation rate in advanced countries over the sample period is 3.3 percent with a standard deviation of 3.8 percent, while the figures in emerging countries are 63.9 percent and 105.6 percent, respectively.

volatility of inflation.

2.4.2 Estimations on Channels of Growth

Understanding the channels through which economic policy uncertainty affects economic growth is another objective of this paper. MRW (1992) argue that physical and human capital accumulations, and TFP are three major factors that determine the long-run growth, thus, it is essential to examine whether economic policy uncertainty contributes to the development of these factors. In doing so, I respectively conduct regression analyses on growth of these three variables across advanced and emerging countries. Tables 2.5-2.7 report all estimation results for the regressions with the average U.S. EPU as one of the independent variables. Following Asien and Veiga (2013), I include the lagged growth of dependent variables, share of government expenditure in GDP, trade openness, population growth, measures of political instability and polity as common regressors along with some specific regressors in each regression. The next three subsections discuss the results.

2.4.2.1 Physical Capital Accumulation

Instead of focusing on the effect of economic policy uncertainty on investment growth, I here address the question on how the EPU affects physical capital accumulation. Since investment directly affects the accumulation of physical capital with a one-to-one relationship, it would be unnecessary to include ratio of investment as a regressor. Meanwhile, I empirically investigate all possible determinants for growth of physical capital accumulation per capita, and report all results in Table 2.5.

Table 2.5: **The Effects of Average EPU on Growth of Physical Capital Accumulation**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
eui_USA_t	−0.0149	−0.0293	0.0014	−0.0188*	−0.0313*	−0.0055	−0.0170*	−0.0303*	−0.0033
	(0.0094)	(0.0181)	(0.0189)	(0.0085)	(0.0154)	(0.0167)	(0.0084)	(0.0149)	(0.0169)
Neoclassical Variables									
g_k_{t-1}	0.6288***	0.6740***	0.6263***	0.6220***	0.6764***	0.6166***	0.6796***	0.6932***	0.6847***
	(0.047)	(0.0493)	(0.0624)	(0.0385)	(0.0476)	(0.0507)	(0.0472)	(0.0465)	(0.0626)
$k\_initial$	−0.0450***	−0.0450**	−0.0482***	−0.0353***	−0.0414**	−0.0375***	−0.0402***	−0.0438**	−0.0400***
	(0.0084)	(0.016)	(0.0132)	(0.0074)	(0.0132)	(0.0105)	(0.0085)	(0.0134)	(0.012)
$g\_k\_USA_t$	0.7969***	0.9772***	0.6132*	0.8059***	0.9997***	0.6476**	0.8244***	1.0027***	0.6649**
	(0.1588)	(0.2202)	(0.2798)	(0.1426)	(0.184)	(0.248)	(0.1411)	(0.1751)	(0.2572)
k_USA_t	−0.0151	−0.0114	−0.0261	−0.0109	−0.0078	−0.0204	−0.0179	−0.0086	−0.0318
	(0.0278)	(0.0318)	(0.052)	(0.0225)	(0.0264)	(0.0409)	(0.0259)	(0.0266)	(0.0496)
hc_t	0.0889	0.0616	0.1208	0.0753	0.0594	0.1233	0.0695	0.0471	0.1064
	(0.0574)	(0.0837)	(0.0945)	(0.0455)	(0.0682)	(0.0733)	(0.0494)	(0.0712)	(0.0884)
n_t	0.473	1.2835	0.4176	0.2737	1.0214	0.2845	0.3124	1.1306*	0.218
	(0.4775)	(0.697)	(0.7606)	(0.3824)	(0.5645)	(0.6488)	(0.3975)	(0.564)	(0.7572)
δ_t	−0.385	−0.1726	−0.286	−0.1329	−0.1411	0.0486	−0.3194	−0.1095	−0.2512
	(0.3668)	(0.5313)	(0.6323)	(0.3201)	(0.4216)	(0.5403)	(0.3424)	(0.4238)	(0.5851)
Other Variables									
gov_t	−0.0555	0.0884	−0.0692	−0.0628	0.0841	−0.0567	−0.0734*	0.0539	−0.0802
	(0.0473)	(0.1507)	(0.052)	(0.0334)	(0.1235)	(0.0456)	(0.0314)	(0.1247)	(0.0478)
$trade_t$	0.0117	0.009	0.0217	0.0096	0.0092	0.0168	0.0144	0.0107	0.0217
	(0.0114)	(0.0141)	(0.0245)	(0.0103)	(0.0118)	(0.0196)	(0.0112)	(0.0119)	(0.0209)
Institution									
$poli\_inst_t$	−0.0037	0.0012	−0.0064	−0.0037	0.0012	−0.0064	−0.0037	0.0012	−0.0062
	(0.0028)	(0.0042)	(0.0038)	(0.0026)	(0.0035)	(0.0034)	(0.0026)	(0.0034)	(0.0035)
$polity_t$	0	−0.0011	0.0003	−0.0001	−0.0008	0.0004	0.0001	−0.0009	0.0004
	(0.0006)	(0.0014)	(0.0007)	(0.0005)	(0.0011)	(0.0006)	(0.0005)	(0.0011)	(0.0007)
Sample	1223	496	677	1223	496	677	1223	496	677

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. Standard errors are reported in the parentheses under the coefficients.

The EPU has shown negative and weakly significant impacts on growth of physical capital accumulation per capita in the pooling and advanced countries regressions. My finding closely relates to that reported by Baker et al. (2013) that firm level investments are negatively affected by this EPU, but differs in the size of the estimates at the aggregate level. Given a 1 percent increase in the EPU, the growth of physical capital accumulation per capita would go down 0.03 percent in advanced countries, and 0.018 percent in all countries, respectively. As expected, the lagged growth of physical capital accumulation per capita is statistically significant and highly persistent. Both country groups have similar speed of convergence to the initial level of physical capital accumulation per capita. The growth of physical capital accumulation per capita in these two country groups also demonstrates a close and positive comovement with the U.S. physical capital accumulation per capita, and particularly, exhibit a near one-to-one effect is found for the advanced countries. However, no significant effects are reported for the level of the U.S. physical capital accumulation per capita on growth in either country group.

Unlike the existing literature (Aizenman and Marion 1993, Brunetti and Weder 1998, and Aisen and Veiga 2013), I find none of the other explanatory variables statistically significantly contribute to the growth of physical capital accumulation per capita. The share of government expenditure in GDP weakly significantly and adversely affects the growth of physical capital accumulation per capita in one pooling regression, which implies a weak crowding out effect on private physical capital accumulation. The main mechanism through which the EPU affects physical capital per capita lies on investment irreversibility and expectation. A higher EPU would create

uncertain future profits and reduce investment activities, and in turn would affect the accumulation of physical capital. These findings suggest that physical capital accumulation is a significant channel through which economic policy uncertainty affects economic growth across countries.

2.4.2.2 Human Capital Accumulation

All results are reported in Table 2.6. In growth estimations, I do not find a significant relationship between human capital accumulation and growth, however, I find a significant and negative relationship between the EPU and human capital accumulation. Generally, human capital is considered as a stock of knowledge that is acquired through education and experience, and a change of the EPU would not be expected to directly affect human capital stock. However, the data generation of this human capital index in the PWT 8.0 consists of years of education and return to education, which is not equivalent to enrollment of education. The returns to education are directly measured by income per person and are indexed for each country within a year. Thus, a change in the EPU could possibly affect real wage rates in the labour market, and further affect return to education and human capital index. But the effect on years of education may not be obvious in the short-run. This finding of a significant connection between the EPU and human capital leads to a conclusion that human capital is an important channel through which the EPU affects growth.

On the other hand, the results indicate that the human capital index is highly persistent in all regressions with larger effects obtained for advanced countries, and converges to its initial level at a relative low speed. Significant and positive corre-

Table 2.6: **The Effects of Average EPU on Growth of Human Capital Accumulation for All Countries**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
eui_USA_t	-0.0214^{**}	-0.0198	-0.0340^{***}	-0.0251^{***}	-0.0211^{*}	-0.0279^{***}	-0.0270^{***}	-0.0229^{*}	-0.0304^{***}
	(0.0101)	(0.0177)	(0.0107)	(0.0076)	(0.011)	(0.01)	(0.0078)	(0.0119)	(0.0102)
Neoclassical Variables									
g_hc_{t-1}	0.7385^{***}	0.6533^{***}	0.7794^{***}	0.7448^{***}	0.7245^{***}	0.7682^{***}	0.7692^{***}	0.7702^{***}	0.7960^{***}
	(0.0312)	(0.0499)	(0.0383)	(0.0272)	(0.0407)	(0.0362)	(0.0273)	(0.0398)	(0.0353)
$hc\_initial$	-0.0251^{***}	-0.0305^{***}	-0.0292^{***}	-0.0280^{***}	-0.0298^{***}	-0.0279^{***}	-0.0296^{***}	-0.0321^{***}	-0.0290^{***}
	(0.0045)	(0.0089)	(0.0045)	(0.0035)	(0.0053)	(0.0042)	(0.0036)	(0.0058)	(0.0043)
$g\_hc\_USA_t$	0.2305^{**}	0.1722	0.128	0.1774^{**}	0.1248	0.1846^{**}	0.1613^{**}	0.1102	0.1628^{**}
	(0.0961)	(0.1674)	(0.0906)	(0.0723)	(0.1026)	(0.0832)	(0.0742)	(0.1101)	(0.0817)
hc_USA_t	0.0275	0.0539^{*}	0.1132^{***}	0.0745^{***}	0.0624^{***}	0.0948^{***}	0.0810^{***}	0.0682^{***}	0.1047^{***}
	(0.017)	(0.0325)	(0.0203)	(0.0127)	(0.0193)	(0.0186)	(0.0135)	(0.0219)	(0.0197)
inv_t	0.311	0.2672	-0.1174	0.2721	0.2637	-0.1016	0.2683	0.2248	-0.0817
	(0.3437)	(0.8292)	(0.3535)	(0.2592)	(0.5185)	(0.3187)	(0.2731)	(0.5516)	(0.317)
n_t	-0.1137^{***}	-0.0418	-0.0388	-0.0589^{**}	0.0202	-0.0488	-0.0675^{**}	0.0146	-0.049
	(0.0415)	(0.0918)	(0.0459)	(0.03)	(0.056)	(0.0423)	(0.0322)	(0.0614)	(0.0457)
Other Variables									
gov_t	0.0959	-0.2642	0.0151	0.0602	0.4276	0.0542	0.0798	0.4546	0.0718
	(0.3587)	(1.8572)	(0.3708)	(0.271)	(1.1124)	(0.3296)	(0.2857)	(1.2359)	(0.3376)
$trade_t$	0.0181	0.053	-0.1272	-0.0254	0.0384	-0.1368	-0.0239	0.0395	-0.158
	(0.1041)	(0.166)	(0.1221)	(0.0786)	(0.1017)	(0.1126)	(0.0823)	(0.1116)	(0.1118)
Institution									
$poli\_inst_t$	-0.0062	0.0097	-0.014	-0.0046	0.0092	-0.0137	-0.0057	0.0086	-0.0139
	(0.0228)	(0.0539)	(0.0212)	(0.0177)	(0.0334)	(0.02)	(0.0181)	(0.0353)	(0.0198)
$polity_t$	-0.0036	-0.0078	-0.0065	-0.0059	-0.0098	-0.0067	-0.0048	-0.0076	-0.0057
	(0.0053)	(0.0148)	(0.0046)	(0.004)	(0.0086)	(0.0043)	(0.0041)	(0.0096)	(0.0044)
Sample	1293	517	722	1293	517	722	1293	517	722

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. Standard errors are reported in the parentheses under the coefficients.

lations between the human capital index and that of the U.S. are reported for the pooling and emerging countries regressions. Analogously, the human capital index in the U.S. shows significant and positive contemporaneous effects on he growth of human capital in both advanced and emerging countries. These two findings indicate that the U.S., the leader in human capital development, has been driving human capital development in other countries over the last two decades through spillovers. Across all countries, higher population growth hurts the growth of human capital in the sense that fewer resources would be available for growing population. I find no significant estimates of all remaining variables, and particularly, share of investment in GDP is insignificant although it has been proven to be a significant factor (Aisen and Veiga 2013) for the growth of human capital in the literature. This may be partly because of the employment of return to education for human capital or the lack of data in human capital investment. Similarly, I find no significant impact by trade openness, which is in contrary to that reported by Aisen and Veiga (2013). One explanation would be that the inclusion of the growth and levels of the U.S. human capital partly offsets trade openness since other countries may gain extra human capital from the U.S.

2.4.2.3 Total Factor Productivity

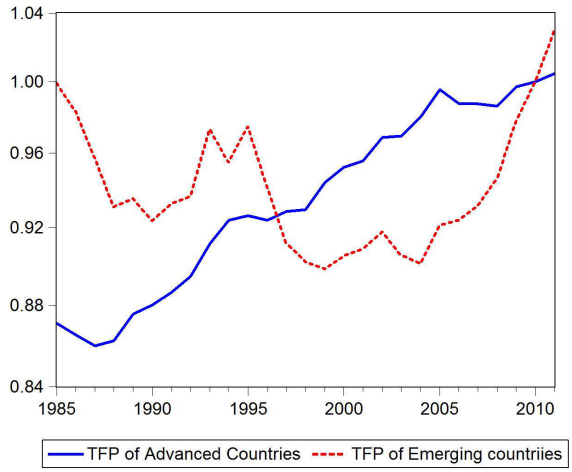
Since the TFP series in the PWT 8.0 data set contains factors other than physical and human capital accumulations after applying growth accounting procedures, if any of the EPU components affect factors of the TFP would result in a connection between the EPU and TFP. In this study, I include several possible factors that have been

theoretically and empirically identified to impact TFP growth along with the EPU. The results are presented in Table 2.7.

Figure 2.7 shows that the TFP of emerging countries was volatile and on a declining trend before the Great Recession, and grew at a much faster pace than that of advanced countries post the Great Recession.[34] I find that the TFP of advanced countries has been growing in the last two and half decades, even during difficult crisis times, thus, it generally does not correlate with the EPU. On the other hand, the TFP of emerging countries occasionally adversely correlates with the EPU, e.g., the Iraq War in 1991, and Asian financial crisis in 1997. The correlations between the EPU and TFP growth in advanced and emerging countries are -0.1654 and 0.1343 in 1985-2006, respectively. The regression results suggest that the EPU does not significantly affect the TFP growth in each country group but significantly and adversely affect the TFP growth across all countries. A 1 percent rise in the EPU would reduce the TFP growth by 0.014 percent.

[34]The natural logarithms of the two series of TFP are normalized to be 1 in 2010.

Figure 2.7: **Normalized Natural Logarithms of TFP in Advanced and Emerging Countries 1985-2011**



In addition, the TFP growth is persistent in both country groups, and the advanced countries have much higher persistence level than that of the emerging countries. I find no clear evidence to support convergence of TFP given any short-run deviation in advanced countries, which links to an interpretation that productivity may not have a possible steady state but rather develops explosively in advanced countries (Lucas 1988). The growth and levels of the U.S. TFP significantly affect the TFP growth in other countries. Opposite effects of the U.S. TFP growth are discovered for the two country groups. Higher U.S. TFP growth is positively associated with higher TFP growth in advanced countries, but is negatively associated with that in emerging countries. These distinct findings correspond to the fact that the TFP growth in the emerging countries has been sluggish before 2007, which leads to such a negative correlation with the U.S. TFP growth. Moreover, higher levels of the U.S. TFP only significantly and positively impact the TFP growth in emerging

Table 2.7: **The Effects of Average EPU on Growth of TFP**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
eui_USA_t	-0.0140^{*}	-0.0097	-0.0174	-0.0136^{**}	-0.0081	-0.0171	-0.0144^{**}	-0.01	-0.0186
	(0.0072)	(0.0078)	(0.0122)	(0.0066)	(0.0055)	(0.0112)	(0.0069)	(0.0081)	(0.0118)
Neoclassical Variables									
g_tfp_{t-1}	0.3537^{***}	0.5167^{**}	0.3884^{***}	0.3678^{***}	0.5852^{***}	0.4037^{***}	0.3830^{***}	0.6977^{*}	0.4179^{***}
	(0.0359)	(0.2282)	(0.0601)	(0.0348)	(0.2203)	(0.0548)	(0.0357)	(0.394)	(0.0563)
$tfp\_initial$	-0.0953^{***}	-0.0718	-0.0960^{***}	-0.0938^{***}	-0.047	-0.0951^{***}	-0.0933^{***}	-0.0442	-0.0940^{***}
	(0.0123)	(0.0518)	(0.0176)	(0.0112)	(0.0316)	(0.0168)	(0.0114)	(0.0417)	(0.0168)
$g\_tfp\_USA_t$	-0.0713	0.4060^{**}	-0.4176^{*}	-0.0704	0.4073^{***}	-0.4068^{*}	-0.0717	0.4033^{**}	-0.4233^{*}
	(0.1515)	(0.1636)	(0.2303)	(0.1407)	(0.1479)	(0.2204)	(0.1422)	(0.2024)	(0.2177)
tfp_USA_t	0.0572^{*}	-0.0044	0.1024	0.0656^{**}	0.0032	0.1044^{*}	0.0699^{**}	0.0077	0.1301^{**}
	(0.0326)	(0.0721)	(0.0679)	(0.0288)	(0.0454)	(0.0596)	(0.0327)	(0.0763)	(0.0634)
inv_t	-0.0235	-0.0838	-0.0163	-0.0108	-0.0552^{*}	-0.0009	-0.0081	-0.0481	0.0079
	(0.0262)	(0.0514)	(0.0413)	(0.0238)	(0.0308)	(0.0375)	(0.0252)	(0.0464)	(0.039)
hc_t	-0.0516	-0.0584	-0.0406	-0.0529	-0.057	-0.0505	-0.0628	-0.0664	-0.0885
	(0.0377)	(0.1142)	(0.0743)	(0.0339)	(0.0762)	(0.0637)	(0.0403)	(0.0701)	(0.0707)
n_t	-0.1637	0.1145	0.3303	-0.2933	-0.182	0.1346	-0.3814	-0.3805	-0.0429
	(0.2573)	(0.6682)	(0.4991)	(0.238)	(0.4123)	(0.4553)	(0.2489)	(0.5498)	(0.5009)
Other Variables									
gov_t	-0.0415	0.0297	-0.0248	-0.035	-0.0415	-0.0167	-0.0341	-0.0397	-0.0105
	(0.0314)	(0.1494)	(0.0392)	(0.0268)	(0.0866)	(0.0345)	(0.0282)	(0.1217)	(0.0365)
$trade_t$	0.013	0.0183^{*}	0.0022	0.0107	0.0121^{*}	0.0016	0.0122	0.0156	0.0022
	(0.0081)	(0.01)	(0.0183)	(0.0073)	(0.0068)	(0.0159)	(0.0081)	(0.0118)	(0.0169)
Institution									
$poli\_inst_t$	-0.0059^{***}	-0.0031	-0.0072^{**}	-0.0059^{***}	-0.003	-0.0071^{**}	-0.0058^{***}	-0.0031	-0.0070^{**}
	(0.0019)	(0.0024)	(0.0032)	(0.0017)	(0.0022)	(0.003)	(0.0017)	(0.0029)	(0.003)
$polity_t$	-0.0003	-0.0001	-0.0007	-0.0003	0.0002	-0.0006	-0.0003	0.0001	-0.0006
	(0.0004)	(0.0017)	(0.0006)	(0.0004)	(0.0013)	(0.0005)	(0.0004)	(0.001)	(0.0006)
Sample	1265	517	696	1265	517	696	1265	517	696

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. Standard errors are reported in the parentheses under the coefficients.

countries only. This implies that in contrast to the advanced countries, emerging countries which are lack of internal driving forces for TFP growth benefit from the higher levels of the U.S. TFP through spillovers at about 0.11 percent for a 1 percent increase in TFP growth.

Other than a few exceptions, most of the remaining variables are found to have no significant effects on the TFP growth. Advanced countries improve productivity through trade, which is revealed by the significant and positive estimates obtained from "trade openness". Alcala and Ciccone (2004) find significant and positive impacts of trade openness on productivity. Hwang and Wang (2004) find mixed effects of trade openness on productivity at industrial levels, and conclude such effects are industry-specific. As a matter of fact, advanced countries trade high technology products more freely with fewer barriers gives them advantage over the emerging countries that are lack of creativity and have to sometimes import outdated technology products from advanced countries over the last few decades. Additionally, the relative higher political instability impedes TFP growth in emerging countries.

2.4.3 Robustness Checks

In order to check the robustness of the estimation results, I employ the maximum monthly EPU and end of year monthly EPU to perform same growth and channel regressions and compare their results with those obtained from using the average monthly EPU. The results of the two sets of regressions are respectively reported in Tables B.3-B.6 and B.7-B.10 in the Appendix B. After comparing these results with

those of regressions employing the average EPU, I find that most of these estimates have the same signs, and are close in magnitude to the ones reported in Tables 2.4-2.7. However, some distinctions are discovered.

Particularly in the growth regressions with the end of year EPU, I observe that the U.S. EPU has no significant impact on growth in advanced countries but has a significant and adverse effect on growth in emerging countries. These findings alter those obtained in the regressions with the average and maximum monthly EPUs. Similarly, I mostly find consistent and close estimates in analyzing the channel regressions, however, variations in estimates are observed in physical capital accumulation and TFP growth analyses. The results of the physical capital accumulation growth regressions with the maximum monthly EPU indicate that the higher U.S. EPU would reduce the growth of physical capital accumulation in emerging countries. Political instability is also found to significantly impede the growth of physical capital accumulation in emerging countries in the regressions employing maximum and end of year monthly U.S. EPU. The estimation results also reveal that the maximum and end of year monthly U.S. EPU would significantly reduce TFP growth in emerging countries, and further more, the maximum monthly U.S. EPU would significantly and negatively affect the TFP growth in advanced countries. No other exceptions are obtained, thus, the results are robust and confirm a general significant and negative impact of the EPU on growth.

2.5 Conclusion

The objectives of this paper are: first, empirically investigating the impact of economic policy uncertainty on growth across both advanced and emerging countries over 1985-2006 by employing the EPU developed by Baker et al. (2013); second, identifying channels through which the EPU affects economic growth. Most estimates show expected signs according to the existing literature, and cross-group differences are also observed. The results suggest significant impacts of the U.S. EPU on growth, and indicate that it also significantly affects the three channels of economic growth, physical capital accumulation per capita, human capital and TFP.

However, it remains a challenge for policy making purpose. Since we need disaggregate data on the individual components of the EPU to examine their effects on economic growth and channel growth across both advanced and emerging countries before any policy recommendations could be addressed, which would be the focus of future research.

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Chapter 3

Exploring Cross-Country Comovement Puzzles in Open Economy Dynamic Stochastic General Equilibrium Models

3.1 Introduction

The international comovement puzzle has been documented as one of the few major puzzles in the international macroeconomic literature over the last two decades (Baxter 1995, Obstfield and Rogoff 2000). The international real business cycle (IBC) models developed by Backus et al. (1992, 1993) (hereafter BKK) resulted in quantitative anomalies of negative cross-country correlation of investment and hours worked, which contradicted the empirical findings. Conventionally, the counterfactual cross-country comovement of investment is interpreted as a result of capital flowing to a country with relatively higher productivity caused by shocks under the assumption of complete asset markets. Since then economists have tried to solve this puzzle by introducing financial frictions (Heathcote and Perri 2002, Kehoe and Perri 2002). Until recently, Dmitriev and Krznar (2012) (hereafter DK) and Dmitriev and Roberts (2012) (hereafter DR) claimed to successfully explain this puzzle by employing time non-separable preferences without any financial frictions. In this paper, I develop a set of two-country open economy dynamic stochastic general equilibrium (DSGE) models to explore cross-country correlations among real variables. One contribution to the

literature is to incorporate available features of modelling from the recent literature to build up a series of DSGE models in a cross-country setup. The other contribution is to seek to answer the question on what features of modelling affect international comovements among real variables. Price stickiness, money, habit formations, international risk sharing under complete asset markets and capital utilization with adjustment costs (AC) are additional features. I find that open economy models are capable of resolving this puzzle even without the additive habit formations or special preference function forms and retaining the key statistical characteristics of real variables in accordance to the data. After quantitatively investigating the impact of each additional feature of the models, I find that spillovers between monetary policies and TFPs, price stickiness and capital utilization are the four major important factors that drive the international comovements among real variables. This finding overturns DK (2012) and DR (2012) conclusion that internal habit formation is the main driver for international comovements.

In contrast to DK (2012) and DR (2012), I employ the additive preference in the DSGE model.[1] Coeurdacier et al. (2010) (hereafter CKM) set up an additive preference function in a set of IBC models to analyze the hedging roles of equity and bonds. They showed that productivity shocks alone produced positive cross-country correlations of investment and hours worked, but investment efficiency shocks led to a negative cross-country correlation of investment and dominated when both shocks were included at the same time. This finding indicates that an IBC model with an

[1] DK (2012) reported that habit models with separable preferences in general failed to predict comovement of investment under a positive TFP shock.

additive preference can produce a positive cross-country correlation of investment. In this paper, I follow the additive preference specified by Engel and Matsumoto (2009) (hereafter EM) which extends CKM (2010) version by including real money demand, and additionally utilize habit formations to capture intensity and persistence in consumption for further comparing results with those reported by DK (2012).

Economists have exploited the role of habit formations in consumption both theoretically and empirically. Campbell and Cochrane (1999) argued that a habit represents "a fundamental feature of psychology: repetition of a stimulus diminishes the perception of the stimulus and responses to it." A number of empirical studies have confirmed the existence of habit formations among most of the advanced economies, and some have linked habits to the positive international comovement of consumption.[2] An external habit formation implies that the habit of a representative economic agent relies on the past aggregate consumption, whereas an internal formation suggests that the habit depends on the agent's own history of consumption. Ideally, a consumer who lowers the current consumption leads to a rise in marginal utility, and increases his/her consumption in the future accompanied by a lower marginal utility. Adjustment of habit allows consumption smoothing over time. Thus, any shock that increases output would cause savings to increase along with a smaller rise in consumption, and foreign consumers would benefit through wealth effect. As a result, a

[2]Ferson and Constantinides (1991), Heaton (1995) and Campbell and Cochrane (1999) employed the U.S. consumption data to examine habits and confirmed the existence. These studies also suggested the role of habit formations in improving the performance of asset pricing models. Fuhrer and Klein (1998), on the other hand, extended the analysis of habit formations to the G7 countries and found six of them possessed this characteristic. They further linked habits to the international comovement of consumption and suggested that habits could generate a positive comovement of consumption. Dynan (2000), however, reported that no evidence suggested the existence of habit formation after empirically examined micro level U.S. consumption data.

larger increase in savings would lead to higher investments in both countries. However, the recent theoretical studies (DK 2012, DR 2012) including this paper have shown evidence that habit adjustment stretches longer periods, and some of the ideal relationships discussed above may not hold. Empirically, studies that use micro- and financial level data tend to support the finding of internal habits (Ferson and Constantides 1991), while those employ aggregate macro-level data support external habits (Heaton 1995, Fuhrer and Klein 1998). In this paper, I follow the specification of habit formation proposed by Ferson and Constantides (1991) where a habit is a stock variable that linearly depends on the history of consumption and habit stock, and perform sensitivity analyses respectively on both internal and external habits.

The IBC literature in general specifies international trade implicitly, which is described as the discrepancy between income and expenditure. Among the IBC literature that assumes no financial frictions, the only channel links the two countries is the spillover on technology. BKK (1992, 1993), DK (2012) and DR (2012) all fall into this category. EM (2009) and CKM (2010), however, explicitly specified international trade in both composite consumption and investment as a combination of final goods produced in both countries. Given the exogenous home bias in consumption and investment, this model setup leads to a potential way of creating cross-country comovement. In this paper, I adopt this specification of international trade and further incorporate the feature of monopolistic competition where firms in each country are allowed to employ intermediate goods produced in both countries. As a result, composite price in each country depends on sale prices of final goods in each country, and furthermore, this implies that domestic monetary policy can possibly affect

price level in the other country. In contrast to the conventional prediction of money neutrality in the real business cycle (RBC) literature, the introduction of nominal price stickiness establishes the real effects of monetary policy theoretically. Empirical evidence has further supported the non-neutrality of money in the short-run (Nakamura and Steinsson 2008, 2010). Chari et al. (2002) and Martínez and Søndergaard (2008) all added the sticky price feature into models where they were able to examine the effects of monetary policy on the volatile and persistent movements of real exchange rate, hence claimed to resolve the so called real exchange rate volatility puzzle.[3] However, these studies have not particularly focused on investigating the international comovements.

Economists typically assume the evolution of capital stock depends on the evolution of investment and exogenous depreciation rate but no restrictions on the capital stock itself. However, economists proved that physical capital stock is affected by other factors. Empirically, the actual investment process is subject to implicit costs, which in turn would affect the optimal capital stock. This implies that any rigidities of investment would affect capital accumulation, and the decision on capital stock would not be optimal if capital stock deviates from its steady state level by any shocks in one period. In fact, the adjustment of capital stock is a gradual process as investment approaches its steady state level. There are two ways of specifying adjustment costs − capital adjustment costs (CAC) and investment adjustment costs (IAC). Hayashi (1982) built CAC as a convex function of $\frac{I}{K}$ in his model, and $\frac{I}{K}$ can be considered

[3]Chari et al. (2002) tried several setups of their sticky price models, and reported that only the model with non-separable preferences produced a high autocorrelation of real exchange rate which was consistent with data.

as the marginal q-ratio. This assumption implies that only a fraction of investment would be transformed into capital stock, which reflects the penalization of additional investment. Alternatively, IAC offers another way of specifying adjustment costs, and has been widely employed in the literature. The IAC connects costs in terms of investment process in which changing investment becomes costly and affects capital stock as a result. Economists have reported that IAC as a real friction could greatly improve quantitative performance of business cycle models, and solve some existing puzzles. Kahn and Tsoukalas (2011) argued that comovements among consumption and other macroeconomic variables in response to an investment shock in closed economy models depended on the specification of cost of capital utilization, and showed that business cycle models with investment adjustment costs could produce such comovements.[4] In this study, I include both the CAC and IAC in my models to examine their impacts on international comovements.

This paper is closely related to the work of DK (2012) who explained the quantitative anomaly of corss-country comovement of investment in their IBC models. Unlike what they claimed that the two features − internal habit and non-separable preference helped to generate positive cross-country correlations of investment and correct some other anomalies, I instead incorporate an additive preference with or without

[4]Kahn and Tsoukalas (2011) argued that the Greenwood-Hercowitz-Huffman (1988) (hereafter GHH) specification of cost of capital utilization that is positively related to depreciation rate of capital could lead to rise of consumption under an investment specific shock. This helps to solve the comovement puzzle in a closed economy. They also showed that a Christiano-Eichenbaum-Evans (2005) (hereafter CEE) specification would not generate a comovement among real variables for a given investment specific shock. Since my models follow the CEE (2005) specification, my models predict cross-country comovements among real variables but fail to generate comovements among real variables within a country for a given investment shock. These results reaffirm the findings of Kahn and Tsoukalas (2011).

habit formations in a set of open economy models. My results indicate that in a model with money and capital utilization with adjustment costs, the international comovement puzzle can be solved with no need for non-separability and habit formations. EM (2009) and CKM (2010) are another two works that closely relate to mine. I follow the ways of building up explicit international trade in the two papers, and in addition, I introduce monopolistic competition and an intermediate goods sector to models. I add in habit formations into the preference function used by EM (2009), and introduce the capital accumulation process which has not been included in their work. The setups of the DSGE models in the two papers serve as the blueprints of my paper.

The remainder of the paper is organized as follows. Section 3.2 discusses data sources and implied stylized facts. Section 3.3 presents the model. Section 3.4 briefly describes calibration of the model. Section 3.5 discusses the quantitative results. Section 3.6 addresses future research. Section 3.7 draws conclusions.

3.2 Empirical Analysis

In this section, I will first discuss data sources of this study, and next present stylized facts about business cycle dynamics within and across the G7 countries.

Data

The macroeconomic variables − GDP, consumption, investment and hours worked at the aggregate levels are collected from the OECD National Accounts (OECDNA) data set over 1970-2011 at quarterly frequency. Real effective exchange rates and bilateral

nominal exchange rates are retrieved from the Bank for International Settlements (BIS) and International Financial Statistics (IFS) of the International Monetary Fund (IMF), respectively. Tables 3.1 and 3.2 present both domestic and international business cycles statistics of three groups of countries derived from various data sources.

Stylized Facts

In general, positive cross-country correlations are widely observed for the real macroeconomic variables across the G7 countries. Cross-country correlation of income is the highest among all cross-country correlations. All other cross-country correlations are less than 0.5.

Table 3.1: **International Comovement Statistics of G7 Countries**

Time Periods	**Cross-Country Correlations**	**Countries**
		G7 Countries
$1970:1-2011:4$	GDP	0.59
	$Consumption$	0.41
	$Investment$	0.46
	$Aggregate\ Hours\ Worked$	0.40

Notes: 1. Most quarterly data of the G7 countries (1970:1 − 2011:4) in this paper are gathered from the OECD National Accounts. The real variables reported in the table are natural logarithmically transformed. All statistics are derived from HP filtered data with a smoothing parameter of 1,600. 2. In deriving the statistics of cross-country correlations, the U.S. serves as the counterpart of each of the other G7 countries, and the aggregate of other G6 countries serves as the counterpart of the U.S.

As most literature has pointed out, investment and real exchange rate have the highest volatility among all variables, but all other variables are much less volatile and have lower volatilities than that of GDP. Most of these variables have high autocorrelations (more than 0.7). Consumption, investment and hours worked are highly

correlated (more than 0.7) with domestic GDP in the exception of net export and real exchange rate.

Table 3.2: **Empirical Business Cycle Statistics of G7 Countries**

Time Periods	**Countries**	**Variables**	**Standard Deviation**	**Auto-correlation**	**Correlation with GDP**
$1970:1-2011:4$	$G7$	GDP	1.45	0.84	
		$Consumption$	1.22	0.76	0.74
		$Investment$	3.73	0.84	0.82
		$Hours\ Worked$	0.75	0.92	0.88
		$Net\ Exports$	0.61	0.69	-0.13
		$Real\ Exchange\ Rate$	4.07	0.81	-0.17

Notes: 1. Most quarterly data of the G7 countries (1970:1 − 2011:4) in this paper are gathered from the OECD National Accounts. The real variables reported in the table are natural logarithmically transformed. All statistics are derived from HP filtered data with a smoothing parameter of 1,600.
2. In deriving the statistics of cross-country correlations, the U.S. serves as the counterpart of each of the other G7 countries, and the aggregate of other G6 countries serves as the counterpart of the U.S.

3.3 Model

There are two symmetric countries in the model, namely, the home and foreign countries denoted by $i = H, F$. All markets are competitive. A large number of differentiated products are produced and consumed in both countries. Both goods and financial markets are internationally traded with no barriers. Labour is immobile across countries.

3.3.1 Preference

A representative household has a utility function as follows:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_{i,t} - \lambda_h H_{i,t})^{1-\sigma}}{1-\sigma} + \chi ln \frac{M_{i,t}}{P_{i,t}} - \eta \frac{\ell_{i,t}^{1+\psi}}{1+\psi} \right], \tag{3.1}$$

where $M_{i,t}$ is the money demand, ℓ_t is the labour supply, and $H_{i,t}$ denotes habit stock that follows the specification by Ferson and Constantinides (1991) as $H_{i,t+1} = \gamma_h C_{i,t} + (1-\gamma_h)H_{i,t},\ i \in H, F$. The parameters, $\lambda_h \in [0,1]$ and $\gamma_h \in [0,1]$ represent habit intensity and habit persistence, respectively. This specification allows more flexibilities, such that a future habit stock can be solely determined by current consumption or current habit stock level. If the habit persistence is at its maximum, then the habit formation simply becomes the more general case where habit depends on past consumption.[5] $H_{i,t} = 0$ is assumed in the benchmark model with no habit. Past consumption is exogenously determined by the aggregate consumption level in external habit models and individual past consumption is used in the internal habit models.

The composite consumption is given as:

$$C_{i,t} = \left[\alpha^{\frac{1}{\phi}}(C^i_{i,t})^{\frac{\phi-1}{\phi}} + (1-\alpha)^{\frac{1}{\phi}}(C^i_{j,t})^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}, \tag{3.2}$$

and the composite consumption of goods produced by country j and consumed by country i is defined as:

$$C^i_{j,t} = \left[\int_0^1 c^i_t(m_j)^{\frac{\varepsilon-1}{\varepsilon}} dm_j\right]^{\frac{\varepsilon}{\varepsilon-1}},\ i,j = H, F\ and\ m_j \in [0,1], \tag{3.3}$$

where $c^i_t(m_j)$ stands for a differentiated good within a continuum of goods produced

[5] See Dynan (2000) for example.

by a firm of country j, α presents the home bias in consumption, ϕ is the elasticity of substitution between home and foreign goods, and ε is the elasticity of substitution among the varieties of goods within a country.

Accordingly, the composite price index is

$$P_{i,t} = \left[\alpha(P^i_{i,t})^{1-\phi} + (1-\alpha)(P^i_{j,t})^{1-\phi}\right]^{\frac{1}{1-\phi}}, \tag{3.4}$$

and the price sub-index is

$$P^i_{j,t} = [\int_0^1 p^i_t(m_j)^{1-\varepsilon} dm_j]^{\frac{1}{1-\varepsilon}},\ \forall i,j = H,F\ and\ m_j \in [0,1], \tag{3.5}$$

where $p^i_t(m_j)$ denotes the price of a differentiated good m_j produced by a firm of country j and sold in country i.

3.3.2 Technologies and Firms

There are a large number of homogeneous monopolistically competitive firms in the market. A firm that produces a differentiated good m_i employs the following production technology,

$$y_t(m_i) = \theta_{i,t} k^s_t(m_i)^{\kappa} \ell_t(m_i)^{1-\kappa} = \theta_{i,t}[Z_{i,t} k_{t-1}(m_i)]^{\kappa} \ell_t(m_i)^{1-\kappa},\ i = H,F\ and\ m_i \in [0,1], \tag{3.6}$$

where the service capital follows $k_t^s(m_i) = Z_{i,t}k_{t-1}(m_i)$, $k_t(m_i)$ is the capital stock, $Z_{i,t}$ is the rate of capital utilization, and $\theta_{i,t}$ is the TFP shock. $Z_{i,t}$ and $\theta_{i,t}$ are common within a country but are allowed to vary from their foreign counterparts.

The labour markets are competitive, and labour force is homogeneous within a country but can be different from labour force in the other country. Labour is assumed immobile across countries, and wage rate $w_{i,t}$ is same within a country.

Similar to consumption, composite investment is assumed to follow a CES functional form as:

$$I_{i,t} = \left[\alpha^{\frac{1}{\phi}}(I^i_{i,t})^{\frac{\phi-1}{\phi}} + (1-\alpha)^{\frac{1}{\phi}}(I^i_{j,t})^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}.^{6} \tag{3.7}$$

Price stickiness specified by Calvo (1983) is introduced to the price setting of monopolistic firms. In a period t, a firm is able to optimally reset its price with a probability of $(1-\alpha_c)$, and maintain its price at the period $t-1$ with a probability α_c. As a result, the price sub-index $P^i_{j,t}$ evolves as:[7]

$$P^i_{j,t} = [(1-\alpha_c)(\tilde{p}^i_t(m_j))^{1-\varepsilon} + \alpha_c(P^i_{j,t-1})^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}},\ i,j = H,F, \tag{3.8}$$

and the composite investment goods produced by country j and consumed by country i are

$$I^i_{j,t} = \left[\int_0^1 i^i_t(m_j)^{\frac{\varepsilon-1}{\varepsilon}} dm_j\right]^{\frac{\varepsilon}{\varepsilon-1}},\ i,j = H,F\ and\ m_j \in [0,1], \tag{3.9}$$

[6] I follow CKM (2011) to assume home bias in investment is same as that in consumption, but one can allow the two home bias parameters to be different. Table 3.5 in the subsection 3.5.4 shows that impact of removing the common home bias leads to very small changes in those comovement realtionships, thus, I would expect no significant changes in results by allowing home bias in invesetment to be different from that in consumption.

[7] Due to symmetry assumption, $P^i_{j,t-1}$ is common for all firms.

where $i_t(m_j)$ represents a differentiated investment good produced by a firm in country j.[8]

In this study, both the capital adjustment costs and investment adjustment costs are examined and specified as Chari et al. (2002) and CEE (2005), respectively.

Under CAC, the law of motion for capital stock follows the Chari et al. (2002) specification with an addition of a product of an investment efficiency shock $\varepsilon_{i,t}$ and investment, and is specified as

$$k_{i,t} = (1-\delta)k_{i,t-1} + \varepsilon_{i,t} I_{i,t} + \left[B(\frac{I_{i,t}}{k_{i,t-1}}) \right] k_{i,t-1}, \tag{3.10}$$

where $B(\cdot)$ is a convex CAC function with $B(\delta) = B'(\delta) = 0$ and $B'' > 0$ at steady states.

Under IAC, the law of motion for capital stock is

$$k_{i,t} = (1-\delta)k_{i,t-1} + \varepsilon_{i,t} \left[1 - A(\frac{I_{i,t}}{I_{i,t-1}}) \right] I_{i,t}, \tag{3.11}$$

where $\varepsilon_{i,t}$ is the investment efficiency shock, and $A(\cdot)$ is a convex IAC function with $A(1) = A'(1) = 0$ and $A'' > 0$ at steady states.

The demands for both home and foreign investment goods are determined by

[8]The home biases in consumption and investment are assumed to be same.

minimizing the cost of generating an investment $I_{i,t}$, and are described as below:

$$I^i_{j,t} = (1-\alpha)(\frac{P^i_{j,t}}{P_{i,t}})^{-\phi} I_{i,t}, \quad I^i_{i,t} = \alpha(\frac{P^i_{i,t}}{P_{i,t}})^{-\phi} I_{i,t}, \quad i,j = H,F; \tag{3.12}$$

similarly, given $I^i_{i,t}$ and $I^i_{j,t}$, the investment demands for each variety are given as:

$$i^i_t(m_j) = \left[\frac{p^i_t(m_j)}{P^i_{j,t}}\right]^{-\varepsilon} I^i_{j,t}, \quad i^i_t(m_i) = \left[\frac{p^i_t(m_i)}{P^i_{i,t}}\right]^{-\varepsilon} I^i_{i,t}, \quad i,j = H,F. \tag{3.13}$$

3.3.3 Exchange Rate and Terms of Trade

In this model, the real exchange rate (rer_t) is defined as:

$$rer_t = \frac{er_t P_{F,t}}{P_{H,t}}, \tag{3.14}$$

and the home terms of trade is specified as:

$$tot_t = \frac{P^F_{H,t}}{P^H_{F,t}}, \tag{3.15}$$

where er_t is the nominal exchange rate.

Under the local currency pricing (LCP) assumption in this study, the law of one price (LOP) does not hold. In the producer currency pricing (PCP), a perfect nominal exchange rate pass-through is associated with the price changes in the counterpart country. In the LCP, home producers set optimal prices in the currency of each country. Given the price stickiness assumption, foreign price responses slowly to nominal

exchange rate, which implies an imperfect nominal exchange rate pass-through consequently.[9]

3.3.4 Monetary Policy and Price Dynamics

Risk-free nominal interest rate is given as:

$$\frac{1}{ir_{i,t}} = E_t\left[\frac{U_{C_{i,t+1}}}{U_{C_{i,t}}}\frac{1}{\pi_{i,t+1}}\right], \tag{3.16}$$

where $\pi_{i,t+1}$ is the inflation rate which is defined as $\pi_{i,t+1} = \frac{P_{i,t+1}}{P_{i,t}}$.

The monetary authority utilizes a Taylor rule as follows:

$$log(\frac{ir_{i,t}}{ir}) = \rho_{ir}log(\frac{ir_{i,t-1}}{ir}) + (1-\rho_{ir})\left[\gamma_\pi log(\frac{\pi_{i,t}}{\pi}) + \gamma_y log(\frac{Y_{i,t}}{Y})\right] + \varepsilon^{ir}_{i,t}, \tag{3.17}$$

where $Y_{i,t} = P_{i,t}y_{i,t}$, ir, π, Y are the steady state values of interest rate, inflation and GDP, respectively.

3.3.5 Household Decision Problem

A representative household solves its optimization problem by facing the following constraints:

$$\begin{aligned} P_{i,t}C_{i,t} + M_{i,t} + P_{i,t}I_{i,t} + \sum S^m_{i,t} \leq w_{i,t}\ell_{i,t} + M_{i,t-1} + Tr_{i,t} + R^K_{i,t}Z_{i,t}k_{i,t-1} \\ - P_{i,t}a(Z_{i,t})k_{i,t-1} + \sum R^m_{i,t}S^m_{i,t-1}, \end{aligned} \tag{3.18}$$

[9] See Devereux and Engel (1998) for example.

and

$$\begin{cases} k_{i,t} = (1-\delta)k_{i,t-1} + \varepsilon_{i,t} I_{i,t} + \left[B(\frac{I_{i,t}}{k_{i,t-1}}) \right] k_{i,t-1}, \text{ under CAC,} \\ k_{i,t} = (1-\delta)k_{i,t-1} + \varepsilon_{i,t} \left[1 - A(\frac{I_{i,t}}{I_{i,t-1}}) \right] I_{i,t}, \text{ under IAC,} \end{cases} \tag{3.19}$$

where $a(Z_{i,t})$ is the cost of capital utilization, and $S^m_{i,t}$ is the holding of asset m by country i with a return to asset m as $R^m_{i,t}$. $a(Z_{i,t})$ satisfies $a(1) = 0$ and $Z = 1$ at steady states. Households can purchase both domestic and foreign assets.[10] Households make investment decisions and get return to capital $R^K_{i,t}$. The two corresponding Lagrangian multipliers are λ_t and v_t.[11] It is assumed that there is a lump-sum transfer from government (Tr) to balance the demand for money (M) such that

$$M_{i,t} = M_{i,t-1} + Tr_{i,t}. \tag{3.20}$$

After solving the FOCs, a household given $C_{i,t}$ has the following optimal composite consumption demands for goods produced in each country:

$$C^i_{j,t} = (1-\alpha)(\frac{P^i_{j,t}}{P_{i,t}})^{-\phi} C_{i,t}, \quad C^i_{i,t} = \alpha(\frac{P^i_{i,t}}{P_{i,t}})^{-\phi} C_{i,t}, \quad i,j = H,F, \tag{3.21}$$

and the demands for each variety are

$$c^i_t(m_j) = \left[\frac{p^i_t(m_j)}{P^i_{j,t}} \right]^{-\varepsilon} C^i_{j,t}, \quad c^i_t(m_i) = \left[\frac{p^i_t(m_i)}{P^i_{i,t}} \right]^{-\varepsilon} C^i_{i,t}, \quad i,j = H,F. \tag{3.22}$$

[10] Under complete asset market that is arbitrage-free (no price differential), the return to capital $R^K_{i,t}$ is equal to return to assets $R^m_{i,t}$.

[11] Due to the symmetry assumption, the two multipliers are same for both countries and the subscript "i" is ignored.

The labour supply is determined as:

$$\eta \ell_{i,t}^{\psi} = \begin{cases} C_{i,t}^{-\sigma} \dfrac{w_{i,t}}{P_{i,t}}, \; No\ Habit, \\ (C_{i,t} - \lambda_h H_{i,t})^{-\sigma} \dfrac{w_{i,t}}{P_{i,t}}, \; External\ Habit, \\ [(C_{i,t} - \lambda_h H_{i,t})^{-\sigma} - h\beta E_t (C_{i,t+1} - \lambda_h H_{i,t+1})^{-\sigma}] \dfrac{w_{i,t}}{P_{i,t}}, \; Internal\ Habit, \end{cases} \tag{3.23}$$

where $h = \lambda_h \gamma_h$.

The Euler equation for assets is

$$1 = E_t \rho_{t,t+1} R_{i,t+1}^m, \tag{3.24}$$

where $\rho_{t,t+1}$ is the pricing kernel and defined as:

$$\rho_{t,t+\tau} = \beta^{\tau} \frac{\lambda_{t+\tau}}{\lambda_t}.$$

Market clearing conditions in goods and assets markets ($i \neq j$) are given as:

$$C_{i,t}^i + C_{i,t}^j + I_{i,t}^i + I_{i,t}^j = y_{i,t}, \tag{3.25}$$

$$S_{i,t}^m + S_{j,t}^m = 0. \tag{3.26}$$

3.4 Model Calibration

3.4.1 Parameters of Model Calibration

Parameters of the model calibration follow Chari et al. (2002), CKM (2010) and Martínez and Søndergaard (2008). This creates convenience to compare my results with those in the literature. Table 3.3 summarizes the parameters employed for all models.[12]

3.4.2 Steady States

The steady states of the variables are symmetric across home and foreign countries. All prices are equal to 1, $\overline{er} = \overline{rer} = 1$, $\overline{Q_H} = \overline{Q_F} = 1$, $\overline{\varepsilon_H} = \overline{\varepsilon_F} = 1$, $\overline{Z_H} = \overline{Z_F} = 1$ and $\overline{\theta_H} = \overline{\theta_F} = 1$. Some other key relationships at steady states are illustrated as follows:

the return to capital

$$\overline{R}^K = \frac{1}{\beta} - 1 + \delta; \tag{3.27}$$

the real wage

$$1 = \frac{\varepsilon}{\varepsilon - 1} \frac{1}{\kappa^\kappa (1-\kappa)^{1-\kappa}} \overline{w}^{1-\kappa} (\overline{R}^K)^\kappa; \tag{3.28}$$

[12]In literature, The parameter on home bias varies and is greater than 0.7 in general. The empirical data suggest the G7 countries have a consumption home bias range from 0.72 (Canada) to 0.89 (UK) with an average of 0.79 during 1970-2011. However, I set this parameter as 0.94 for the purpose of comparison with other literature in this study.

Table 3.3: **Parameters of Model Calibration**

Parameter	*Description*	*Value*
σ	*Intertemporal Elasticity of Substitution*	5
α_c	*Calvo Price Parameter*	0.75
β	*Discount Rate*	0.99
ψ	*Inverse Elasticity of Labour Supply*	1.5
ϕ	*Elasticity of Substitution across Countries*	1
ε	*Elasticity of Substitution across Varieties*	10
α	*Home Bias*	0.94
ρ_{ir}	*Interest Rate Persistence*	0.85
ρ_i	*Investment Efficiency Shock Persistence*	0.79
ρ^{ir}	*Interest Rate Shock Persistence*	0.7
γ_π	*Inflation Weight on Taylor Rule*	2
γ_y	*Output Weight on Taylor Rule*	0.5
ρ_θ	*TFP Persistence*	0.75
κ	*Capital Share*	0.37
$B''(\cdot)$	*Second Order Derivative of CAC*	11.8
$A''(\cdot)$	*Second Order Derivative of IAC*	5
$\frac{a''(\cdot)}{a'(\cdot)}$	*Capital Utilization Parameter*	1.8
δ	*Depreciation Rate of Physical Capital*	0.05

and the investment share Λ

$$\Lambda = \delta\kappa\frac{\varepsilon-1}{\varepsilon}\frac{\beta}{1-\beta+\beta\delta}. \tag{3.29}$$

3.4.3 Log-linearization

The "hat" variables stand for the relative deviations from their steady states, and variables with no super-/subscript represent the corresponding steady states.

Two sets of variables, namely, the world and relative variables $X_{i,t}^{W}$ and $X_{i,t}^{R}$ are defined as follows:

$$X_{i,t}^{i,W} = {X_{i,t}^{i}}^{\alpha} {X_{i,t}^{j}}^{1-\alpha}, \tag{3.30}$$

and

$$X_{i,t}^{i,R} = \frac{X_{i,t}^{i}}{X_{i,t}^{j}}. \tag{3.31}$$

Thus, log-linearizations of $X_{i,t}^{W}$ and $X_{i,t}^{R}$ imply

$$\widehat{X_{i,t}^{i,W}} = \alpha \widehat{X_{i,t}^{i}} + (1-\alpha)\widehat{X_{i,t}^{j}}, \tag{3.32}$$

and

$$\widehat{X_{i,t}^{i,R}} = \widehat{X_{i,t}^{i}} - \widehat{X_{i,t}^{j}}. \tag{3.33}$$

These two sets of variables apply to consumption, investment, output, prices and inflation rates.

Under the assumption of complete asset market, the international risk sharing condition (Backus and Smith 1993) suggests that

$$\frac{U'_{F,t}}{U'_{H,t}} = rer_t, \tag{3.34}$$

thus,

$$\begin{cases} \sigma(\widehat{C_{H,t}} - \widehat{C_{F,t}}) = \widehat{rer}_t,\ No\ Habit, \\ \dfrac{\sigma}{1-\lambda_h}(\widehat{C_{H,t}} - \widehat{C_{F,t}}) - \dfrac{h\sigma}{1-\lambda_h}(\widehat{C_{H,t-1}} - \widehat{C_{F,t-1}}) - \dfrac{\lambda_h - h}{1-\lambda_h}(\widehat{H_{H,t-1}} - \widehat{H_{F,t-1}}) = \widehat{rer}_t,\ External\ Habit, \\ \dfrac{\sigma}{(1-h\beta)(1-\lambda_h)}\Big[(1+h^2\beta)(\widehat{C_{H,t}} - \widehat{C_{F,t}}) - h\beta E_t(\widehat{C_{H,t+1}} - \widehat{C_{F,t+1}}) - h(\widehat{C_{H,t-1}} - \widehat{C_{F,t-1}}) + \dots \\ \qquad h\beta(\lambda_h - h)(\widehat{H_{H,t}} - \widehat{H_{F,t}}) - (\lambda_h - h)(\widehat{H_{H,t-1}} - \widehat{H_{F,t-1}})\Big] = \widehat{rer}_t,\ Internal\ Habit. \end{cases} \tag{3.35}$$

Log-linearizing the Taylor rule − equation (3.17) implies

$$\widehat{ir_{i,t}} = \rho_{ir}\widehat{ir_{i,t-1}} + (1-\rho_{ir})[\gamma_\pi \widehat{\pi_{i,t}} + \gamma_y \widehat{y_{i,t}}] + \widehat{\varepsilon^{ir}_{i,t}}, \tag{3.36}$$

and the risk-free interest rate − equation (3.16) gives the following Euler equations for consumption:

$$\begin{cases} \widehat{C_{i,t}} = E_t\widehat{C_{i,t+1}} - \dfrac{1}{\sigma}(\widehat{ir_{i,t}} - E_t\widehat{\pi_{i,t+1}}),\ No\ Habit, \\ \widehat{C_{i,t}} = \dfrac{1}{1+h}E_t\widehat{C_{i,t+1}} + \dfrac{h}{1+h}\widehat{C_{i,t-1}} - \dfrac{\lambda_h - h}{1+h}(\widehat{H_{i,t}} - \widehat{H_{i,t-1}}) - \dfrac{1-\lambda_h}{\sigma(1+h)}(\widehat{ir_{i,t}} - E_t\widehat{\pi_{i,t+1}}), \\ \qquad External\ Habit, \\ \widehat{C_{i,t}} = -\dfrac{h\beta}{1+h-h^2\beta}E_t\widehat{C_{i,t+2}} + \dfrac{1-h\beta-h^2\beta}{1+h-h^2\beta}E_t\widehat{C_{i,t+1}} - \dfrac{h}{1+h-h^2\beta}\widehat{C_{i,t-1}} + \dots \\ \qquad \dfrac{h\beta(\lambda_h - h)}{1+h-h^2\beta}\widehat{H_{i,t+1}} - \dfrac{(\lambda_h - h)(1+h\beta)}{1+h-h^2\beta}\widehat{H_{i,t}} + \dfrac{\lambda_h - h}{1+h-h^2\beta}\widehat{H_{i,t-1}} - \dots \\ \qquad \dfrac{(1-\lambda_h)(1-h\beta)}{\sigma(1+h-h^2\beta)}(\widehat{ir_{i,t}} - E_t\widehat{\pi_{i,t+1}}),\ \text{Internal Habit.} \end{cases} \tag{3.37}$$

The log-linearization of the money demand is

$$\widehat{m_{i,t}} = \begin{cases} \frac{1-\beta}{\chi}\sigma\widehat{C_{i,t}},\ No\ Habit, \\ \frac{1-\beta}{\chi}\sigma\left(\frac{1}{1-\lambda_h}\widehat{C_{i,t}} - \frac{h}{1-\lambda_h}\widehat{C_{i,t-1}} - \frac{\lambda_h - h}{1-\lambda_h}\widehat{H_{i,t-1}}\right),\ External\ Habit, \\ \frac{1-\beta}{\chi}\frac{\sigma}{1-\lambda_h - h\beta + h\lambda_h\beta}\Big[h\beta E_t\widehat{C_{i,t+1}} - (1+h^2\beta)\widehat{C_{i,t}} + h\widehat{C_{i,t-1}} - \dots \\ \qquad h\beta(\lambda_h - h)\widehat{H_{i,t}} + (\lambda_h - h)\widehat{H_{i,t-1}}\Big],\ Internal\ Habit, \end{cases} \tag{3.38}$$

where $m_{i,t} = \frac{M_{i,t}}{P_{i,t}}$ is the real money demand.

Log-linearizing equations (3.10) and (3.11) give

$$\widehat{k_{i,t}} = (1-\delta)\widehat{k_{i,t-1}} + \delta(\widehat{\varepsilon_{i,t}} + \widehat{I_{i,t}}),\ \text{under IAC and CAC}, \tag{3.39}$$

and the capital utilization equation implies

$$\widehat{k^s_{i,t}} = \widehat{Z_{i,t}} + \widehat{k_{i,t-1}}. \tag{3.40}$$

Capital and investment decisions indicate the following log-linear relationships:

$$\begin{cases} \widehat{q_{i,t}} = E_t\Big[-\sigma(\widehat{C_{i,t+1}} - \widehat{C_{i,t}}) + (1-\beta+\beta\delta)\widehat{r^K_{i,t+1}} + \beta(1-\delta)\widehat{q_{i,t+1}} - \dots \\ \qquad \beta B''(\delta)\delta^2(\widehat{I_{i,t+1}} - \widehat{k_{i,t}})\Big],\ \text{under CAC}, \\ \widehat{q_{i,t}} = E_t\Big[-\sigma(\widehat{C_{i,t+1}} - \widehat{C_{i,t}}) + (1-\beta+\beta\delta)\widehat{r^K_{i,t+1}} + \beta(1-\delta)\widehat{q_{i,t+1}}\Big],\ \text{under IAC}, \end{cases} \tag{3.41}$$

$$\begin{cases} 0 = \widehat{q_{i,t}} + \widehat{\varepsilon_{i,t}} - B''(\delta)\delta(\widehat{I_{i,t}} - \widehat{k_{i,t-1}}), \text{ under CAC,} \\ 0 = \widehat{q_{i,t}} + \widehat{\varepsilon_{i,t}} - A''(1)(\widehat{I_{i,t}} - \widehat{I_{i,t-1}}) + \beta A''(1) E_t \left[\widehat{I_{i,t+1}} - \widehat{I_{i,t}}\right], \text{ under IAC,} \end{cases} \tag{3.42}$$

and

$$\widehat{r^K_{i,t}} = \frac{a''(1)}{a'(1)} \widehat{Z_{i,t}}, \tag{3.43}$$

where $q_{i,t} = \frac{v_t}{\lambda_t P_{i,t}}$ is the shadow value of installed capital in consumption units, $r^K_{i,t} = R^K_{i,t}/P_{i,t}$ is the real rental cost and $\widehat{r^K_{i,t}} = \widehat{R^K_{i,t}} - \widehat{P_{i,t}}$.[13]

Under the case with capital utilization, solving the firms' problem yields the new Keynesian Phillips curves for home and foreign countries as:

$$\widehat{\pi_{H,t}} = \beta E_t \left(\widehat{\pi_{H,t+1}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c} \times \ldots$$

$$\left\{ \begin{array}{l} \left[\sigma + (1-\Lambda)\psi \dfrac{\psi(1-\kappa)^2 + \kappa(1+\psi)^2}{(1-\kappa)\psi + \kappa(1-\kappa)\psi^2}\right] [\alpha \widehat{C^W_{H,t}} + (1-\alpha)\widehat{C^W_{F,t}}] + \ldots \\ \Lambda\psi \dfrac{\psi(1-\kappa)^2 + \kappa(1+\psi)^2}{(1-\kappa)\psi + \kappa(1-\kappa)\psi^2} [\alpha \widehat{I^W_{H,t}} + (1-\alpha)\widehat{I^W_{F,t}}] + \ldots \\ 2\alpha(1-\alpha)\widehat{rer_t} + (2\alpha-1)\phi\psi \dfrac{\psi(1-\kappa)^2 + \kappa(1+\psi)^2}{(1-\kappa)\psi + \kappa(1-\kappa)\psi^2} (\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}) - \ldots \\ \dfrac{1+\psi}{1-\kappa} [\alpha \widehat{\theta_{H,t}} + (1-\alpha)\widehat{\theta_{F,t}}] - \dfrac{\kappa(1+\psi)}{1-\kappa} \widehat{k^W_{H,t-1}} + \ldots \\ \dfrac{\Lambda}{\delta}(\dfrac{1}{\beta} - 1 + \delta)\psi \dfrac{\psi(1-\kappa)^2 + \kappa(1+\psi)^2}{(1-\kappa)\psi + \kappa(1-\kappa)\psi^2} [\alpha \widehat{Z_{H,t}} + (1-\alpha)\widehat{Z_{F,t}}] \end{array} \right\}, \tag{3.44}$$

[13] The relative consumption $-$ $(\widehat{C_{i,t+1}} - \widehat{C_{i,t}})$ in equation (3.41) and world consumption $-$ $\widehat{C^W_{i,t}}$ afterwards are modified for the models of external and internal habits.

$$\widehat{\pi_{F,t}} = \beta E_t\left(\widehat{\pi_{F,t+1}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c} \times \ldots$$

$$\left\{\begin{array}{l} \left[\sigma + (1-\Lambda)\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}\right][\alpha\widehat{C^W_{F,t}} + (1-\alpha)\widehat{C^W_{H,t}}] + \ldots \\ \Lambda\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}[\alpha\widehat{I^W_{F,t}} + (1-\alpha)\widehat{I^W_{H,t}}] - \ldots \\ 2\alpha(1-\alpha)\widehat{rer_t} + (2\alpha-1)\phi\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}(\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}) - \ldots \\ \frac{1+\psi}{1-\kappa}[\alpha\widehat{\theta_{F,t}} + (1-\alpha)\widehat{\theta_{H,t}}] - \frac{\kappa(1+\psi)}{1-\kappa}\widehat{k^W_{F,t-1}} + \ldots \\ \frac{\Lambda}{\delta}(\frac{1}{\beta} - 1 + \delta)\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}[\alpha\widehat{Z_{F,t}} + (1-\alpha)\widehat{Z_{H,t}}] \end{array}\right\}, \tag{3.45}$$

where the dynamics of $\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}$ are

$$\begin{aligned} &\Delta\left(\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}\right) - \beta E_t\Delta\left(\widehat{P^{F,W}_{F,t+1}} - \widehat{P^W_{F,t+1}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\left(\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}\right) \\ &= \frac{2\alpha(1-\alpha)}{2\alpha-1}\left[\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\widehat{rer_t} - \widehat{\pi^R_t} + \beta E_t\widehat{\pi^R_{t+1}}\right]. \end{aligned} \tag{3.46}$$

3.4.4 Shocks

Both the TFP and investment efficiency shocks are assumed to respectively follow an AR(1) process as:

$$\widehat{\theta_{i,t}} = \rho^A\widehat{\theta_{i,t-1}} + \widehat{\epsilon^A_{i,t}}, \tag{3.47}$$

and

$$\widehat{\varepsilon_{i,t}} = \rho^I\widehat{\varepsilon_{i,t-1}} + \widehat{\epsilon^I_{i,t}}, \tag{3.48}$$

where $\widehat{\epsilon^A_{i,t}} \sim N(0, \sigma^A_{i,t})$ and $\widehat{\epsilon^I_{i,t}} \sim N(0, \sigma^I_{i,t})$. Following CKM (2010), I set $\rho^A = 0.75$, $\sigma^A_{i,t} = 0.012$, $corr(\widehat{\epsilon^A_{H,t}}, \widehat{\epsilon^A_{F,t}}) = 0.45$, and $\rho^I = 0.79$, $\sigma^I_{i,t} = 0.0173$, $corr(\widehat{\epsilon^I_{H,t}}, \widehat{\epsilon^I_{F,t}}) = 0.19$. The TFP and investment efficiency shocks are assumed to be independent.

The monetary shock in the Taylor rule has an AR(1) representation as:

$$\widehat{\varepsilon^{ir}_{i,t}} = \rho^{ir} \widehat{\varepsilon^{ir}_{i,t}} + \widehat{\epsilon^{ir}_{i,t}}, \tag{3.49}$$

where $\widehat{\epsilon^{ir}_{i,t}} \sim N(0, \sigma^{ir}_{i,t})$. The parameters are adopted from Martínez and Søndergaard (2008), and are set as $\rho^{ir} = 0.7$, $\sigma^{ir}_{i,t} = 0.0155$, $corr(\widehat{\epsilon^{ir}_{H,t}}, \widehat{\epsilon^{ir}_{F,t}}) = 0.56$.

3.5 Results

The quantitative results of the study share similarities with business cycle statistics reported for the G7 countries overall, and these models are capable of predicting positive cross-country correlations among real variables under different specifications.

The results are reported by two groups − CAC and IAC models. For each group, results of models with capital utilization and without capital utilization are reported for different specifications of habit formations. The following subsections quantitatively analyze the results from three perspectives − sensitivity of international comovements among real variables, impulse responses against the three sets of random shocks, and quantitative impacts of modeling features on international comovements.

All results are reported in Tables 3.5 and 3.6, Tables C.1 through C.4, and Figures C.1 through C.25 in the Appendix C.

3.5.1 International Comovement

BKK (1992, 1993) found that the IBC models under various financial frictions were not able to produce positive cross-country comovements of investments and hours worked or a large cross-country comovement of outputs. DK (2012) introduced time none-separable preferences to the IBC models, and reported that their models successfully predicted a positive comovement of investment but failed to produce a positive comovement of hours worked and a large comovement of outputs. My models, however, are capable of explaining positive comovements of real variables with or without habit formations. Despite this success, my models suffer from a similar shortcoming documented in the IBC literature in predicting some business cycle relationships.

Cross-country Correlations

In this paper, I choose three modeling features to analyze performance of these models on predicting cross-country correlations among real variables. First, the models are generally grouped into CAC and IAC models. Secondly, each group of models is further categorized by capital utilization. Thirdly, I allow different habit formations, and in particular, I use different parameters on habit persistence and intensity to specify three sets of models. The first set of models are specified as cases where no habit formation is introduced ($\lambda_h = 0$); the second set of models sets constant habit intensity (λ_h), but allows habit persistence (γ_h) to vary; the third set of models represents a case where habit is fully determined by past consumption level, i.e.,

$\gamma_h = 1$, and investigates changes in international comovements given variation in habit intensity (λ_h).

When habit persistence is 1, the optimal habit intensity under the external and internal habit formations are 0.3 and 0.07 for CAC models, and 0.7 and 0.41 for IAC models, respectively. Otherwise, habit intensity and habit persistence are set at 0.7 and 0.4 for CAC models with external habit formation, and 0.63 and 0.4 for CAC models with internal habit formation; habit intensity and habit persistence are set at 0.72 and 0.82 for IAC models with external habit formation, and 0.59 and 0.64 for IAC models with internal habit formation.

Tables C.1 and C.4 in the Appendix C display statistics of international comovements and business cycles generated from using G7 data, reported in the existing IBC literature, and generated under CAC and IAC models with/without capital utilizations in this study, and all results are Hodrick-Prescott (HP) filtered.[14] We can find that CAC and IAC models are capable of predicting positive cross-country correlations among these real variables. The introduction of external habit formation significantly reduces or even alters signs of the positive cross-country correlations predicted by CAC and IAC models with no habit formations, but the introduction of internal habit formation has little impact on these positive cross-country correlations.

Compared to other IBC models, my models predict much larger cross-country correlations of GDP that vary between 0.47 and 0.63 in models with no habit or in-

[14] I have also applied the Baxter-King bandpass (BK) and Christiano-Fitzgerald random walk (CF) filters to the G7 data. The statistics are very similar to those derived from the HP filter, but both the BK and CF filters produce larger first order autocorrelations than the HP filter does. As a result, I report the HP filtered statistics as what most literature has done to have a consistent comparison.

ternal habit formations. IBC models tend to predict larger international consumption correlations than those suggested by data, but my models with no habit and internal habit formations produce much closer correlations in a range between 0.40 and 0.59. Generally, models in this study exhibit an advantage in the prediction of positive cross-country correlations of hours worked, while no existing IBC models have successfully generated such positive correlations by contrast. Specifications on capital utilization and habit formations have much smaller impacts on cross-country correlations of hours worked. In line with the recent IBC models (DK 2012, DR 2012), my models successfully establish positive cross-country correlations of investment except those with capital utilization and external habit formations, and the estimates of models with no habit and internal habit formations are in a close range to empirical estimate of 0.46.

External VS Internal Habits – Sensitivity Analyses

Sensitivity to Habit Intensity. Figures C.1 through C.4 in the Appendix C display the sensitivity of the four cross-country correlations among real variables with respect to habit intensity (λ_h) under constant habit persistence (γ_h) in CAC and IAC models with external and internal habit formations.[15]

In internal habit models, these cross-country correlations are mostly positive with the exception of a sharp drop of these cross-country correlations when habit intensity approaches 0.9 in the IAC model with internal habit and capital utilization. Con-

[15]In the DSGE simulations, I depict the evolutions of these cross-country correlations by allowing habit persistence or habit intensity to have an incremental change of 0.05 from 0 to 1 if feasible.

sumption comovement increases as habit intensity rises in three out of four models. In CAC and IAC models with capital utilization, all cross-country correlations show small variations up to a habit intensity level at 0.8. In CAC and IAC models without capital utilization, other than the increasing consumption comovement and flat hours worked comovement, both investment and GDP comovements indicate "hump" shapes, and reach highest levels when habit intensity reaches between 0.4 and 0.5, and decrease afterwards.

Sensitivity to Habit Persistence. Figures C.5 through C.8 in the Appendix C exhibit the international comovements among the real variables by allowing variations in habit persistence (γ_h) given constant habit intensity (λ_h) in CAC and IAC models with external and internal habit formations. Overall, the cross-country correlations are less volatile to rise in habit persistence compared to those in models with constant habit persistence.

In external habit models, all these cross-country correlations are positive when capital utilization is introduced. However, only cross-country correlations of hours worked are positive under models without capital utilization. Most cross-country correlations demonstrate flat or slightly decreasing sensitivity response to increasing habit persistence although some show "hump" shapes when habit persistence is less than 0.5. Unlike in external habit models, all cross-country correlations are positive in internal habit models. Cross-country correlations of consumption and hours worked are least volatile with upward trends. On the other hand, cross-country correlations of investment and income illustrate more volatile changes with respect to habit persistence. Cross-country correlation of investment increases with rising habit persistence

but decreases after reaching its peak at low habit persistence, and bounces upward when hits its low when habit persistence passes 0.6.

These habit sensitivity analyses suggest that habit models can generate positive cross-country correlations among real variables, and especially such positive cross-country correlations in external habit models crucially depend on the inclusion of capital utilization.

3.5.2 Business Cycles Statistics

All business cycle statistics of these models are reported in Tables C.1 − C.4. Some of my models provide good estimates of some key business cycle statistics. Compared to the previous IBC literature, however, large deviations or even counterfactual results are still found in some statistics.

The IBC literature fell short in predicting the standard deviations of GDP, consumption and hours worked, most of their autocorrelations and some of their correlations with domestic GDP. Both BKK (1993) and DK (2012) failed to generate large enough volatilities of consumption and employment, and DK (2012) only produced half of the empirical standard deviation of GDP. Neither of these two studies could generate an autocorrelation of GDP that is close to the data. DK (2012) predicted an excess autocorrelation of consumption but inadequate autocorrelations of investment and employment. Although DK (2012) overcame the problem of predicting a low investment correlation with income from BKK (1993), they reported a cyclical correlation between net exports and GDP.

I calibrate models with capital utilization to match the standard deviation of income as close as possible. Overall, CAC and IAC models with capital utilization tend to predict smaller volatility of consumption, hours worked and real exchange rate. External habit models generate closer volatility of net exports under capital utilization than the much larger volatility predicted by internal habit models, and both groups of models produce much smaller volatility of these series if no capital utilization is introduced. IAC models predict larger and closer estimates of volatility of investment than CAC models do. The CAC and IAC models with internal habit formation tend to generate much lower standard deviation of consumption, investment, and real exchange rate, but much larger standard deviations of net exports and hours worked by various types of labour. Moreover, the CAC models do not match the autocorrelations of GDP, investment, hours worked, net exports and real exchange rate, and even generate counterfactual correlation between net exports and GDP. In contrast, IAC models are able to generate large autocorrelations of income, consumption and investment, but not for hours worked, net exports and real exchange rate. External habit models tend to predict larger and closer consumption, investment and hours worked correlations with income than internal habit models do, but all models predict either larger or counterfactual correlations of net exports and real exchange rate against income with the only exception of CAC and IAC models with internal habit models and no capital utilization. The lower volatility of investment could be the reason that CAC penalizes capital stock which in turn leads to smoother change in investment. This implies that an investment decision depends on capital stock level, and higher capital stock level would discourage investment. The low volatility of consumption

is mainly due to the habit assumption where an economic agent makes consumption decision based on past information and future expectations to adjust current consumption accordingly, which results in a much lower change of consumption. Given the complete market assumption, volatility of real exchange rate is closely connected to change in relative consumption, thus, lower consumption volatility inevitable leads to lower exchange rate volatility.

The IAC model without capital utilization produces closer estimates among all these models with a few exceptions. Some standard deviations of investment in these habit models are greater than the average of the G7 countries, but empirical evidence in literature suggests that the estimates depend on the sample periods and vary from 4.35 to 6.89.[16] Hence some of these estimates are still within a reasonable range. The reported standard deviations of real exchange rate and net exports are close to the empirical estimates in external habit models.[17] The most obvious distinction of these standard deviations comes from the hours worked. My models predict that the standard deviations range from 1.39 to 4.64 but the data suggest 0.84.[18] Some other studies, however, have shown much larger standard deviations of hours worked. For instance, BKK (1992, 1993) reported an hours worked standard deviation of 1.47 at quarterly level, and CKM (2010) also found a value of 1.89 for the standard deviation of hours worked by using annual data. As a result, other than the large

[16] DK (2012) and DR (2012) examined the same sample over 1970-2008; BKK (1992, 1993) utilized a data set that covered a sample period 1970-1990; CKM (2010) employed data over the sample period 1984-2004.

[17] Empirical estimates of the G7 countries indicate that the two standard deviations respectively have ranges of [2.42, 7.36] and [0.39, 0.77].

[18] Due to unavailability of data on hours worked at quarterly level, I use the statistics reported by DK (2012) as a reference.

standard deviations reported for models without capital utilization, the finding of higher standard deviations of hours worked in models with capital utilization does not necessarily indicate that they are outliers. Compared to the empirical average standard deviation of consumption of the G7 countries at 1.22, my models only predict smaller standard deviations range from 0.11 to 1.06. But these estimates are still better than predictions in some IBC literature.

The different specifications of habit formations play a key role in determining the autocorrelation of consumption. Intuitively, the introduction of habit persistence and intensity allows consumers to smooth out consumption over time, which leads to a higher first order autocorrelation of consumption. This is confirmed by the resulting lower autocorrelation of consumption when no habit formation is included in the models.[19] The predicted autocorrelations of GDP and investment are almost within a close deviation of those obtained from the empirical data in IAC models but not in CAC models. Only models without capital utilization are capable of predicting a close autocorrelation of net exports. Similar to the finding by Chari et al. (2002) and Martínez and Søndergaard (2008) about lower first order autocorrelations of real exchange rate, my models also failed to predict a high exchange rate autocorrelation. This result implies that the so called real exchange rate puzzle in the open macroeconomic literature still remains even though the large volatility issue has been resolved.

The predicted correlations of consumption, investment and hours worked with respect to domestic GDP are within a close deviation of those obtained from the

[19]Internal habit models are the exception.

empirical data in CAC models without capital utilization. Models without capital utilization explain negative correlations of net exports and GDP but larger than the empirical findings. Meanwhile, real exchange rate positively correlates with GDP in almost all models with varying sizes, which is consistent with the empirical finding.[20]

3.5.3 Impulse Responses

Figures C.13 through C.25 in the Appendix C report the impulse responses (IR) of real variables against the three shocks at home (first columns) and foreign (second columns) countries under different specifications of capital utilization and habit formations. The results of IR are organized as follows: there are four sets of IRs in the order of CAC models with capital utilization, CAC models without capital utilization, IAC models with capital utilization and IAC models without capital utilization. For each set of IRs, there are three groups specified as no habit, external habit and internal habit. In the end, Figure C.25 plots the IRs of the four real variables w.r.t. a positive TFP shock derived from CAC and IAC models with neither habit formation nor capital utilization against those implied by the IBC model in BKK (1992).

CAC and IAC Models with Various Habit Formations

IRs to each shock exhibit a number of similarities across all four groups, thus, I discuss them together and highlight the differences when necessary.

[20]The real exchange rates of the G7 countries are using the volume quotation, while the exchange rate in this study is applying the price quotation. Due to such an inverse relationship of the two quotations, the opposite signs of correlations between real exchange rate and domestic GDP obtained from data and the sticky price models still suggest consistent estimates of these correlations.

Responses to a TFP Shock. Given one positive standard deviation of TFP shock in the home country, both home and foreign real variables increase initially in most models except the IAC models with capital utilization. Such a positive TFP shock increases the output and marginal product of labour directly, which induces higher investment indirectly. This shock also creates incentive for consumers to raise consumption as income is higher, however, with the inclusion of habit intensity and persistence, home consumers response differently to allocate their consumption intertemporally. However, the hours worked shows the exact opposite response for this positive TFP shock. As a result, the initial response in the IAC model with capital utilization has been driven to slight negativeness. Meanwhile, international comovement relationships between the home real variables and their foreign counterparts are discovered. Models in this study are assumed to allow free international trade, and both home and foreign outputs are utilized for consumption and investment. As a result, if one country faces a positive productivity shock, both countries would benefit. Net exports balance the income identity equation for both home and foreign countries. The "spillover effect" serves as a major factor to drive such international comovements, and especially the spillover between monetary policy and TFPs which are discussed quantitatively in the next subsection. The mechanism of adjustment costs makes changes of investment to be costly and penalizes any rapid changes in investment, hence investment takes a longer time to absorb the initial impact by the TFP shock. Furthermore, investment responses negatively to a positive TFP shock in an internal habit IAC model without capital utilization. Overall, these habit models tend to show less volatile responses

compared to models without habit formations, and display "hump" shapes due to the existence of adjustment cost and habit formations.

Responses to an Investment Efficiency Shock. In general, international comovements are broadly observed across all real variables although the speeds of adjustment are different across the two countries. In line with conclusions by Khan and Tsoukalas (2011), a positive investment efficiency shock does not lead to a positive initial response of consumption, which does not lead to domestic comovement with investment and income in all my models because of the CEE (2005) specification of cost of capital utilization adopted in this study.[21] This finding implies the crowding out effect of investment over consumption. It also indicates that my models suffer from a similar shortcoming of the traditional RBC models in that the specification of the additive preference function and cost of capital utilization (CEE 2005) may possibly contribute to this result. In contrast, Khan and Tsoukalas (2011) argued that the GHH (1988) specification of depreciation rate as an increasing function of capital utilization leads to a positive response of consumption for a given investment efficiency shock in a closed economy. Therefore, it will be a useful examination of incorporating GHH (1988) specification of cost of capital utilization for future research to solve the negative response of consumption given investment shocks.

Responses to a Monetary Shock. A contractionary (an increase in interest rate) monetary policy shock results in reductions in all domestic real variables, and simultaneously lowers foreign GDP and hours worked in most models with the exceptions

[21] Please see Figures C.14, C.17, C.20 and C.23.

on negative international comovements among income, consumption and investment in CAC and IAC models with external habit formations. This finding seems to suggest that an economic agent foresees one period ahead takes advantage of relative cheaper borrowing cost of capital to raise investment, consumption and economic growth eventually, but agents rely on contemporaneous response to shocks or foresee two periods ahead would negatively respond to a foreign monetary shock. For agents have internal habit preference, further smoothing their investment and consumption is the decision, which is confirmed by their least volatile responses. A higher domestic interest rate raises the borrowing cost to entrepreneurs, which would lead to reduction in economic activities and negative responses. Foreign economic agents with external habits would eventually realize the impact of the shock and reduce their activities accordingly.

CAC and IAC Models vs BKK (1992)

Another experiment of this study is to compare IRs to a positive TFP shock in CAC and IAC models with no capital utilization and no habit formation with those reported in BKK (1992). First of all, the most obvious difference is that BKK (1992) predicted only one international comovement relationship of consumption, but my models predict international comovements among all four real variables. Secondly, BKK (1992) predicted non-convergence of foreign income and both domestic and foreign consumption, but my models predict convergence for all real variables. Thirdly, BKK (1992) predicted no "hump" shaped IRs, while my models do. Different results

indeed are due to the differences in building up models. BKK (1992) employed a time non-separable preference with habit formation in leisure, applied a CES production function that included inventories and set up a lower cross-country correlation between TFP shocks at 0.258. All these features distinguish their model from mine, however, their pioneer work is a useful reference for comparison.

3.5.4 What Causes the International Comovements

The mechanism that makes my models be capable of generating such positive cross-country correlations deserves attention to better understand the possible major driver(s). In this study, I identify the impact of each feature independently, which would help to understand what factors play an important role in predicting international co-movements among macroeconomic variables by comparing with some existing IBC literature. The benchmark values of cross-country correlations are taken from those of CAC and IAC models with capital utilization but no habit formation. The descriptions of changes in all additional features are summarized in Table 3.4, and all results are reported in Tables 3.5 and 3.6.

I first examine whether home bias in consumption and investment plays a role in generating international comovement of investment. By doing so, I reset the home bias to be 1, which implies that international trade becomes implicitly defined in the models. This reflects a similar model specification as BKK (1992,1993) and DK (2012). The resulting changes in cross-country correlations are still very close to benchmark values in both CAC and IAC models. Thus, I conclude that home bias is

not a major factor to predict international comovements.

As important ingredients in macroeconomics, price stickiness and capital utilization serve as another two main differences between my models and the existing IBC models. The introduction of price stickiness allows the monopolistic firms to adjust price according to the market changes with certain probability, which further implies that price would react imperfectly to market demand and the market would deviate from equilibrium in the short-run or even in the long-run. Capital utilization adopts a similar idea such that entrepreneurs are penalized for adjusting the level of investment in each period rather than the free adjustment costs assumption made in some IBC literature.

Table 3.4: **Descriptions of Changes in Additional Features**

Home Bias	*Changing to Perfect Home Bias*
Price Stickiness	*Removing Price Stickiness*
Capital Utilization	*Removing Capital Utilization*
Spillover on Monetary Policy	*Removing Spillover on Monetary Policy*
Spillover on Investment Shock	*Removing Spillover on Investment Shock*
Spillover on TFP	*Removing Spillover on TFP*

To examine the impacts of price stickiness, I start with investigating the sensitivity of international comovements by allowing variation in price stickiness parameter in CAC and IAC models with capital utilization and different habit formation specifications, and results are displayed in Figures C.9 and C.12 in the Appendix C.

Table 3.5: **Impacts of Additional Features on Cross-country Correlations in CAC Models**

Variable	*Benchmark Value*	*Home Bias*	*Price Stickiness*	*Capital Utilization*	*Spillover on Monetary Policy*	*Spillover on Investment Shock*	*Spillover on TFP*	*3 Spillovers*
GDP	0.47	0.45	0.51	0.54	0.05	0.50	0.49	0.03
Consumption	0.44	0.41	0.41	0.40	−0.02	0.40	0.37	−0.07
Investment	0.31	0.37	0.38	0.40	−0.002	0.34	0.37	−0.06
Hours Worked	0.42	0.42	0.48	0.52	0.24	0.46	0.28	0.03

Table 3.6: **Impacts of Additional Features on Cross-country Correlations in IAC Models**

Variable	*Benchmark Value*	*Home Bias*	*Price Stickiness*	*Capital Utilization*	*Spillover on Monetary Policy*	*Spillover on Investment Shock*	*Spillover on TFP*	*3 Spillovers*
GDP	0.56	0.45	0.51	0.54	0.17	0.45	0.34	0.02
Consumption	0.44	0.44	0.43	0.42	0.26	0.45	0.24	0.02
Investment	0.48	0.35	0.38	0.35	0.19	0.25	0.10	−0.07
Hours Worked	0.45	0.44	0.47	0.52	0.41	0.44	0.07	0.02

If price is perfectly flexible where firms can setup prices at will, the international comovements among real variables generally start at very high and positive levels, but decline as the parameter α_c increases. The exceptions that the comovements end up higher are mainly found for investment and income. Negative cross-country correlations of investment, consumption and income are only observable for external habit formations in both CAC and IAC models when α_c approaches 1. On the other hand, cross-country correlations of hours worked have been positive in all models. Thus, if a firm has more flexibility to reset its prices both domestically and abroad in following periods, it promotes the cross-country connections on economic activities since a profit oriented firm is granted more market power to generate profits. Subsequently, I examine the impact of capital utilization on international comovements by blocking the processes of capital utilization. I find that the impacts on cross-country correlations are minimal. However, from discussion in the previous subsection "International comovement", we conclude that capital utilization has significant negative effects on cross-country correlations in external habit models, but little effects on cross-country correlations in models with no habit and internal habit formations. Therefore, both price stickiness and capital utilization have potential large effects on cross-country correlations, and particularly, the effect of capital utilization depends on specification of habit formations in models.

The next set of potential factors is the so called - spillover effect which has been cited for its great importance in IBC literature (BKK 1992, DK 2012). In this study, there are three spillovers overall. I start with examining the individual effect of each spillover, and next examine the combined effect of all three spillovers. First,

if I assume that two monetary policies are independent from each other, the cross-country correlations of GDP, consumption and investment drop significantly or even become negative, and the cross-country correlation of hours worked drops more than 40 percent in CAC model but moderately in IAC models; secondly, I assume the two investment efficiency shocks have no interaction and find that the cross-country correlations almost have very little changes; thirdly, I restrict the correlation between the two TFP shocks at 0, and observe all cross-country correlations become insignificant in the IAC model but at much smaller scales in the CAC model; finally, I set all three intersections to be equal to 0, and find all cross-country correlations become insignificant and some of them are even negative in the both models. These findings indicate that spillover effects have the overall largest impact on international comovements, and in particular, the spillover between monetary policy brings the most effects, and the spillover between TFPs delivers a larger impact on hours worked. My finding challenges the conclusion in DK (2012) regarding the dominant effect of habit formations in generating positive international comovements of investment.

Another factor that may affect international comovements is money. As an important difference between the IBC models and open economy models, it is natural to assess its effect on cross-country correlations. I consider the effect of money from two perspectives, money supply and the Taylor rule. Theoretically, the Taylor rule that governs the interest rate has the potential impact on international comovement of investment given the assumption that money supply (demand) is purely driven by consumption as EM (2009). A higher domestic nominal interest rate leads to higher borrowing costs at home and attracts more capital inflow for higher returns, which

indicates that if no spillover between the home and foreign monetary policies, the cross-country investment correlation would go down. However, it remains a challenge to explicitly examine its impact since a process for determining interest rate is necessary to complete the model.

3.6 Future Research

Economists have investigated the cyclical behaviour of skilled and unskilled labour, and the increasing volatility of skill premium (ratio of wage of skilled labour over that of unskilled labour) in closed economy models over the last few decades (Krusell et al. 2000). Most of these studies focused on the U.S. As a matter of fact, similar phenomenon has also been observed in other developed countries (Castro and Coen-Pirani 2008). However, it remains unknown whether the hours worked at aggregate and disaggregate levels, and skill premiums comove across countries. On the other hand, economists introduced capital-skill complementarity into theoretical models to match empirical findings other than to rely on the conventional skill-biased technological change. Krusell et al. (2000) first considered capital-skill complementarity as a main factor and empirically examined the complementary relationships between capital and different skill types. They found a strong complementary relationship between capital equipment and skilled labour, but no such a relationship was discovered between capital equipment and unskilled labour. This finding later became a blueprint for setting up RBC and partial equilibrium models. So far no existing international macroeconomic literature has built this feature into open economy general

equilibrium models, thus, it is very interesting to incorporate it to explore international comovements among hours worked of various types of labour and other real variables.

I have done some preliminary research on this subject. Empirically, I only have access to microeconomic level data in Canada and the U.S. Evidence presented in the Table 3.7 suggests positive cross-country correlations between skilled labour, unskilled labour and skill premium. It is no surprising to observe such positive cross-country correlations between the two countries given close their economic ties, but the question is whether we can find similar cross-country correlations among other countries and the U.S. However, I do not have access to any of microeconomic data sets from any other G7 countries. The limited evidence obtained from using the Labour Statistics Database (LABORSTA) of the International Labour Organization (ILO) for four G7 countries (Canada, Italy, UK and US) over 1994-2008 does not indicate significant cross-country correlations.[22] Thus, the empirical evidence is still inconclusive.

Theoretically, a model can be developed based on Krusell et al. (2000). First, we can specify the capital-skill complementarity as $\ell_t = \left[(\mu \ell_t^U)^\sigma + (1-\mu)\left(\gamma_k (k_t^e)^\rho + (1-\gamma_k)(\ell_t^S)^\rho\right)^{\frac{\sigma}{\rho}}\right]^{\frac{1}{\sigma}}$, where k_t^e is the capital equipment, $\frac{1}{1-\sigma}$ is the elasticity of substitution between the two types of labour, $\frac{1}{1-\rho}$ is the elasticity of substitution between skilled labour and capital equipment, and μ and γ_k represent distribution parameters for labour and capital equipment. Second, laws of motion for capital structures and capital equipment could individually follow a similar process given

[22]The cross-country correlation of aggregate hours worked is 0.18, and those of industry classified skilled and unskilled hours worked are 0.08 and -0.18. All annual data are seasonally adjusted and HP filtered with a parameter of 6.25.

Table 3.7: **Empirical International Comovement Statistics**

Time Periods	**Cross-Country Correlations**	**Countries**
		Canada vs USA
$1984:1-2013:4$	*Aggregate Hours Worked*	0.65
	Education Classified Skilled Hours Worked	0.54
	Education Classified Unskilled Hours Worked	0.58
$1996:1-2011:4$	*Education Classified Skill Premium*	0.23

Notes: 1. Data sources include Current Population Survey (CPS) of the U.S. extracted from the Merged Outgoing Rotation Groups (MORG), and Labour Force Survey (LFS) and Survey of Labour and Income Dynamics (SLID) of Canada. Other than SLID, all other data sets are available at monthly frequency.
2. All variables were seasonally adjusted by using the Census X-13 ARIMA SEATS seasonal adjustment program, and all variables are Hodrick-Prescott (HP) filtered with a parameter 1,600 for quarterly data.

in equation (3.10) or could be combined in an equation as $k_{i,t} = (1-\delta^{st})k^{st}_{i,t-1} + (1-\delta^{e})k^{e}_{i,t-1} + \varepsilon_{i,t}I_{i,t} + \left[B(\frac{I_{i,t}}{k_{i,t-1}})\right]k_{i,t-1}$, under CAC, and $k_{i,t} = (1-\delta^{st})k^{st}_{i,t-1} + (1-\delta^{e})k^{e}_{i,t-1} + \varepsilon_{i,t}\left[1-A(\frac{I_{i,t}}{I_{i,t-1}})\right]I_{i,t}$, under IAC, where k^{st} is the capital structure, δ^{e} and δ^{st} are the depreciation rates of capital equipment and capital structure, respectively. The separate laws of motion of the two capital have already been applied in IBC literature (Lindquist 2004) and partial equilibrium literature (Krusell et al. 2000 and Castro and Coen-Pirani 2008), but it is questionable whether separating laws of motion leads to any advantage in a general equilibrium model because prices need determinations in a general equilibrium model. In such a general equilibrium model, prices cannot be replaced by ratio of inputs as in IBC literature or use empirical estimates as in partial equilibrium models, instead it possibly requires us to specify price determination processes. Third, income share of each labour input (skilled, unskilled labour and capital equipment) is time varying. This is due to the CES function form of the aggregate labour supply, thus, it challenges the notion of steady states of these

variables. If they exist, how do we determine them.

In sum, incorporating capital-skill complementarity in a general equilibrium model would be a good addition to this subject of research and a new contribution to the international macroeconomic literature. This study could serve as a base. However, it is necessary to clarify these empirical and theoretical questions before proceed further research.

3.7 Conclusion

This paper departs from the IBC literature by developing a set of two-country open economy DSGE models with price stickiness, money, habit formations and capital utilization under monopolistic competition to explore the existing international co-movement puzzles. Asset markets are complete, and the perfect international risk sharing is allowed. The Taylor rule monetary policy, and capital and investment adjustment costs are built into the models. In contrast to the literature (DK 2012), I employ an additive preference, and I find that these models with various specifications of habit formations and capital utilization widely predict cross-country comovement relationships. After quantitatively investigating the impacts of additional features of the models, I find that spillovers on monetary policies and TFPs, price stickiness and capital utilization are the four major factors that drive the international comovements among real variables.

Unlike DK (2012) and DR (2012) who claimed internal habit models outperformed no habit and external habit models in their IBC studies, I find no evidence

that supports such superiority of internal habit models. Other than the external habit models, I find that models without habits can generate positive cross-country correlations among real variables. Habit formation, however, improves the statistical matchings of other real variables and smoothes consumption over time in some models. The results indicate that both domestic and international business cycle statistics match the empirical statistics better than the IBC literature does, and shed light on exploiting some other existing puzzles in the IBC literature such as the exchange rate volatility puzzle, but my models suffer from similar shortcomings of the IBC literature on matching some empirical findings. To further extend this study in the future, an inclusion of capital-skill complementarity in open economy general equilibrium models will represent a first attempt to explore international comovements in the literature, but more empirical evidence from microeconomic data sets is needed to support this idea, and some theoretical challenges have to be resolved.

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Appendix A: Chapter 1

A.1 Background of Asian Financial Crisis in 1997

During the last four decades, the "export-oriented" policy has led to a great success of economic development, and intensified the international trade integration of ASEAN-5.[1] However, this "Asian economic miracle" came to an abrupt end when the 1997 Asian financial crisis broke out, to which the prelude was a series of capital outflows and speculative attacks against the currencies of Thailand, Philippines and Malaysia in the early May, 1997.[2] On July 2, 1997, the Thai government announced the devaluation of its currency, the Bhat, ending the U.S. dollar-peg system, which caused the Thai Bhat sharply depreciated by 17 percent against the U.S. Dollar. On the next day, the Philippine Central Bank doubled its overnight rate to fight the Peso's plunge. This financial crisis rapidly spread across the whole East Asian region, affected Indonesia in August, Hong Kong and Taiwan in October and South Korea in November, and even caused some large securities firms and banks in Japan to collapse. Even after a series of emergency loans with a sum over $100 billion from the IMF and other international organizations within a few months after the outbreak of the crisis, however, the ASEAN stock markets suffered heavy sell-off and the Asian

[1] Data Source: World Development Indicators (WDI). The average growth rate of exports reaches 7.2 percent during 1960 - 2007, which is 1.5 percent higher than their average growth rate of GDP. The international trade integration is defined as the ratio of sum of exports and imports to GDP. Illustrated in Figure A.1, it has increased from about 40 percent in the 1960s up to 90 percent in the late 2000s before the financial crisis struck in 2008.

[2] INR (Indonesian Rupiah), MYR (Malaysian Dollar), PHP (Philippine Peso), SGD (Singapore Dollar), THP (Thai Baht), USD (U.S. Dollar), JPY (Japanese Yen) and CNY (Chinese Yuan/Renminbi) are the currency ISO codes.

currencies continued to plunge.[3] The foreign exchange rates of ASEAN-5 and some other Asian currencies have been highly volatile since the abandonments of the fixed exchange rate regimes in 1997. Towards the end of 1997 and early 1998, ASEAN-5 started experiencing economic recessions, and it took 1-4 years for them to fully recover to the pre-crisis level of GDP as demonstrated.

The Asian financial crisis exposed the financial vulnerability of the ASEAN countries, but indirectly promoted the regional financial and economic reforms in the following years. One major step was to establish the ASEAN-Free Trade Area (AFTA) in early 2003 by following the the Common Effective Preferential Tariff (CEPT) Scheme for AFTA (CEPT-AFTA) Agreement signed in 1992. Consequently, tariff on 64.12 percent of the products of ASEAN-6 was removed, and the average tariff rate was brought down to 1.51 percent from the previous 12.76 percent.[4] The other four newer members of ASEAN started to implement the CEPT-AFTA from 2006 to 2010, and their average tariff fell below 5 percent.[5] The more consolidated economic integration among the ASEAN countries has encouraged the economic cooperation, and has boosted the intra-ASEAN trade and economic growth. Furthermore, ASEAN achieved another milestone in relationship with some large Asian economies by negotiating and signing bilateral FTAs. The first international FTAs, the ASEAN-China FTA (ACFTA) and ASEAN-India FTA (AIFTA) were launched on January 1, 2010. Each FTA opened up a market with over 1.7 billion population. The expansion of

[3]Figure A.2 shows the movements of the ASEAN-5 exchange rates against the U.S. Dollar, and clearly indicates the depreciations in 1997.

[4]ASEAN-6 are the original six members of ASEAN which consist of the ASEAN-5 and Brunei Darussalam.

[5]The four newer members of ASEAN are Cambodia, Laos, Myanmar and Viet Nam.

FTAs with other major economies diversifies the international demands and supplies, and potentially helps to reduce the exchange rate risk. Figure A.3 visualizes the pattern of increasing shares of ASEAN-intra and ASEAN-China trade accompanied by the gradual decline of the shares with the other three major trade partners, the EU, Japan and the U.S. over the past thirty years. The Chiang Mai Initiative (CMI) agreed in 2000 represented the creation of a network of bilateral swap agreements (BSAs) in the region, and a total of $64 billion BSAs fund was conducted among ASEAN-5, China, Korea and Japan in the subsequent years.[6] The CMI aimed to stabilize financial and foreign exchange markets, however, this effort was not generally appreciated by the academics. Economists drew conclusions that the pre-conditions for launching a monetary union were not met and the CMI may not result in the desired financial and foreign exchange stabilities.[7]

[6]CMI was passed during the ASEAN+3 Finance Ministers meeting in 2000, and ASEAN+3 are the ten members of ASEAN and China, Korea and Japan.

[7]See, e.g., Bayoumi et al. (2000), Bayoumi and Mauro (2001), Chow and Kim (2003), Eichengreen (2003), Zhang et al. (2004) and Aminian (2005).

A.2 Theoretical Models

A.2.1 Hooper and Kohlhagen Model

An importer has a demand function of its own outputs Q which increases with domestic income Y and price of other domestic goods PD, and decreases with its price P and non-price rationing CU (manufacture capacity utilization),

$$Q = aP + bPD + cY + dCU. \tag{A.1}$$

The utility function is specified as

$$\max_{Q} U = E\pi - \gamma(V(\pi))^{\frac{1}{2}}, \tag{A.2}$$

where γ is the relative risk aversion.

By assuming a constant input-output ratio, i.e., $q = iQ$, the profit is written as

$$\pi = Q \cdot P(Q) - UC \cdot Q - H \cdot P^* \cdot iQ, \tag{A.3}$$

where $H = \beta(\alpha F + (1-\alpha)R_1) + (1-\beta)F$ is the weighted average foreign exchange cost, UC is the unit cost, R_1 is the future spot rate and F is the forward rate at payment date, α is the share of foreign currency hedged in the forward market, and β is the proportion of imports dominated in the exporter's currency.

Suppose $cov(R_1, P) = 0$ and all variables are known with certainty except R_1, then $V(\pi)$ is solved as

$$V(\pi) = (P^* iQ\beta(1-\alpha))^2 \sigma_{R_1}^2. \tag{A.4}$$

Substituting equation (A.4) into the utility function, and solving the F.O.C. yields

$$q = \frac{i}{2}(bPD + cY + dCU + aUC) + \frac{a}{2}P^* i^2 (EH + \gamma\delta\sigma_{R_1}), \tag{A.5}$$

where $\delta = \beta(1-\alpha)$.

The exporter knows the aggregate demand of n identical competitive importers, i.e.,

$$q^* = nq = \frac{in}{2}(bPD + cY + dCU + aUC) + \frac{an}{2}P^* i^2 (EH + \gamma\delta\sigma_{R_1}). \tag{A.6}$$

The exporter has the same utility function as the importer:

$$\max_{q^*} U^* = E\pi^* - \gamma^* (V(\pi^*))^{\frac{1}{2}}. \tag{A.7}$$

where γ^* is the relative risk aversion.

The exporter's profit function is

$$\pi^* = q^* P^* H^* - q^* UC^*, \tag{A.8}$$

where UC^* is the exporter's unit cost of production, the holding of the exporter's own currency is $H^* = \beta + (1-\beta)F(\frac{\alpha^*}{F} + \frac{1-\alpha^*}{R_1}) = \beta + \alpha^*(1-\beta) + (1-\alpha^*)(1-\beta)\frac{F}{R_1}$,

and α^* represents the share of foreign currency hedged in the forward market.

The variance of the exporter's expected profit is

$$V(\pi^*) = (P^* q^*(1-\beta)(1-\alpha^*)R)^2 \sigma_{\frac{1}{R_1}}{}^2. \tag{A.9}$$

Rearranging the exporter's utility function by substituting equation (A.9) to equation (A.7), and solving F.O.C. as

$$q^* = (1/\frac{\partial P^*}{\partial q^*})(\frac{UC^*}{EH^* - \gamma^* \delta^* \sigma_{\frac{1}{R_1}}} - P^*), \tag{A.10}$$

where $\delta^* = (1-\beta)(1-\alpha^*)F$.

Jointly solving equation (A.6) and equation (A.10) gives

$$q^* = \frac{ni}{4}(aUC + bPD + cY + dCU) + \frac{nai^2 UC^*(EH + \gamma\delta\sigma_{R_1})}{4(EH^* - \gamma^*\delta^*\sigma_{\frac{1}{R_1}})}. \tag{A.11}$$

Applying Taylor series expansion to approximate $\sigma_{\frac{1}{R_1}} = \frac{\sigma_{R_1}}{R_1^2}$, and differentiating equation (A.11) with respective to $\sigma_{\frac{1}{R_1}}$ yields

$$\frac{\partial q^*}{\partial \sigma_{R_1}} = (\frac{nai^2 UC^*}{4(EH^* - \gamma^*\delta^* R_1^{-2}\sigma_{R_1})})(\gamma\delta + \frac{(EH + \gamma\delta\sigma_{R_1})\gamma^*\delta^* R_1^{-2}}{EH^* - \gamma^*\delta^* R_1^{-2}\sigma_{R_1}}). \tag{A.12}$$

This result indicates that exchange rate uncertainty has a negative impact on trade under risk aversion ($\gamma, \gamma^* > 0$), no effects on trade if traders are risk neutral ($\gamma, \gamma^* = 0$), and a positive impact on trade in the case of risk loving ($\gamma, \gamma^* < 0$).

A.2.2 De Grauwe Model

A producer is assumed to allocate its total resources, x, to produce both domestically and internationally, and later to maximize its utility which is a function of its profit. Variables with "~" are random, and subscripts d and f represent domestic and foreign countries, respectively.

Same production technology is employed in the two countries,

$$q_i = q(x_i), \quad \forall i = d, f. \tag{A.13}$$

The profit function is defined as

$$\widetilde{\Pi} = \widetilde{y} - wx = p^* \widetilde{e} q(x_f) + p_d q(x - x_f) - wx, \tag{A.14}$$

where w is the constant unit cost of production.

Since the total cost is constant, the maximization of its profit is equivalent to the maximization of its total revenue $\widetilde{y}$ which consists of export $\widetilde{Y_f}$ and domestic Y_d revenues, i.e., $\widetilde{y} = \widetilde{Y_f} + Y_d = p^* \widetilde{e} q(x_f) + p_d q(x - x_f)$.

A concave utility function is defined as a separable function of the domestic and foreign revenues, and the optimization problem is

$$\max_{x_f} (EU_f(p^* \widetilde{e} q(x_f)) + U_d(p_d q(x - x_f))). \tag{A.15}$$

The F.O.C yields

$$EU'_f\widetilde{e} = U'_d \frac{p_d q'(x - x_f)}{p^* q'(x_f)}. \tag{A.16}$$

$\widetilde{e}$ is assumed to follow a mean preserving spread process. If an increase of $\widetilde{e}$ leads to a raise in $EU'_f\widetilde{e}$, both x_f and the export increase; if an increase of $\widetilde{e}$ reduces $EU'_f\widetilde{e}x_f$, both x_f and the export decrease. Thus, the convexity or concavity of $EU'_f\widetilde{e}$ in $\widetilde{e}$ determines the effect of $\widetilde{e}$ on exports. The slope of this $EU'_f\widetilde{e}$ function is

$$\frac{d^2 U'_f\widetilde{e}}{d\widetilde{e}^2} = -\frac{1}{\widetilde{e}}(R(1-R) + R'\widetilde{Y_f}), \tag{A.17}$$

where $R = U''_f \frac{\widetilde{Y_f}}{U'_f}$.

He assumes a constant relative risk aversion (R) of the utility function, and concludes convexity if $R > 1$ and concavity if $R < 1$. If the producer is more risk averse ($R > 1$), an increase in exchange rate risk leads to a higher marginal utility of exports along with higher exports; if the producer is less risk averse ($R < 1$), the higher risk causes a decline in the marginal utility of exports and also a reduction in exports. Both of these effects are displayed in Figure A.4.

Relaxing the constant relative risk averse assumption, the generalized condition on convexity and concavity is

$$R(1-R) + R'\widetilde{Y_f} \lesseqgtr 0 \tag{A.18}$$

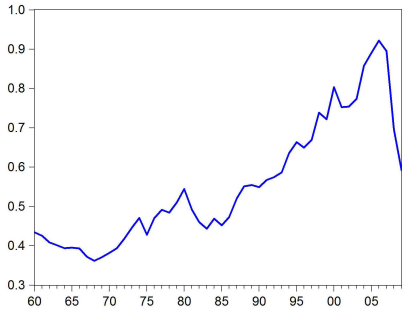
If R' is negative, a lower degree of risk aversion is needed to positively affect the export; on the other hand, a positive R' associated with a higher degree of risk averse

can also generate such a positive relation.

The economic intuition lies on relative dominance between substitution effect and income effect. Substitution effect implies that an increase in risk will reduce the attractiveness of the risky production and the exports; however, income effect oppositely impacts the the marginal utility of export revenue and raises the resources to export production. If income effect dominates substitution effect, exchange rate risk will positively influence exports.

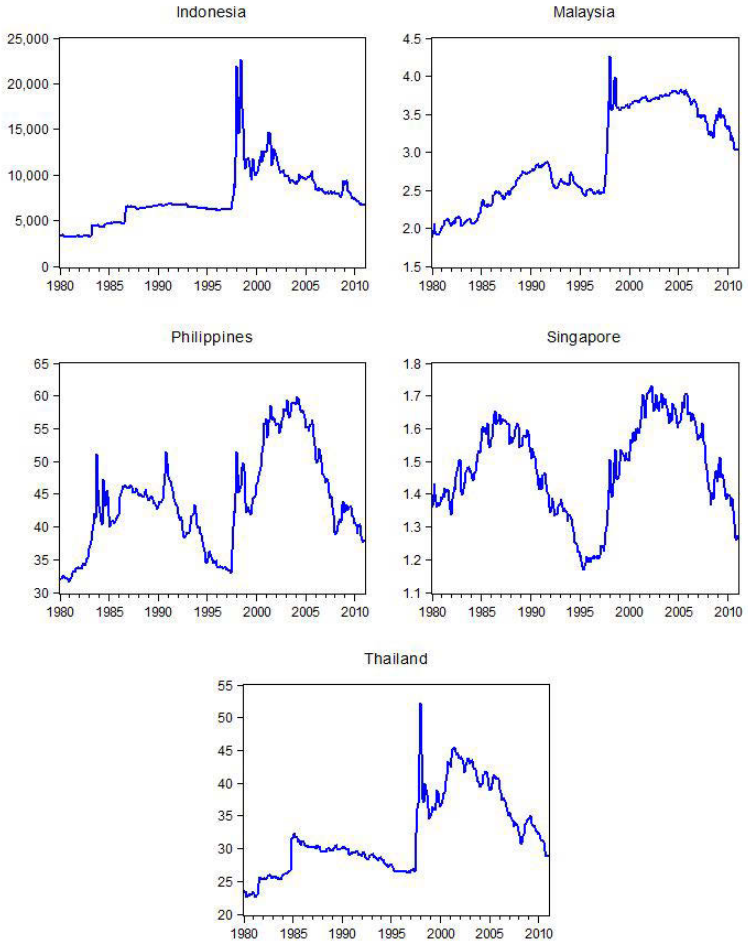
A.3 Figures

Figure A.1: **ASEAN-5 Export as a Percentage of GDP**



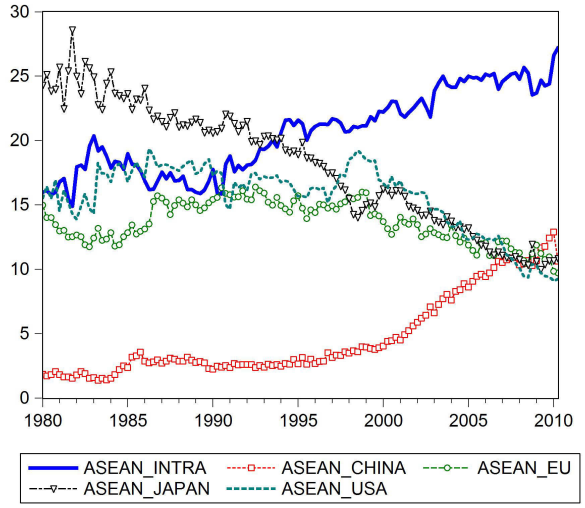
Source: WDI & IFS.

Figure A.2: **Real Exchange Rate of ASEAN-5 Currencies against the U.S. Dollar**



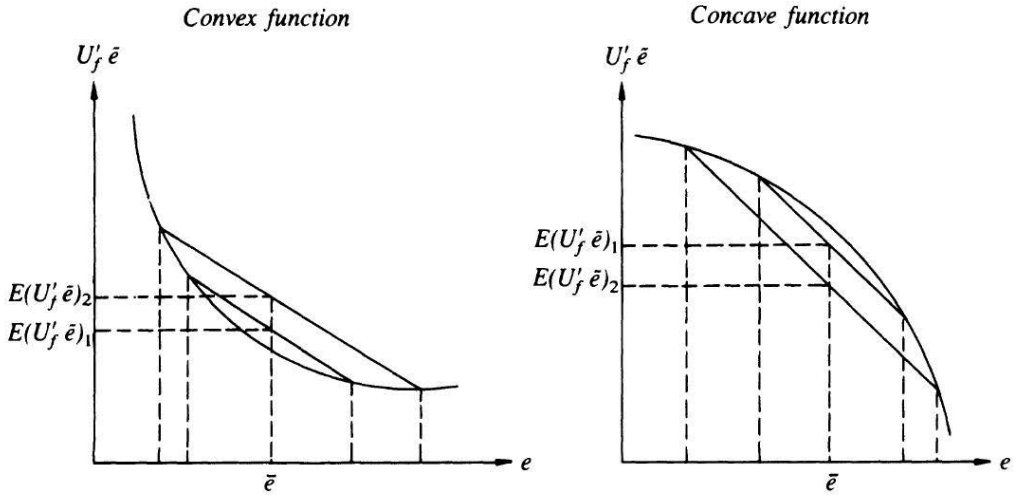
Source: IFS.

Figure A.3: **Trade Weights of ASEAN-5 Against Major Trade Partners**



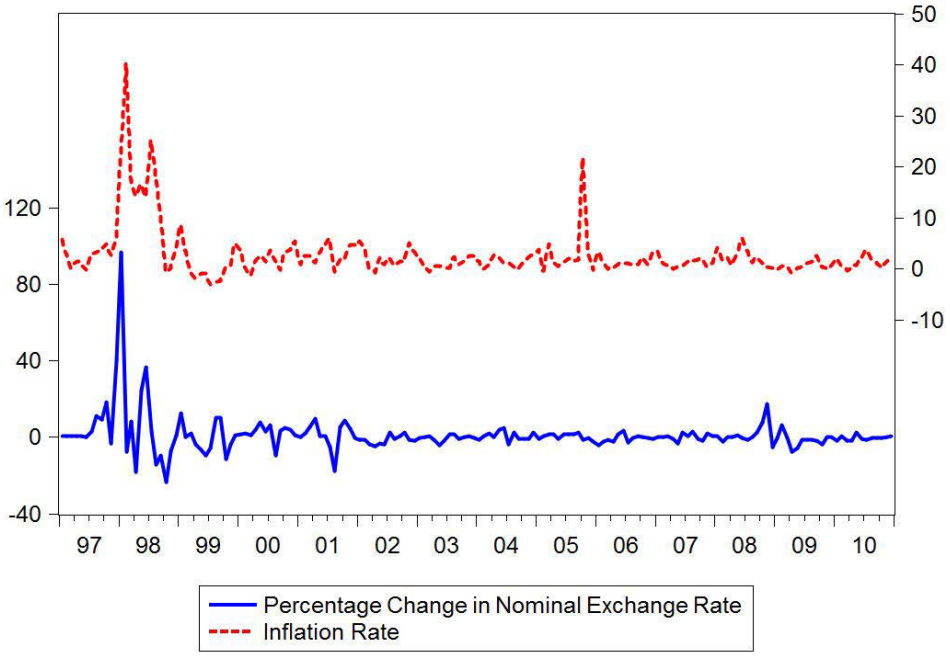
Source: DOTS.

Figure A.4: **Effects of an increase in the MPS of $\widetilde{e}$ on $EU'_f\widetilde{e}$**



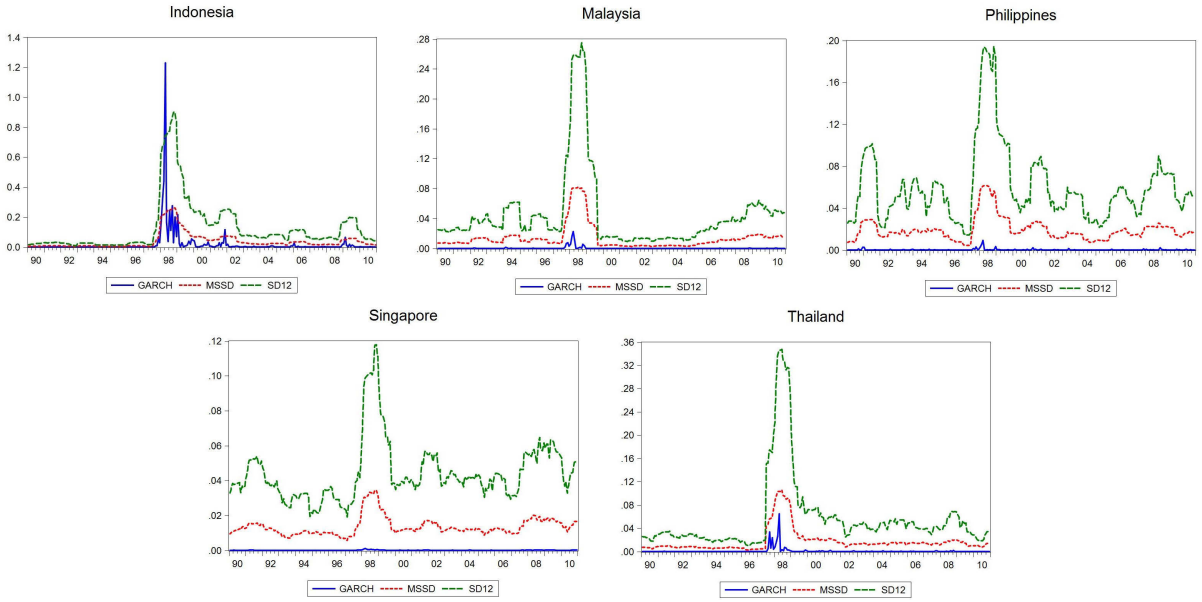
Source: De Grauwe (1988).

Figure A.5: **Percentage Change in Nominal Exchange Rate and Inflation Rate of Indonesia 1997-2010**



Source: IFS.

Figure A.6: **Real Exchange Rate Volatility 1990-2010**



Source: IFS.

A.4 Tables

Table A.1: **ARIMA-GARCH Results of Model**

Indonesia		
$ARIMA(0,1,0)$	$LB-Q(4)$	16.84^{***}
$\Delta re_t = -0.004^{***} + \epsilon_t$	$LB-Q(8)$	35.122^{***}
	$LB-Q(12)$	47.684^{***}
	$LB-Q^2(4)$	64.009^{***}
$GARCH(3,0)$	$LB-Q^2(8)$	85.057^{***}
$V_t = 0.00003^{**} + 0.821^{***}V_{t-1} + 0.183^{**}V_{t-2} +$	$LB-Q^2(12)$	94.712^{***}
$3.216^{*}V_{t-3}$	$ARCHLM(4)$	45.146^{***}
Malaysia		
$ARIMA(0,1,0)$	$LB-Q(4)$	19.208^{***}
$\Delta re_t = 0.0007 + \epsilon_t$	$LB-Q(8)$	25.944^{***}
	$LB-Q(12)$	28.342^{***}
	$LB-Q^2(4)$	205.8^{***}
$GARCH(2,0)$	$LB-Q^2(8)$	249.57^{***}
$V_t = 0.00005^{***} + 0.5887^{***}V_{t-1} + 0.4.629V_{t-2}$	$LB-Q^2(12)$	252.06^{***}
	$ARCHLM(4)$	132.7872^{***}
Philippines		
$ARIMA(1,1,0)$	$LB-Q(4)$	16.811^{***}
$\Delta re_t = -0.0002 + 0.4488AR(1) + \epsilon_t$	$LB-Q(8)$	27.196^{***}
	$LB-Q(12)$	29.564^{***}
	$LB-Q^2(4)$	10.769^{**}
$GARCH(1,0)$	$LB-Q^2(8)$	59.786^{***}
$V_t = 0.0002^{***} + 0.583^{***}V_{t-1}$	$LB-Q^2(12)$	60.602^{***}
	$ARCHLM(4)$	73.32^{***}
Singapore		
$ARIMA(1,1,0)$	$LB-Q(4)$	15.131^{***}
$\Delta re_t = -0.0014^{*} + 0.135^{**}AR(1) + \epsilon_t$	$LB-Q(8)$	15.815^{**}
	$LB-Q(12)$	20.165^{*}
	$LB-Q^2(4)$	62.292^{***}
$GARCH(1,1)$	$LB-Q^2(8)$	86.847^{***}
$V_t = 0.00003^{**} + 0.164^{**}V_{t-1} + 0.685^{***}\epsilon_{t-1}$	$LB-Q^2(12)$	98.177^{**}
	$ARCHLM(4)$	43.1808^{***}
Thailand		
$ARIMA(0,1,1)$	$LB-Q(4)$	3.698
$\Delta re_t = 0.0003 + 0.532^{***}MA(1) + \epsilon_t$	$LB-Q(8)$	4.686
	$LB-Q(12)$	9.411
	$LB-Q^2(4)$	46.338^{***}
$GARCH(2,0)$	$LB-Q^2(8)$	60.618^{***}
$V_t = 0.00006^{***} + 0.23^{*}V_{t-1} + 1.383V_{t-2}$	$LB-Q^2(12)$	67.077^{***}
	$ARCHLM(4)$	36.598^{***}

Notes: 1. ARIMA and GARCH equations are reported in the table.

2. $LB-Q$ and $LB-Q^2$ are Ljung-Box statistics for level and squared residuals up to K lags.

3. $ARCHLM(4)$ tests for ARCH effects of the residuals.

4. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

Table A.2: **Descriptive Statistics of Exchange Rate Volatilities**

		Indonesia	***Malaysia***	***Philippines***	***Singapore***	***Thailand***
$GARCH$	STD	0.714	0.413	0.306	0.153	0.437
$MSSD$	STD	0.627	0.731	0.354	0.225	0.326
$SD12$	STD	0.65	0.72	0.365	0.224	0.377
$\Delta GARCH$	STD	0.595	0.424	0.399	0.151	0.634
$\Delta MSSD$	STD	0.286	0.303	0.205	0.134	0.175
$\Delta SD12$	STD	0.316	0.299	0.24	0.147	0.377

Source: IMF International Financial Statistics.

Table A.3: **Vector Error Correction Results for Optimal Lag Length P of Manufacturing Sector**

		With deterministic trend				Without deterministic trend			
Country	*Volatility*	***P***	*AIC*	*SIC*	*Chi*(4)	***P***	*AIC*	*SIC*	*Chi*(4)
Indonesia	*GARCH*	5	−11.555	−8.632	6.302	5	−11.53	−8.762	5.328
	MSSD	6	−13.454	−9.907	17.944	6	−13.241	−9.85	9.212
	*SD*12	6	−13.156	−9.609	19.619	6	−12.941	−9.549	11.122
Malaysia	*GARCH*	6	−15.37	−11.822	10.173	5	−14.963	−12.196	15.794
	MSSD	5	−15.674	−12.75	16.923	5	−15.552	−12.784	15.611
	*SD*12	5	−15.666	−12.742	13.507	5	−15.51	−12.742	11.705
Philippines	*GARCH*	8	−13.925	−9.13	14.912	4	−13.766	−11.621	8.802
	MSSD	8	−15.158	−11.61	−10.836	4	−14.771	−12.627	13.35
	*SD*12	8	−14.799	−10.005	9.543	4	−14.452	−12.307	13.111
Singapore	*GARCH*	5	−15.43	−12.506	23.353	5	−15.367	−12.599	20.209
	MSSD	5	−16.357	−13.433	19.198	5	−16.18	−13.412	11.02
	*SD*12	5	−15.861	−12.937	19.619	5	−15.732	−12.964	15.852
Thailand	*GARCH*	7	−14.559	−10.387	14.647	5	−14.524	−11.757	13.074
	MSSD	6	−17.297	−13.749	19.389	6	−17.069	−13.677	17.97
	*SD*12	6	−16.142	−12.594	9.276	6	−15.939	−12.547	8.345

Notes: 1. Statistics for the *AIC*, *SIC* and *LM* test for autocorrelationships of residuals up to the fourth lag are reported.

2. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

Table A.4: **Vector Error Correction Results for Optimal Lag Length P of Bilateral Exports**

		With deterministic trend				Without deterministic trend			
Country	*Volatility*	***P***	*AIC*	*SIC*	*Chi*(4)	***P***	*AIC*	*SIC*	*Chi*(4)
Indonesia	*GARCH*	5	−11.614	−8.469	8.948	5	−11.594	−8.448	6.58
	MSSD	6	−13.391	−9.844	11.219	6	−13.241	−9.85	9.351
	*SD*12	6	−13.116	−9.568	14.049	6	−13.046	−9.654	11.767
Malaysia	*GARCH*	6	−16.612	−13.064	8.586	6	−16.066	−12.675	11.453
	MSSD	6	−16.372	−12.825	18.626	5	−15.997	−13.229	22.289
	*SD*12	6	−16.341	−12.793	17.413	5	−15.991	−13.223	19.983
Philippines	*GARCH*	8	−13.745	−8.95	19.616	5	−13.399	−10.631	6.422
	MSSD	6	−15.003	−11.455	12.812	4	−14.502	−12.358	12.133
	*SD*12	8	−14.459	−9.664	10.833	4	−14.169	−12.025	11.321
Singapore	*GARCH*	5	−15.715	−12.791	19.041	5	−15.657	−12.889	16.563
	MSSD	5	−16.542	−13.619	16.284	5	−16.438	−13.67	11.807
	*SD*12	5	−16.132	−13.208	18.332	5	−16.051	−13.283	17.264
Thailand	*GARCH*	5	−14.573	−11.649	17.034	5	−14.539	−11.771	14.868
	MSSD	6	−17.302	−13.755	15.776	6	−17.044	−13.653	16.69
	*SD*12	6	−16.436	−12.889	13.085	6	−16.176	−12.784	11.762

Notes: 1. Statistics for the *AIC*, *SIC* and *LM* test for autocorrelationships of residuals up to the fourth lag are reported.

2. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

Table A.5: **Auto Regressive Distributed Lag Bounds Tests**

Manufacturing Sector				
country	*Trend*	*GARCH*	*MSSD*	*SD*12
Indonesia	*T*	6.94^c	8.81^c	9.09^c
	NT	7.25^c	9.22^c	7.49^c
Malaysia	*T*	2.33^a	2.27^a	2.54^a
	NT	3.38^b	2.36^a	1.88^a
Philippines	*T*	5.22^c	4.38^b	2.43^a
	NT	1.59^a	0.96^a	1.24^a
Singapore	*T*	1.96^a	2.03^a	3.78^a
	NT	2.57^a	2.08^a	4.49^c
Thailand	*T*	9.78^c	4.49^b	8.38^c
	NT	7.21^c	2.92^a	6.99^c
Bilateral Exports				
country	*Trend*	*GARCH*	*MSSD*	*SD*12
Indonesia	*T*	5.94^c	5.07^b	6.57^c
	NT	7.83^c	7.58^c	7.65^c
Malaysia	*T*	3.67^a	3.09^a	0.86^a
	NT	3.69^b	2.34^a	1.16^a
Philippines	*T*	3.49^a	3.62^a	1.28^a
	NT	1.56^a	0.83^a	1.11^a
Singapore	*T*	2.1^a	2.66^a	3.14^a
	NT	2.27^a	2.06^a	3.16^a
Thailand	*T*	2.76^a	4.01^b	5.62^c
	NT	0.91^a	3.21^a	5.15^c

Notes: 1. F-statistics are reported in the table.

2. ^{a} indicates that the statistic falls below the 0.05 lower bound, ^{b} that it lies between the two 0.05 bounds, and ^{c} that is above the 0.05 upper bound.

Table A.6: **Long-run Forcing Tests**

Trend	Variable	*Indonesia*	*Malaysia*	*Philippines*	*Singapore*	*Thailand*
Manufacturing Sector						
T	$GARCH$	-0.22^a	0.98^a	1.07^a	0.77^a	-1.18^a
	re	-0.26^a	1.01^a	0.69^a	-4.94^c	-1.06^a
	gdp_US	-2.38^a	1.72^a	0.99^a	0.78^a	-0.84^a
NT	$GARCH$	-0.34^a	0.38^a	-0.1^a	-0.99^a	-0.02^a
	re	1.78^a	0.48^a	-0.57^a	-2.56^a	-2.16^a
	gdp_US	-1.4^a	-1.03^a	-1.3^a	-2.17^a	-0.18^a
T	$MSSD$	1.15^a	0.8^a	1.29^a	-0.09^a	-5.41^c
	re	0.03^a	1.28^a	2.43^b	-5.16^c	-2.5^a
	gdp_US	-1.23^a	2.29^a	2.12^a	1.29^a	-1.59^a
NT	$MSSD$	-0.28^a	-0.02^a	2.08^a	-1.78^a	-1.37^a
	re	1.55^a	0.56^a	2.3^a	-3.36^b	1.00^a
	gdp_US	-0.58^a	-1.06^a	0.56^a	-2.4^a	-0.38^a
T	$SD12$	1.31^a	0.07^a	1.91^a	-0.85^a	-3.63^b
	re	-0.26^a	0.6^a	0.64^a	-5.27^c	0.58^a
	gdp_US	-1.00^a	-2.69^a	1.24^a	0.65^a	0.55^a
NT	$SD12$	-0.31^a	-0.22^a	0.1^a	-2.03^a	-1.01^a
	re	1.19^a	-0.23^a	0.44^a	-3.21^b	2.44^a
	gdp_US	-0.55^a	-2.7^a	-0.88^a	-2.27^a	0.21^a
Bilateral Exports						
Trend	Variable	*Indonesia*	*Malaysia*	*Philippines*	*Singapore*	*Thailand*
T	$GARCH$	-0.68^a	2.45^a	1.07^a	0.2^a	-0.96^a
	re	-5.33^c	1.66^a	0.69^a	-1.55^a	-1.37^a
	gdp_US	0.88^a	1.78^a	0.99^a	1.87^a	0.59^a
NT	$GARCH$	-1.02^a	1.72^a	-0.1^a	-0.67^a	-0.6^a
	re	-2.44^a	0.26^a	-0.57^a	-0.86^a	0.86^a
	gdp_US	-2.11^a	-1.16^b	-1.3^a	-0.09^a	0.1^a
T	$MSSD$	0.38^a	0.2^a	2.06^a	0.09^a	-3.42^b
	re	-0.53^a	0.55^a	1.76^a	-5.18^c	-3.12^a
	gdp_US	-1.11^a	0.79^a	1.23^a	1.79^a	-1.64^a
NT	$MSSD$	-0.22^a	0.2^a	2.19^a	-1.74^a	-2.2^a
	re	0.39^a	1.27^a	2.36^a	-3.04^b	0.34^a
	gdp_US	-0.95^a	-0.14^a	0.53^a	-2.23^a	-1.2^a
T	$SD12$	0.6^a	-0.1^a	2.41^a	-0.9^a	-3.13^a
	re	-0.75^a	0.09^a	0.64^a	-5.61^c	0.02^a
	gdp_US	-1.08^a	0.48^a	2.05^a	0.83^a	-1.31^a
NT	$SD12$	-0.2^a	0.34^a	0.3^a	-2.13^a	-2.11^a
	re	0.36^a	-0.61^a	0.47^a	-3.19^b	2.69^a
	gdp_US	-0.82^a	-2.17^a	-0.93^a	-2.43^a	-1.15^a

Notes: 1. t-statistics are reported in the table.

2. ^{a} indicates that the statistic falls below the 0.05 lower bound, ^{b} that it lies between the two 0.05 bounds, and ^{c} that is above the 0.05 upper bound.

Table A.7: **Seemingly Unrelated Regression Model of Manufacturing Exports − GARCH**

		Indonesia	***Malaysia***	***Philippines***	***Singapore***	***Thailand***
	Lag	$ARDL(4,5,2,5)$	$ARDL(5,4,1,3)$	$ARDL(7,5,2,1)$	$ARDL(4,3,3,3)$	$ARDL(5,5,2,1)$
$\Delta exports_t$	1	0.477***	−0.266**	1.027***	0.129	0.111
	2	0.402***	−0.023	0.928***	−0.42***	−0.11
	3	0.41***	−0.442***	0.938***	0.089	0.334***
	4	0.239**	−0.445***	0.639***	−0.538***	0.406***
	5		0.137	0.73***		0.266***
	6			0.526***		
	7			0.49***		
Δre_t	0	0.271***	1.992***	−0.193	−0.461	0.159
	1	−0.174**	1.228**	0.272	0.545	0.26*
	2	0.038	0.787	0.268*	0.686	0.336***
	3	−0.045	1.105**	0.466***	0.69	0.194**
	4	−0.126***	1.336***	0.16		0.209***
	5	0.088**		−0.185*		0.27***
Δgdp_US_t	0	−1.997***	3.525***	−0.942	−1.489	−1.147*
	1	1.102	3.022**	0.385	2.801	0.562
	2	1.844**		3.155***	−0.389	4.571***
	3				1.286	
$\Delta garch_t$	0	−0.008	0.022	−0.029*	−0.021	−0.041***
	1	−0.087***	−0.029	0.053***	−0.053	0.05***
	2	−0.087***	−0.015		−0.054	
	3	−0.066***	−0.045**		−0.249***	
	4	−0.041***				
	5	−0.032***				
$dc99q102q2$		−0.172***				
$dt99q102q2$		0.012***				
$dc99q101q4$				−1.327***		0.378***
$dt99q101q4$				0.074***		−0.026***
$exports_{t-1}$		−1.172***		−1.487***		−0.991***
re_{t-1}		0.305***		−0.649***		0.291**
gdp_US_{t-1}		1.556***		0.145		3.67***
$garch_{t-1}$		0.091***		−0.147***		−0.162***
$Trend$				−0.044***	0.003**	−0.013***
$Constant$			−0.032***	26.922***	−0.303**	−19.874***
$Reset$		0.16	5.38***	2.03	0.55	0.42
$JBNorm$		0.994	1.277	0.175	2.68	0.513
$SKtest$		1.31	2.29	0.01	4.92*	0.51
$LM(4)$		5.764	2.802	2.698	1.385	7.345
$BPind$		20.071**				

Notes: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. $ARDL(P,Q,M,N)$ represents the selected leg length of the first difference of natural logs of real exports, real exchange rate, real U.S. GDP and exchange rate volatility in the $ARDL$ regression.

3. $Reset$ is the Ramsey test for mis-specification up to the cubic of the residuals, $JBNorm$ and $SKtest$ are respectively the Jarque-Bera and Skewness-Kurtosis normality tests for the residuals, $LM(4)$ tests the serial correlationships of the residuals up to the fourth lag, and $BPind$ represents the Breusch-Pagan test for cross-sectional independence.

Table A.8: **Seemingly Unrelated Regression Model of Bilateral Exports – GARCH**

		Indonesia	***Malaysia***	***Philippines***	***Singapore***	***Thailand***
	Lag	$ARDL(3,4,4,5)$	$ARDL(5,2,5,1)$	$ARDL(1,1,3,2)$	$ARDL(4,3,3,3)$	$ARDL(4,3,2,3)$
$\Delta exports_t$	1	0.803***	0.388***	0.158	0.039	−0.186**
	2	0.782***	−0.33***		−0.211*	−0.269***
	3	0.682***	0.059		0.119	0.11
	4		−0.332***		−0.547***	−0.283***
	5		0.485***			
Δre_t	0	0.08	0.729**	−0.007	0.154	0.288*
	1	−0.292***	−0.346	−0.167	0.542	0.072
	2	−0.079	1.339***		0.952**	0.368***
	3	0.013			1.052***	0.211**
	4	−0.077**				
Δgdp_US_t	0	−0.414	0.28	−0.388	−1.658	0.595
	1	−1.594**	2.398***	0.531	1.929	3.041***
	2	−0.659	1.565*	2.565**	1.24	2.698***
	3	1.084	−0.459	−2.791***	2.028	
	4	−0.991	−1.212*			
	5		−1.518*			
$\Delta garch_t$	0	−0.007	0.038***	0.017	−0.019	−0.018***
	1	−0.056***	−0.036**	−0.026*	0.012	−0.022***
	2	−0.072***		−0.007	−0.067	−0.026***
	3	−0.039***			−0.195***	−0.021***
	4	−0.029***				
	5	−0.012				
$dc99q102q2$		0.138***				
$dc99q101q4$				0.022		−0.035***
$exports_{t-1}$		−1.696***				
re_{t-1}		0.029				
gdp_US_{t-1}		2.513***				
$garch_{t-1}$		0.051***				
$Trend$					0.003***	0.001**
$Constant$		−10.256***		−0.017*	−0.38***	−0.091**
$Reset$		0.22	0.89	0.31	0.63	0.82
$JBNorm$		1.013	2.34	0.494	2.13	0.302
$SKtest$		1.22	3.59	0.83	4.95*	0.1
$LM(4)$		5.472	1.699	3.73	1.276	3.94
$BPind$		42.854***				

Notes: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. $ARDL(P,Q,M,N)$ represents the selected leg length of the first difference of natural logs of real exports, real exchange rate, real U.S. GDP and exchange rate volatility in the $ARDL$ regression.

3. $Reset$ is the Ramsey test for mis-specification up to the cubic of the residuals, $JBNorm$ and $SKtest$ are respectively the Jarque-Bera and Skewness-Kurtosis normality tests for the residuals, $LM(4)$ tests the serial correlationships of the residuals up to the fourth lag, and $BPind$ represents the Breusch-Pagan test for cross-sectional independence.

Table A.9: **Seemingly Unrelated Regression Model of Manufacturing Exports − MSSD**

		Indonesia	***Malaysia***	***Philippines***	***Singapore***	***Thailand***
	Lag	$ARDL(3,3,3,4)$	$ARDL(5,3,1,4)$	$ARDL(2,2,3,4)$	$ARDL(5,5,4,5)$	$ARDL(5,5,4,1)$
$\Delta exports_t$	1	0.536***	−0.257**	0.348***	−0.093	−0.068
	2	0.418***	0.04	−0.144	−0.597***	−0.424***
	3	0.334***	−0.068		0.107	0.205*
	4		−0.606***		−0.882***	−0.143
	5		0.25*		−0.149	−0.267**
Δre_t	0	0.123	2.486***	0.101	0.266	0.398**
	1	−0.061	1.501***	−0.099	−1.005**	0.085
	2	0.056	0.882**	−0.207	1.352***	0.314*
	3	0.157***	1.043***		0.965**	0.336***
	4				0.893**	0.097
	5				1.531***	0.305***
Δgdp_US_t	0	−0.601	4.319***	−1.049	−2.957**	0.904
	1	−1.71*	3.801**	1.573	−1.078	4.024***
	2	1.71**		2.068**	0.293	1.818**
	3	2.42***		−3.218***	7.309***	0.048
	4				−2.203	1.559*
$\Delta mssd_t$	0	0.036**	0.003	−0.02	−0.054	−0.044
	1	−0.13***	−0.034	0.002	−0.194***	−0.095***
	2	−0.134***	0.015	−0.021	−0.177**	
	3	−0.081***	0.046*	−0.058**	−0.321***	
	4	−0.034*	0.069***	0.049*	−0.323***	
	5				0.297***	
$dc99q102q2$		−0.256***				
$dt99q102q2$		0.016***				
$dc99q101q4$				0.018		−0.041***
$dc99q100q3$					−0.128***	
$exports_{t-1}$		−1.349***				
re_{t-1}		0.215**				
gdp_US_{t-1}		2.663***				
$mssd_{t-1}$		0.178***				
$Trend$		−0.005**			0.004***	0.001**
$Constant$		−6.174*	−0.032***	−0.018**	−0.457***	−0.152***
$Reset$		0.38	4.9***	0.31	0.71	0.12
$JBNorm$		0.792	2.8	1.693	1.122	3.546
$SKtest$		0.7	3.96	2.06	1.7	4.54
$LM(4)$		4.832	3.964	4.393	5.884	1.691
$BPind$		17.317*				

Notes: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. $ARDL(P,Q,M,N)$ represents the selected leg length of the first difference of natural logs of real exports, real exchange rate, real U.S. GDP and exchange rate volatility in the $ARDL$ regression.

3. $Reset$ is the Ramsey test for mis-specification up to the cubic of the residuals, $JBNorm$ and $SKtest$ are respectively the Jarque-Bera and Skewness-Kurtosis normality tests for the residuals, $LM(4)$ tests the serial correlationships of the residuals up to the fourth lag, and $BPind$ represents the Breusch-Pagan test for cross-sectional independence.

Table A.10: **Seemingly Unrelated Regression Model of Bilateral Exports – MSSD**

$\Delta exports_t$	1	0.255**	0.208**	0.146	0.021	0.012
	2	0.38***	−0.257**	−0.087	−0.389***	−0.198*
	3		0.066		0.229*	0.281**
	4		−0.323***		−0.633***	−0.281**
	5		0.413***			
Δre_t	0	0.037	0.345	0.106	0.2	0.237*
	1	−0.015	0.489*		−0.027	−0.16
	2	0.249***	0.769***		1.085***	0.328**
	3	0.22***	0.471**		1.187***	0.132
	4	−0.063*			0.418	0.108
	5	0.116***			0.839**	0.131*
	6	0.071**				−0.212***
Δgdp_US_t	0	−1.64**	−0.262	−1.006	−3.257**	−0.674
	1	0.769	3.642***	1.344	−0.222	2.923***
	2	1.735**	1.385	2.716**	1.022	1.601**
	3	2.503***	−0.843	−3.182***	4.08**	−0.119
	4		−0.545			0.401
	5		−2.021***			0.284
	6					−1.786***
$\Delta mssd_t$	0	0.057***	0.009	−0.024	−0.063	−0.115***
	1	−0.067***	−0.004	−0.017	−0.025	−0.051*
	2	−0.064***	−0.02*	−0.048*	−0.144**	0.025
	3				−0.138*	0.038*
	4				−0.191***	−0.044**
	5				0.2***	
$dc99q102q2$		−0.095*				
$dt99q102q2$		0.009***				
$dc99q101q4$						−0.035**
$exports_{t-1}$		−0.934***				
re_{t-1}		−0.239**				
gdp_US_{t-1}		1.055***				
$mssd_{t-1}$		0.084023***				
$Trend$					0.005***	
$Constant$				−0.014	−0.496***	
$Reset$		0.21	2.05	0.55	0.53	1.26
$JBNorm$		0.3868	0.352	0.392	1.079	0.047
$SKtest$		0.87	0.31	0.68	1.54	0.03
$LM(4)$		8.361*	3.509	4.672	6.059	3.638
$Bphetero$		0.2	0.86	0.77	0.89	0
$BPind$		27.469***				

Notes: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. $ARDL(P,Q,M,N)$ represents the selected leg length of the first difference of natural logs of real exports, real exchange rate, real U.S. GDP and exchange rate volatility in the $ARDL$ regression.

3. $Reset$ is the Ramsey test for mis-specification up to the cubic of the residuals, $JBNorm$ and $SKtest$ are respectively the Jarque-Bera and Skewness-Kurtosis normality tests for the residuals, $LM(4)$ tests the serial correlationships of the residuals up to the fourth lag, and $BPind$ represents the Breusch-Pagan test for cross-sectional independence.

Table A.11: **Seemingly Unrelated Regression Model of Manufacturing Exports − SD12**

		Indonesia	***Malaysia***	***Philippines***	***Singapore***	***Thailand***
	Lag	$ARDL(3,0,3,4)$	$ARDL(5,3,1,4)$	$ARDL(2,2,3,1)$	$ARDL(4,3,1,2)$	$ARDL(3,1,5,1)$
$\Delta exports_t$	1	0.35**	−0.288**	0.243*	0.116	0.133
	2	0.299**	0.018	−0.112	−0.343***	−0.208**
	3	0.385***	−0.131		−0.034	0.176*
	4		−0.548***		−0.338**	
	5		0.213			
Δre_t	0	0.145*	2.499***	0.136	−0.277	0.55***
	1		1.614***	−0.054	0.725	−0.309**
	2		0.921**	−0.233	0.631	
	3		1.113***		0.535	
Δgdp_US_t	0	−0.706	4.5***	−0.347	−3.225*	1.0004*
	1	−0.838	4.243**	0.941	3.286**	2.739***
	2	1.859**		2.145**		2.04***
	3	1.808*		−2.926***		−0.046
	4					1.073
	5					2.621***
$\Delta sd12_t$	0	0.016	0.008	−0.036	−0.143**	−0.065***
	1	−0.083***	−0.024	−0.014	0.021	−0.055***
	2	−0.089***	0.007		−0.212***	
	3	−0.058*	0.042			
	4	−0.013	0.075***			
$dc99q102q2$		−0.189***				
$dt99q102q2$		0.014***				
$dc99q101q4$				0.018		−0.014
$exports_{t-1}$		−1.146***				−0.466***
re_{t-1}		0.147*				0.158***
gdp_US_{t-1}		1.689***				0.68***
$sd12_{t-1}$		0.11***				−0.021
$Trend$		−0.002			0.002**	
$Constant$			−0.035***	−0.02**	−0.251**	
$Reset$		0.39	5.41***	1.07	2.65*	0.07
$JBNorm$		0.573	4.042	0.6399	0.506	0.177
$SKtest$		0.42	4.67*	0.52	0.33	0.23
$LM(4)$		4.38	5.029	0.859	3.961	2.68
$BPind$		23.472***				

Notes: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. $ARDL(P,Q,M,N)$ represents the selected leg length of the first difference of natural logs of real exports, real exchange rate, real U.S. GDP and exchange rate volatility in the $ARDL$ regression.

3. $Reset$ is the Ramsey test for mis-specification up to the cubic of the residuals, $JBNorm$ and $SKtest$ are respectively the Jarque-Bera and Skewness-Kurtosis normality tests for the residuals, $LM(4)$ tests the serial correlationships of the residuals up to the fourth lag, and $BPind$ represents the Breusch-Pagan test for cross-sectional independence.

Table A.12: **Seemingly Unrelated Regression Model of Bilateral Exports – SD12**

$\Delta exports_t$	1	0.262**	0.192*	0.106	0.08	0.244*
	2	0.445***	−0.234**	−0.085	−0.306**	
	3		0.018		0.029	
	4		−0.303***		−0.404***	
	5		0.385***			
Δre_t	0	0.014	0.396	0.158	−0.101	0.471***
	1	0.085	0.529**		0.502	−0.47***
	2	0.328***	0.783***		0.678*	−0.346**
	3	0.292***	0.468**		0.781**	
	4	−0.013				
	5	0.162***				
	6	0.103**				
Δgdp_US_t	0	−1.185*	−0.161	−1.033	−3.454**	−0.374
	1	0.472	3.636***	1.463	3.249**	0.817
	2	1.254	1.428	2.329**		1.232
	3	2.218***	−0.947	−3.077***		−0.934
	4		−0.587			0.914
	5		−1.932***			2.659***
$\Delta sd12_t$	0	0.057***	0.012	−0.026	−0.107*	−0.088***
	1	−0.08***	−0.011	−0.04*	0.018	−0.037
	2	−0.074***	−0.022	−0.019	−0.218***	−0.001
	3				−0.033	−0.004
	4				−0.036	−0.041**
	5				0.07	−0.028
$dc99q102q2$		−0.169**				
$dt99q102q2$		0.013***				
$dc99q101q4$						0.465*
$dt99q101q4$						−0.025
$exports_{t-1}$		−0.946***				−0.727***
re_{t-1}		−0.442***				0.588***
gdp_US_{t-1}		1.293504***				1.701***
$sd12_{t-1}$		0.0996***				−0.059
$Trend$		−0.003			0.002***	0.002
$Constant$				−0.013	−0.259***	−12.405**
$Reset$		0.32	1.85	0.01	0.49	0.24
$JBNorm$		0.777	0.337	0.296	0.77	1.08
$SKtest$		1.37	0.3	0.09	0.68	1.11
$LM(4)$		7.997*	3.491	4.139	7.463	2.685
$Bphetero$		0	0.64	0.36	2.27	0.41
$BPind$		30.347***				

Notes: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. $ARDL(P,Q,M,N)$ represents the selected leg length of the first difference of natural logs of real exports, real exchange rate, real U.S. GDP and exchange rate volatility in the $ARDL$ regression.

3. $Reset$ is the Ramsey test for mis-specification up to the cubic of the residuals, $JBNorm$ and $SKtest$ are respectively the Jarque-Bera and Skewness-Kurtosis normality tests for the residuals, $LM(4)$ tests the serial correlationships of the residuals up to the fourth lag, and $BPind$ represents the Breusch-Pagan test for cross-sectional independence.

Table A.13: **Normalized Coefficients of Long-run Level Relationships**

		re_{t-1}	gdp_US_{t-1}	vol_{t-1}
Manufacturing Exports				
GARCH	**Indonesia**	0.26^{***}	1.327^{***}	0.078^{***}
	Philippines	-0.436^{***}	0.097^{***}	-0.099^{***}
	Thailand	0.293^{***}	3.702^{***}	-0.164^{***}
MSSD	**Indonesia**	0.16^{***}	1.974^{***}	0.132^{***}
SD12	**Indonesia**	0.128^{***}	1.474^{***}	0.096^{***}
	Thailand	0.34^{***}	1.459^{***}	-0.045
Bilateral Exports				
GARCH	**Indonesia**	0.017	1.482^{***}	0.03^{***}
MSSD	**Indonesia**	-0.256^{***}	1.129^{***}	0.09^{***}
SD12	**Indonesia**	-0.468^{***}	1.368^{***}	0.105^{***}
	Thailand	0.81^{***}	2.34^{***}	-0.082

Appendix B: Chapter 2

B.1 Bias Approximation of Kiviet's LSDV Estimator

Bun and Kiviet (2003) approximate the bias as

$$E[\lambda_{LSDV} - \lambda] = c_1(T^{-1}) + c_2(N^{-1}T^{-1}) + c_3(N^{-1}T^{-2}) + O(N^{-2}T^{-2}), \tag{B.1}$$

and

$$c_1(T^{-1}) = \sigma_u^2 tr(\Pi) q_1,$$

$$c_2(N^{-1}T^{-1}) = -\sigma_u^2[Q\bar{W}'\Pi A\bar{W} + tr(Q\bar{W}\Pi A\bar{W})I_{k+1} + 2\sigma_u^2 q_{11} tr(\Pi'\Pi\Pi)I_{k+1}]q_1,$$

$$c_3(N^{-1}T^{-2}) = \sigma_u^4 tr(\Pi)\{2q_{11}Q\bar{W}'\Pi\pi'\bar{W}q_1 + [(q_1'\bar{W}\Pi\Pi'\bar{W}q_1) + q_{11}tr(Q\bar{W}'\Pi\Pi'\bar{W}) + 2tr(\Pi'\Pi\Pi'\Pi)q_{11}^2]q_1\},$$

where $Q = [E(W'AW)]^{-1} = [\bar{W}'A\bar{W} + \sigma_u^2 tr(\Pi'\Pi)e_1e_1']^{-1}$, $\bar{W} = E(W)$, $e_1 = [1,0,\ldots,0]_('k \times 1)$, $q_1 = Qe_1$, $q_{11} = e_1'q_1$, $\Pi = AL\Gamma$, $\Gamma = I_N \bigotimes \Gamma_T$, $\Gamma_T = (I_T - \rho L_T)$, $L = I_N \bigotimes L_T$, L_T is a $T \times T$ matrix with ones in the subdiagonal and zeroes elsewhere.

B.2 Figures

Figure B.1: **Monthly Economic Policy Uncertainty Index of the USA 1985-2013**

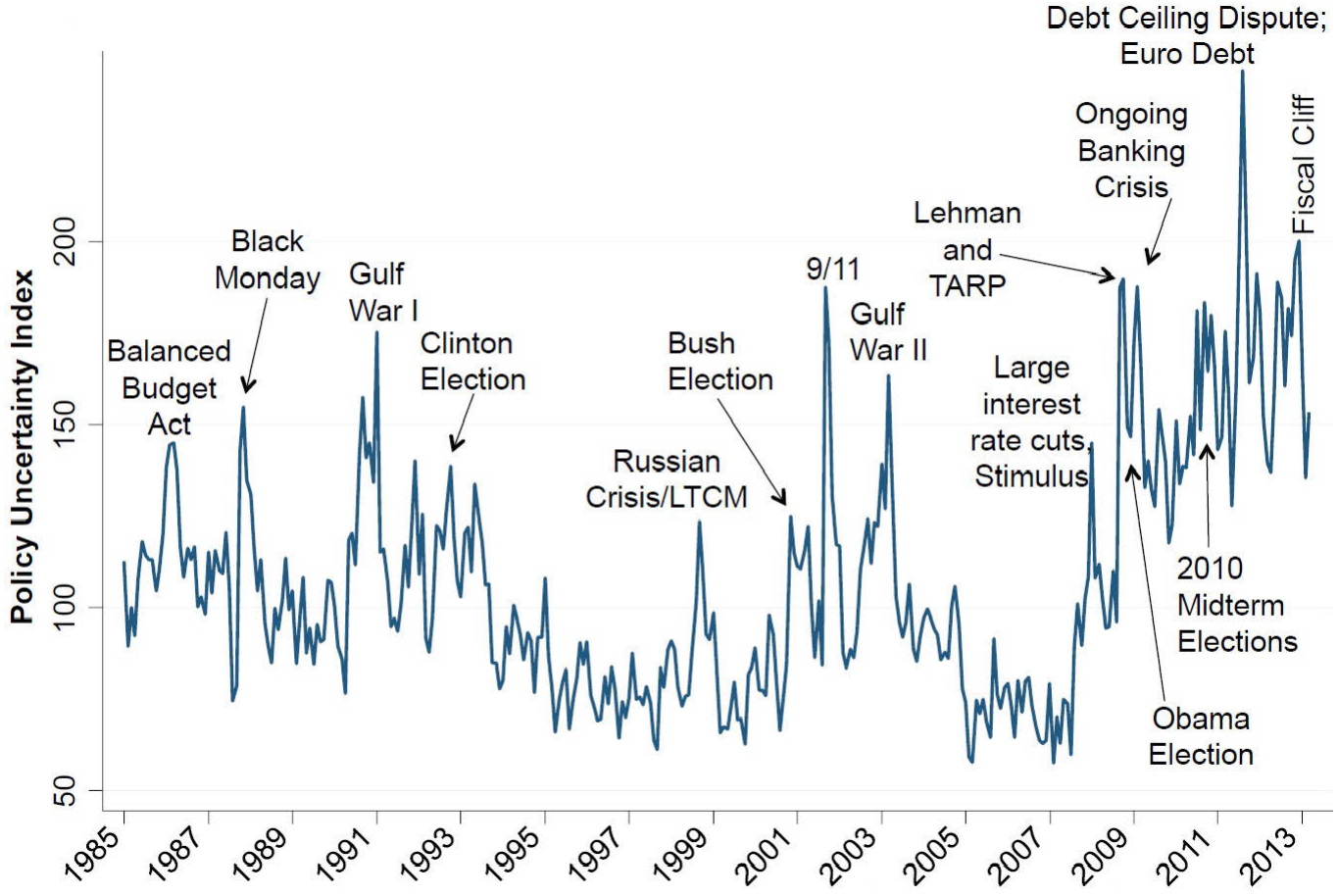
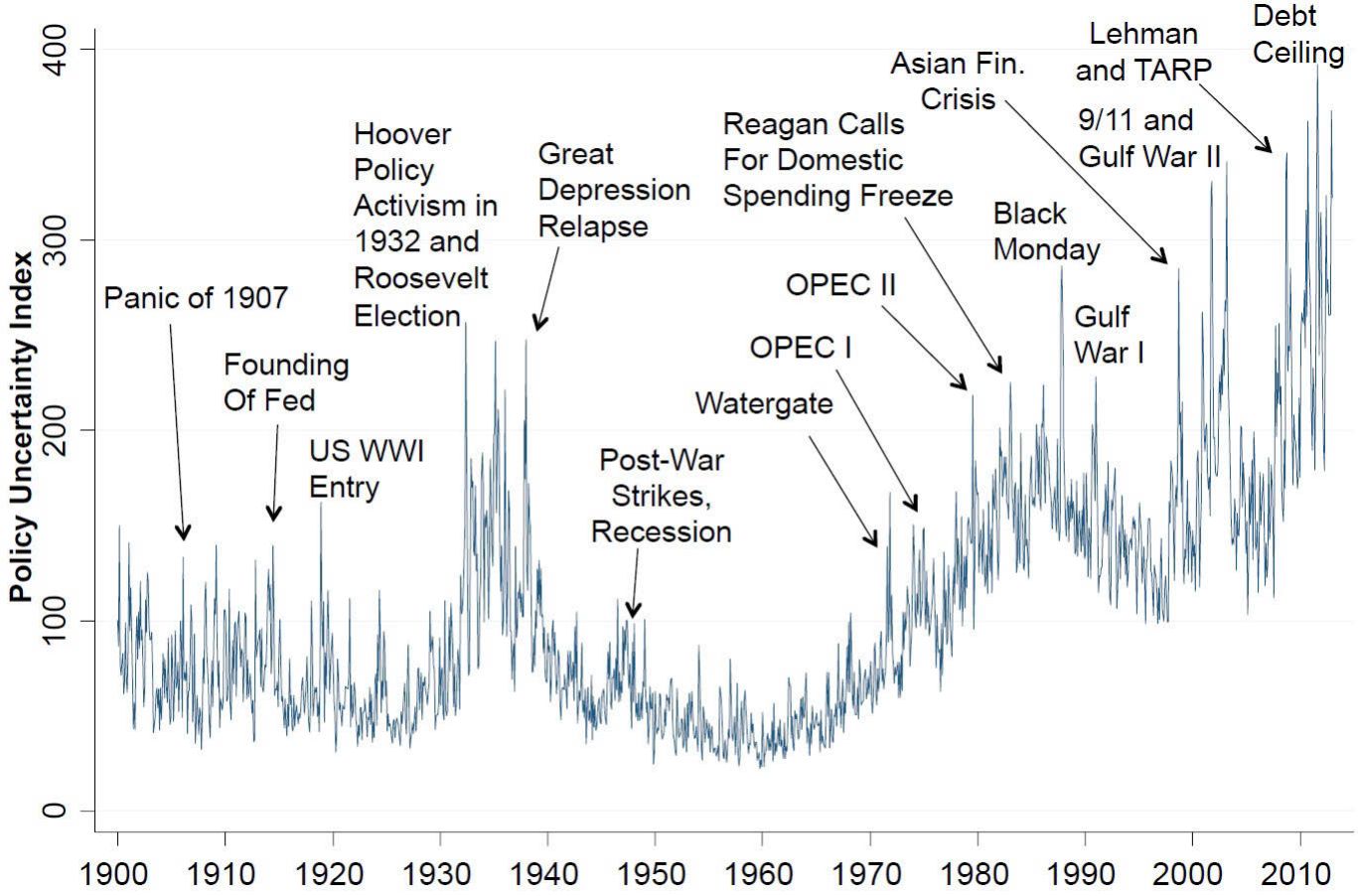


Figure B.2: **News Based Quarterly Economic Policy Uncertainty Index of the USA 1900-2013**



B.3 Tables

Table B.1: **List of Countries**

Advanced Countries
Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Hong Kong, Iceland, Ireland, Italy, Japan, Luxembourg, Malta, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, United Kingdom, United States
Emerging Countries
Argentina, Brazil, Bulgaria, Chile, China, Colombia, Czech Republic, Ecuador, Egypt, Estonia, Hungary, India, Indonesia, Israel, Jordan, Republic of Korea, Latvia, Lithuania, Malaysia, Mexico, Morocco, Nigeria, Pakistan, Panama, Peru, Philippines, Poland, Romania, Russia, Slovak Republic, Slovenia, South Africa, Sri Lanka, Taiwan, Thailand, Turkey, Ukraine, Venezuela

Table B.2: **Descriptive Statistics of Variables**

Variables	**Advanced Countries**		**Emerging Countries**	
	Mean	*STD*	*Mean*	*STD*
Growth of GDP per capita	0.028	0.037	0.027	0.072
GDP per capita	27703.23	9668.736	8627.634	6108.751
Human capital index	2.891	0.308	2.552	0.489
Government expenditure ratio	0.161	0.042	0.198	0.085
Trade openness	0.456	0.099	0.263	0.099
Investment ratio	0.257	0.059	0.213	0.077
Investment	7081.996	3057.502	1983.828	1772.834
Population growth	0.006	0.0003	0.016	0.015
Depreciation rate	0.0402	0.007	0.0395	0.009
GDP deflator	0.033	0.038	0.639	1.056
Log of REER	4.611	0.283	4.582	0.341
Foreign direct investment	-0.006	0.045	0.004	0.018
Net foreign assets	-0.019	0.46	-0.029	0.12
Political instability	0.33	0.493	0.539	0.621
Polity	7.397	5.377	4.134	6.101

Note: Foreign direct investment and Net foreign assets are in trillion 2005 constant USD.

Table B.3: **Growth Regression Results with Maximum Monthly EPU of the USA**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
epu_USA_t	−0.0301***	−0.0187*	−0.0346**	−0.0301***	−0.0190**	−0.0351***	−0.0308***	−0.0187**	−0.0358***
	(0.0092)	(0.0111)	(0.014)	(0.0077)	(0.009)	(0.0115)	(0.0078)	(0.0087)	(0.012)
Neoclassical Variables									
g_gdppc_{t-1}	0.3058***	0.2345***	0.2971***	0.2993***	0.2688***	0.2812***	0.3310***	0.3299***	0.3306***
	(0.0353)	(0.0632)	(0.0411)	(0.0338)	(0.0633)	(0.0382)	(0.0355)	(0.0759)	(0.0415)
$gdppc\_initial$	−0.1165***	−0.0745***	−0.1432***	−0.1060***	−0.0644***	−0.1300***	−0.1095***	−0.0623***	−0.1339***
	(0.0135)	(0.0237)	(0.0217)	(0.0115)	(0.019)	(0.0185)	(0.0118)	(0.0183)	(0.0193)
$g\_gdppc\_USA_t$	−0.3275*	0.4977**	−0.8909***	−0.3140**	0.4912***	−0.8742***	−0.3152**	0.4905***	−0.8564***
	(0.1697)	(0.1959)	(0.2289)	(0.144)	(0.1592)	(0.1906)	(0.1425)	(0.1532)	(0.1945)
$gdppc\_USA_t$	0.0281	0.0586	−0.035	0.03	0.0358	−0.0189	0.0263	0.0245	−0.0311
	(0.0318)	(0.0469)	(0.0622)	(0.0254)	(0.0332)	(0.0502)	(0.0277)	(0.0368)	(0.0577)
inv_t	0.0249***	0.0337**	0.0325**	0.0287***	0.0312**	0.0366***	0.0288***	0.0310**	0.0353***
	(0.0079)	(0.0159)	(0.0132)	(0.0067)	(0.0122)	(0.011)	(0.0068)	(0.0132)	(0.0111)
hc_t	−0.0219	−0.0134	−0.0125	−0.0391	−0.0189	−0.0377	−0.0347	−0.0241	−0.0231
	(0.0608)	(0.089)	(0.1024)	(0.0517)	(0.067)	(0.0818)	(0.0568)	(0.0728)	(0.0924)
n_t	0.2047	−0.9107	−0.4374	0.066	−0.9822*	−0.3439	0.1477	−1.1004**	−0.2316
	(0.5171)	(0.6937)	(0.8168)	(0.4174)	(0.5247)	(0.6763)	(0.4596)	(0.5596)	(0.7689)
δ_t	0.4624	0.4628	0.3437	0.5134*	0.3735	0.4638	0.4251	0.3359	0.3009
	(0.3401)	(0.4279)	(0.7084)	(0.2845)	(0.31)	(0.5731)	(0.31)	(0.3187)	(0.6204)
Other Variables									
gov_t	−0.0007	−0.009	−0.0028	0.0034	−0.0142	0.005	0.0026	−0.0079	0.0034
	(0.0089)	(0.0221)	(0.0148)	(0.0073)	(0.0165)	(0.0118)	(0.0076)	(0.0185)	(0.0125)
π_t	−0.0040***	0.2097***	−0.0042***	−0.0042***	0.2209***	−0.0045***	−0.0041***	0.2137***	−0.0044***
	(0.0011)	(0.0513)	(0.0014)	(0.0009)	(0.0417)	(0.0012)	(0.0009)	(0.0391)	(0.0012)
$reer_t$	−0.0054	−0.0482**	0.0004	−0.0051	−0.0443***	−0.0005	−0.0072	−0.0477***	−0.0018
	(0.0088)	(0.0214)	(0.0137)	(0.0075)	(0.0169)	(0.0112)	(0.0076)	(0.0161)	(0.0115)
$trade_t$	0.0265***	0.0127	0.0343***	0.0234***	0.0164	0.0293***	0.0243***	0.02	0.0307***
	(0.0094)	(0.0226)	(0.0121)	(0.0079)	(0.0173)	(0.0099)	(0.0086)	(0.0193)	(0.0105)
Volatility									
gov_vol_t	0.0877	0.129	0.0679	0.1109*	0.0866	0.1021	0.1048*	0.0719	0.0985
	(0.0705)	(0.2083)	(0.105)	(0.0592)	(0.1648)	(0.0861)	(0.0607)	(0.1516)	(0.09)
π_vol_t	0.0001***	−0.6023	0.0001**	0.0001***	−0.7337	0.0001***	0.0001***	−0.6076	0.0001***
	(0)	(1.069)	(0)	(0)	(0.8592)	(0)	(0)	(0.8361)	(0)
$reer\_vol_t$	−0.0019	−0.0016	−0.0021	−0.0018	−0.0014	−0.0021	−0.0018	−0.0015	−0.002
	(0.0016)	(0.0018)	(0.003)	(0.0013)	(0.0015)	(0.0025)	(0.0013)	(0.0014)	(0.0026)
International Financial Integration									
fdi_t	−0.0044	−0.0152	0.3134	−0.0042	−0.014	0.341	−0.0006	−0.0082	0.3513
	(0.1069)	(0.0675)	(0.3863)	(0.0906)	(0.0556)	(0.3217)	(0.0899)	(0.053)	(0.3294)
nfa_t	0.0142	−0.0092	0.1348**	0.0107	−0.0115	0.1377**	0.0159	−0.0064	0.1448**
	(0.0198)	(0.0136)	(0.0679)	(0.0166)	(0.0093)	(0.057)	(0.0169)	(0.0097)	(0.0611)
Institution									
$poli\_inst_t$	−0.0052*	−0.0023	−0.0057	−0.0052*	−0.0023	−0.0058	−0.0052*	−0.0026	−0.0057
	(0.0031)	(0.0032)	(0.0043)	(0.0027)	(0.0027)	(0.0036)	(0.0027)	(0.0026)	(0.0037)
$polity_t$	−0.0003	−0.0007	0.0001	−0.0002	−0.0006	0.0002	−0.0003	−0.0006	0.0002
	(0.0007)	(0.0012)	(0.001)	(0.0006)	(0.0008)	(0.0008)	(0.0006)	(0.0009)	(0.0009)
Sample	1190	491	650	1190	491	650	1190	491	650

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. Standard errors are reported in the parentheses under the coefficients.

Table B.4: **The Effects of Maximum Monthly EPU on Growth of Physical Capital Accumulation**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
epu_USA_t	−0.0008	−0.004	0.005	−0.0009	−0.0044	0.0036	−0.0008	−0.0041	0.0039
	(0.0075)	(0.0108)	(0.0123)	(0.007)	(0.0093)	(0.011)	(0.007)	(0.009)	(0.0112)
Neoclassical Variables									
g_k_{t-1}	0.6199***	0.6580***	0.6211***	0.6118***	0.6588***	0.6115***	0.6689***	0.6789***	0.6786***
	(0.0481)	(0.0439)	(0.0641)	(0.0396)	(0.0434)	(0.0504)	(0.0446)	(0.0429)	(0.0616)
$k\_initial$	−0.0464***	−0.0530***	−0.0473***	−0.0377***	−0.0495***	−0.0385***	−0.0430***	−0.0524***	−0.0410***
	(0.0085)	(0.0142)	(0.013)	(0.0064)	(0.012)	(0.0103)	(0.0074)	(0.0122)	(0.0118)
$g\_k\_USA_t$	0.6798***	0.7939***	0.5685**	0.6621***	0.8097***	0.5572**	0.6808***	0.8122***	0.5722**
	(0.1523)	(0.1994)	(0.2574)	(0.1399)	(0.1757)	(0.2343)	(0.1428)	(0.1693)	(0.2477)
$\_USA_t$	−0.0024	0.0035	−0.0183	0.0016	0.0059	−0.0111	−0.0023	0.0063	−0.0185
	(0.027)	(0.0316)	(0.0501)	(0.0229)	(0.0271)	(0.0393)	(0.0274)	(0.0278)	(0.0485)
hc_t	0.0786	0.0638	0.1156	0.0666	0.0628	0.1181	0.056	0.0472	0.0955
	(0.0573)	(0.0768)	(0.0923)	(0.0486)	(0.0663)	(0.0721)	(0.0574)	(0.0686)	(0.0852)
n_t	0.4549	1.4253*	0.4264	0.2624	1.1886*	0.2929	0.3015	1.3053*	0.2347
	(0.4549)	(0.794)	(0.7483)	(0.3932)	(0.6735)	(0.6486)	(0.4498)	(0.6829)	(0.7562)
δ_t	−0.3644	−0.2473	−0.2605	−0.1222	−0.2237	0.0656	−0.3031	−0.1936	−0.2204
	(0.3734)	(0.5382)	(0.6264)	(0.3327)	(0.4516)	(0.5424)	(0.3635)	(0.4502)	(0.5868)
Other Variables									
gov_t	−0.0547	0.0231	−0.0671	−0.0641*	0.0235	−0.0583	−0.0742**	0.0198	−0.0812*
	(0.0452)	(0.0221)	(0.0513)	(0.0362)	(0.0183)	(0.0454)	(0.0358)	(0.0184)	(0.0477)
$trade_t$	0.0102	0.0058	0.0201	0.0082	0.006	0.0162	0.0127	0.0076	0.0208
	(0.0129)	(0.0116)	(0.0241)	(0.0113)	(0.0099)	(0.0195)	(0.0121)	(0.0099)	(0.0208)
Institution									
$poli\_inst_t$	−0.0038	0.0013	−0.0065*	−0.0038	0.0013	−0.0066*	−0.0038	0.0012	−0.0064*
	(0.0027)	(0.0034)	(0.0037)	(0.0025)	(0.003)	(0.0034)	(0.0025)	(0.0029)	(0.0035)
$polity_t$	−0.0001	−0.0012	0.0002	−0.0001	−0.001	0.0004	0	−0.0011	0.0003
	(0.0006)	(0.0013)	(0.0007)	(0.0005)	(0.0011)	(0.0006)	(0.0005)	(0.0011)	(0.0006)
Sample	1234	506	677	1234	506	677	1234	506	677

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. Standard errors are reported in the parentheses under the coefficients.

Table B.5: **The Effects of Maximum Monthly EPU on Growth of Human Capital Accumulation**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
epu_USA_t	-0.0207^{***}	-0.0203^{*}	-0.0297^{***}	-0.0237^{***}	-0.0206^{***}	-0.0260^{***}	-0.0250^{***}	-0.0221^{***}	-0.0278^{***}
	(0.0065)	(0.0111)	(0.007)	(0.005)	(0.0069)	(0.0066)	(0.0052)	(0.0076)	(0.0067)
Neoclassical Variables									
g_hc_{t-1}	0.7169^{***}	0.6546^{***}	0.7839^{***}	0.7459^{***}	0.7250^{***}	0.7692^{***}	0.7709^{***}	0.7716^{***}	0.7982^{***}
	(0.0308)	(0.0493)	(0.0376)	(0.027)	(0.0402)	(0.0358)	(0.0272)	(0.0395)	(0.0351)
$hc\_initial$	-0.0278^{***}	-0.0313^{***}	-0.0307^{***}	-0.0289^{***}	-0.0303^{***}	-0.0292^{***}	-0.0306^{***}	-0.0327^{***}	-0.0306^{***}
	(0.0044)	(0.0088)	(0.0044)	(0.0036)	(0.0052)	(0.0043)	(0.0037)	(0.0058)	(0.0043)
$g\_hc\_USA_t$	0.2224^{**}	0.1563	0.1285	0.1693^{**}	0.1145	0.1793^{**}	0.1495^{**}	0.0951	0.1528^{*}
	(0.0913)	(0.1621)	(0.0866)	(0.0692)	(0.0991)	(0.0806)	(0.0719)	(0.1076)	(0.0797)
hc_USA_t	0.0419^{***}	0.0568^{*}	0.1124^{***}	0.0745^{***}	0.0624^{***}	0.0960^{***}	0.0813^{***}	0.0686^{***}	0.1068^{***}
	(0.0158)	(0.0311)	(0.0188)	(0.0118)	(0.0186)	(0.0176)	(0.0126)	(0.0214)	(0.0187)
inv_t	0.3884	0.3615	−0.0406	0.3398	0.3272	−0.0287	0.3442	0.3028	−0.0018
	(0.3372)	(0.8166)	(0.3435)	(0.2581)	(0.5113)	(0.3166)	(0.2733)	(0.5479)	(0.3161)
n_t	-0.1097^{***}	−0.0358	−0.039	-0.0584^{**}	0.0233	−0.0491	-0.0665^{**}	0.0186	−0.0485
	(0.0405)	(0.0904)	(0.0446)	(0.0296)	(0.0553)	(0.0418)	(0.032)	(0.0613)	(0.0454)
Other Variables									
gov_t	0.1331	−0.1208	0.0466	0.0968	0.5322	0.0874	0.1172	0.5607	0.1086
	(0.3491)	(1.7678)	(0.3575)	(0.2673)	(1.0675)	(0.3245)	(0.2835)	(1.2033)	(0.3335)
$trade_t$	0.0083	0.0624	−0.1095	−0.013	0.0465	−0.1187	−0.0097	0.0484	−0.1386
	(0.1007)	(0.1637)	(0.1169)	(0.0772)	(0.1001)	(0.1104)	(0.0814)	(0.1113)	(0.1106)
Institution									
$poli\_inst_t$	−0.0044	0.009	−0.0128	−0.004	0.0087	−0.0126	−0.005	0.0082	−0.0126
	(0.0223)	(0.0531)	(0.0207)	(0.0175)	(0.0329)	(0.0198)	(0.018)	(0.0352)	(0.0198)
$polity_t$	−0.0043	−0.0083	−0.0071	−0.0063	−0.01	-0.0073^{*}	−0.0053	−0.0079	−0.0065
	(0.0052)	(0.0148)	(0.0045)	(0.004)	(0.0085)	(0.0043)	(0.0041)	(0.0097)	(0.0044)
Sample	1293	517	722	1293	517	722	1293	517	722

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. Standard errors are reported in the parentheses under the coefficients.

Table B.6: **The Effects of Maximum Monthly EPU on Growth of TFP**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
epu_USA_t	-0.0145^{***}	-0.0107^{*}	-0.0186^{**}	-0.0141^{***}	-0.0103^{**}	-0.0181^{**}	-0.0147^{***}	-0.0116	-0.0190^{**}
	(0.0053)	(0.006)	(0.0093)	(0.0048)	(0.0044)	(0.0088)	(0.005)	(0.0072)	(0.0092)
Neoclassical Variables									
g_tfp_{t-1}	0.3546^{***}	0.5379^{**}	0.3873^{***}	0.3673^{***}	0.5962^{***}	0.4004^{***}	0.3830^{***}	0.6999^{*}	0.4161^{***}
	(0.0352)	(0.2381)	(0.0597)	(0.0342)	(0.2265)	(0.0545)	(0.0353)	(0.3914)	(0.0563)
$tfp\_initial$	-0.0957^{***}	-0.0734	-0.0977^{***}	-0.0942^{***}	-0.0463	-0.0967^{***}	-0.0939^{***}	-0.0432	-0.0957^{***}
	(0.0123)	(0.0542)	(0.0175)	(0.0112)	(0.0326)	(0.0167)	(0.0114)	(0.0413)	(0.0168)
$g\_tfp\_USA_t$	-0.1505	0.3502^{**}	-0.5209^{**}	-0.1478	0.3511^{**}	-0.5054^{**}	-0.157	0.3283	-0.5337^{**}
	(0.1549)	(0.1762)	(0.2335)	(0.1439)	(0.1491)	(0.2231)	(0.1471)	(0.2103)	(0.2222)
tfp_USA_t	0.0616^{*}	0.0039	0.1111^{*}	0.0697^{**}	0.004	0.1141^{*}	0.0740^{**}	0.0092	0.1385^{**}
	(0.0321)	(0.075)	(0.0663)	(0.0287)	(0.0455)	(0.0588)	(0.0323)	(0.0765)	(0.0627)
inv_t	-0.0272	-0.0872^{*}	-0.0195	-0.0143	-0.0592^{*}	-0.0037	-0.0122	-0.0552	0.0045
	(0.0261)	(0.0528)	(0.0413)	(0.0239)	(0.0309)	(0.0376)	(0.0253)	(0.0455)	(0.0392)
hc_t	-0.0517	-0.0593	-0.0433	-0.0531	-0.0569	-0.0533	-0.0634	-0.0685	-0.0905
	(0.0376)	(0.1199)	(0.0736)	(0.034)	(0.0775)	(0.063)	(0.0403)	(0.0714)	(0.0699)
n_t	-0.1763	0.1674	0.3268	-0.3048	-0.1618	0.1297	-0.4043	-0.3994	-0.0583
	(0.2545)	(0.6751)	(0.4941)	(0.2365)	(0.4335)	(0.4502)	(0.2483)	(0.5466)	(0.4988)
Other Variables									
gov_t	-0.0424	0.0437	-0.0253	-0.0363	-0.0356	-0.0172	-0.0357	-0.0416	-0.0112
	(0.0312)	(0.1488)	(0.0391)	(0.0266)	(0.0879)	(0.0345)	(0.0281)	(0.1229)	(0.0365)
$trade_t$	0.0115	0.0163	-0.0008	0.0093	0.0107	-0.0011	0.0108	0.0142	-0.0005
	(0.0081)	(0.01)	(0.0181)	(0.0074)	(0.0066)	(0.0159)	(0.0082)	(0.0113)	(0.0169)
Institution									
$poli\_inst_t$	-0.0058^{***}	-0.0031	-0.0072^{**}	-0.0058^{***}	-0.0029	-0.0071^{**}	-0.0058^{***}	-0.003	-0.0070^{**}
	(0.0019)	(0.0024)	(0.0032)	(0.0017)	(0.0022)	(0.003)	(0.0017)	(0.0029)	(0.003)
$polity_t$	-0.0003	0	-0.0006	-0.0002	0.0002	-0.0006	-0.0003	0.0001	-0.0006
	(0.0004)	(0.0017)	(0.0006)	(0.0004)	(0.0013)	(0.0005)	(0.0004)	(0.001)	(0.0006)
Sample	1265	517	696	1265	517	696	1265	517	696

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. Standard errors are reported in the parentheses under the coefficients.

Table B.7: **Growth Regression Results with End of Year EPU of the USA**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
epu_USA_t	−0.0236**	0.001	−0.0397**	−0.0216**	0.0018	−0.0379***	−0.0228**	−0.0003	−0.0389***
	(0.0113)	(0.0125)	(0.0172)	(0.0094)	(0.0103)	(0.0143)	(0.0094)	(0.0098)	(0.0146)
Neoclassical Variables									
g_gdppc_{t-1}	0.3071***	0.2171***	0.2955***	0.3013***	0.2368***	0.2813***	0.3321***	0.3042***	0.3294***
	(0.0353)	(0.0627)	(0.0409)	(0.0338)	(0.0634)	(0.0384)	(0.0352)	(0.0783)	(0.0414)
$gdppc\_initial$	−0.1173***	−0.0805***	−0.1410***	−0.1066***	−0.0693***	−0.1277***	−0.1098***	−0.0667***	−0.1317***
	(0.0137)	(0.0237)	(0.0222)	(0.0114)	(0.0189)	(0.0188)	(0.0118)	(0.0183)	(0.0195)
$g\_gdppc\_USA_t$	−0.1776	0.7347***	−0.8192***	−0.1649	0.7233***	−0.8070***	−0.1672	0.6961***	−0.7836***
	(0.1621)	(0.1879)	(0.2583)	(0.1355)	(0.1544)	(0.2122)	(0.1325)	(0.1463)	(0.2145)
$gdppc\_USA_t$	0.0277	0.0569	−0.0346	0.0297	0.0353	−0.021	0.0264	0.0239	−0.0309
	(0.0325)	(0.0475)	(0.0631)	(0.0256)	(0.0335)	(0.0505)	(0.0278)	(0.0368)	(0.0577)
inv_t	0.0250***	0.0338**	0.0311**	0.0289***	0.0334***	0.0350***	0.0289***	0.0331**	0.0337***
	(0.008)	(0.0159)	(0.0134)	(0.0067)	(0.0122)	(0.011)	(0.0068)	(0.0131)	(0.0111)
hc_t	−0.0354	−0.0307	−0.039	−0.0425	−0.0259	−0.0464	−0.0382	−0.0281	−0.0346
	(0.0619)	(0.0898)	(0.1055)	(0.0522)	(0.0676)	(0.0832)	(0.0571)	(0.0729)	(0.0937)
n_t	0.1787	−0.9175	−0.4587	0.0547	−1.0277*	−0.3548	0.1481	−1.1132**	−0.2335
	(0.5342)	(0.7109)	(0.8282)	(0.4258)	(0.5318)	(0.6792)	(0.4692)	(0.5639)	(0.769)
δ_t	0.45	0.4688	0.3229	0.5136*	0.4288	0.4499	0.4224	0.392	0.2843
	(0.3468)	(0.4316)	(0.7178)	(0.2853)	(0.3107)	(0.576)	(0.3092)	(0.316)	(0.6193)
Other Variables									
gov_t	−0.0014	−0.0167	−0.0033	0.0029	−0.0204	0.0046	0.0021	−0.0151	0.0032
	(0.009)	(0.0219)	(0.0151)	(0.0073)	(0.0162)	(0.0119)	(0.0076)	(0.0181)	(0.0125)
π_t	−0.0040***	0.2052***	−0.0041***	−0.0041***	0.2224***	−0.0044***	−0.0040***	0.2164***	−0.0043***
	(0.0011)	(0.0517)	(0.0015)	(0.0009)	(0.0422)	(0.0012)	(0.0009)	(0.0392)	(0.0012)
$reer_t$	−0.0038	−0.0466**	0.0032	−0.0036	−0.0428**	0.0021	−0.0055	−0.0452***	0.0009
	(0.009)	(0.0215)	(0.0139)	(0.0076)	(0.0169)	(0.0112)	(0.0076)	(0.016)	(0.0116)
$trade_t$	0.0277***	0.0243	0.0341***	0.0246***	0.0253	0.0291***	0.0255***	0.0291	0.0304***
	(0.0095)	(0.0238)	(0.0126)	(0.0079)	(0.0182)	(0.0101)	(0.0086)	(0.0199)	(0.0107)
Volatility									
gov_vol_t	0.0888	0.1731	0.0615	0.1168**	0.128	0.1015	0.1117*	0.1037	0.0982
	(0.0708)	(0.2131)	(0.1057)	(0.0589)	(0.1688)	(0.0858)	(0.0603)	(0.1544)	(0.0892)
π_vol_t	0.0001***	−0.5276	0.0001**	0.0001***	−0.6937	0.0001***	0.0001***	−0.5384	0.0001***
	(0)	(1.071)	(0)	(0)	(0.8614)	(0)	(0)	(0.8357)	(0)
$reer\_vol_t$	−0.0016	−0.0012	−0.0022	−0.0016	−0.0011	−0.0023	−0.0015	−0.0011	−0.0021
	(0.0016)	(0.0018)	(0.0031)	(0.0013)	(0.0015)	(0.0025)	(0.0013)	(0.0014)	(0.0026)
International Financial Integration									
fdi_t	−0.0077	−0.0167	0.2619	−0.0071	−0.0149	0.2929	−0.0036	−0.0097	0.2987
	(0.1085)	(0.0678)	(0.3915)	(0.0907)	(0.0559)	(0.3227)	(0.0898)	(0.053)	(0.3292)
nfa_t	0.0155	−0.0055	0.1447**	0.0109	−0.0093	0.1447**	0.0158	−0.0053	0.1530**
	(0.0202)	(0.0132)	(0.0689)	(0.0167)	(0.0092)	(0.0577)	(0.0169)	(0.0096)	(0.0615)
Institution									
$poli\_inst_t$	−0.0053*	−0.0022	−0.0059	−0.0053**	−0.0023	−0.0060*	−0.0053**	−0.0025	−0.0059
	(0.0032)	(0.0033)	(0.0043)	(0.0027)	(0.0027)	(0.0036)	(0.0027)	(0.0026)	(0.0037)
$polity_t$	−0.0003	−0.0007	0.0001	−0.0002	−0.0006	0.0003	−0.0003	−0.0007	0.0002
	(0.0007)	(0.0012)	(0.0011)	(0.0006)	(0.0008)	(0.0009)	(0.0006)	(0.0009)	(0.0009)
Sample	1190	491	650	1190	491	650	1190	491	650

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. Standard errors are reported in the parentheses under the coefficients.

Table B.8: **The Effects of End of Year EPU on Growth of Physical Capital Accumulation**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
epu_USA_t	-0.0344^{***}	-0.0212^{*}	-0.0473^{***}	-0.0337^{***}	-0.0211^{*}	-0.0478^{***}	-0.0338^{***}	-0.0213^{**}	-0.0471^{***}
	(0.0082)	(0.0121)	(0.014)	(0.0075)	(0.0109)	(0.0122)	(0.0075)	(0.0103)	(0.0122)
Neoclassical Variables									
g_k_{t-1}	0.6071^{***}	0.6483^{***}	0.6065^{***}	0.5930^{***}	0.6464^{***}	0.5926^{***}	0.6471^{***}	0.6665^{***}	0.6561^{***}
	(0.0463)	(0.044)	(0.0621)	(0.0393)	(0.0439)	(0.0481)	(0.0443)	(0.0434)	(0.0577)
$k\_initial$	-0.0528^{***}	-0.0583^{***}	-0.0547^{***}	-0.0406^{***}	-0.0540^{***}	-0.0404^{***}	-0.0464^{***}	-0.0576^{***}	-0.0435^{***}
	(0.0081)	(0.0143)	(0.0125)	(0.0063)	(0.0122)	(0.01)	(0.0072)	(0.0124)	(0.0114)
$g\_k\_USA_t$	0.3064^{**}	0.5640^{***}	0.073	0.3196^{**}	0.5704^{***}	0.0984	0.3139^{**}	0.5687^{***}	0.0814
	(0.1489)	(0.1974)	(0.2633)	(0.1333)	(0.1778)	(0.237)	(0.1407)	(0.1744)	(0.2605)
k_USA_t	0.0369	0.02	0.0471	0.0301	0.0228	0.0348	0.0336	0.0248	0.0384
	(0.0258)	(0.0311)	(0.0481)	(0.0222)	(0.0268)	(0.0382)	(0.0263)	(0.0277)	(0.0473)
hc_t	0.0558	0.0594	0.0718	0.0418	0.0574	0.0667	0.0206	0.0401	0.0296
	(0.0572)	(0.0742)	(0.0916)	(0.049)	(0.0655)	(0.0708)	(0.0584)	(0.0681)	(0.0818)
n_t	0.3413	1.4010^{*}	0.4475	0.1439	1.1666^{*}	0.2865	0.1442	1.2773^{*}	0.2046
	(0.4505)	(0.7552)	(0.745)	(0.3891)	(0.6594)	(0.6452)	(0.4413)	(0.6717)	(0.7434)
δ_t	-0.3346	-0.3087	-0.1683	-0.1098	-0.2909	0.1592	-0.2729	-0.2608	-0.0984
	(0.3726)	(0.5215)	(0.621)	(0.332)	(0.4476)	(0.5354)	(0.36)	(0.4487)	(0.5712)
Other Variables									
gov_t	-0.0518	0.0319	-0.0667	-0.0628^{*}	0.0324^{*}	-0.059	-0.0732^{**}	0.0297	-0.0823^{*}
	(0.0448)	(0.0216)	(0.0508)	(0.036)	(0.0184)	(0.0447)	(0.0357)	(0.0186)	(0.0472)
$trade_t$	0.0051	0.0014	0.0159	0.0042	0.0016	0.0133	0.0073	0.0029	0.0162
	(0.0127)	(0.0113)	(0.0239)	(0.0111)	(0.0099)	(0.0192)	(0.0118)	(0.0099)	(0.0203)
Institution									
$poli\_inst_t$	-0.0044^{*}	0.001	-0.0072^{*}	-0.0043^{*}	0.001	-0.0073^{**}	-0.0044^{*}	0.001	-0.0071^{**}
	(0.0027)	(0.0034)	(0.0037)	(0.0025)	(0.003)	(0.0034)	(0.0025)	(0.0029)	(0.0034)
$polity_t$	-0.0003	-0.0012	-0.0001	-0.0003	-0.001	0.0001	-0.0001	-0.0011	0
	(0.0006)	(0.0013)	(0.0007)	(0.0005)	(0.0011)	(0.0006)	(0.0005)	(0.0011)	(0.0006)
Sample	1234	506	677	1234	506	677	1234	506	677

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. Standard errors are reported in the parentheses under the coefficients.

Table B.9: **The Effects of End of Year EPU on Growth of Human Capital Accumulation**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
epu_USA_t	-0.0348^{***}	-0.0290^{**}	-0.0472^{***}	-0.0365^{***}	-0.0288^{***}	-0.0434^{***}	-0.0385^{***}	-0.0305^{***}	-0.0458^{***}
	(0.0074)	(0.0125)	(0.0081)	(0.0059)	(0.0077)	(0.0078)	(0.0061)	(0.0083)	(0.008)
Neoclassical Variables									
g_hc_{t-1}	0.7010^{***}	0.6565^{***}	0.7916^{***}	0.7467^{***}	0.7265^{***}	0.7708^{***}	0.7723^{***}	0.7729^{***}	0.8006^{***}
	(0.0299)	(0.0494)	(0.036)	(0.0266)	(0.0396)	(0.0347)	(0.0269)	(0.0392)	(0.034)
$hc\_initial$	-0.0311^{***}	-0.0322^{***}	-0.0327^{***}	-0.0300^{***}	-0.0309^{***}	-0.0316^{***}	-0.0319^{***}	-0.0334^{***}	-0.0331^{***}
	(0.0043)	(0.0088)	(0.0043)	(0.0036)	(0.0052)	(0.0043)	(0.0037)	(0.0059)	(0.0044)
$g\_hc\_USA_t$	0.2676^{***}	0.2078	0.2093^{**}	0.2337^{***}	0.1700^{*}	0.2461^{***}	0.2154^{***}	0.1511	0.2202^{***}
	(0.0833)	(0.1637)	(0.0847)	(0.0657)	(0.097)	(0.0798)	(0.069)	(0.1046)	(0.0798)
hc_USA_t	0.0774^{***}	0.0702^{**}	0.1339^{***}	0.0904^{***}	0.0724^{***}	0.1202^{***}	0.0991^{***}	0.0795^{***}	0.1328^{***}
	(0.0159)	(0.0322)	(0.0182)	(0.0124)	(0.0194)	(0.0176)	(0.0133)	(0.0223)	(0.0189)
inv_t	0.4767	0.396	0.0917	0.4174	0.3506	0.0983	0.4366	0.3402	0.1313
	(0.3236)	(0.8058)	(0.33)	(0.2551)	(0.503)	(0.3087)	(0.2724)	(0.5389)	(0.3126)
n_t	-0.0985^{**}	-0.026	-0.0427	-0.0599^{**}	0.0258	-0.051	-0.0674^{**}	0.0235	-0.0499
	(0.0388)	(0.0922)	(0.0427)	(0.0292)	(0.0554)	(0.041)	(0.0319)	(0.0618)	(0.0449)
Other Variables									
gov_t	0.2261	0.1312	0.1222	0.1553	0.6757	0.1697	0.1848	0.7891	0.1993
	(0.3331)	(1.8291)	(0.3469)	(0.2633)	(1.0723)	(0.3172)	(0.2823)	(1.2142)	(0.3304)
$trade_t$	0	0.0657	-0.1129	-0.0103	0.0486	-0.1215	-0.0037	0.0519	-0.137
	(0.096)	(0.1638)	(0.1133)	(0.0761)	(0.0992)	(0.1077)	(0.081)	(0.1114)	(0.1095)
Institution									
$poli\_inst_t$	-0.0019	0.0133	-0.0122	-0.0021	0.0131	-0.012	-0.0032	0.0127	-0.0122
	(0.0214)	(0.0528)	(0.0197)	(0.0172)	(0.0324)	(0.0193)	(0.0179)	(0.035)	(0.0195)
$polity_t$	-0.006	-0.0089	-0.0087^{**}	-0.0071^{*}	-0.0101	-0.0088^{**}	-0.0063	-0.0082	-0.0083^{*}
	(0.005)	(0.0148)	(0.0043)	(0.0039)	(0.0085)	(0.0042)	(0.004)	(0.0097)	(0.0044)
Sample	1293	517	722	1293	517	722	1293	517	722

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

2. Standard errors are reported in the parentheses under the coefficients.

Table B.10: **The Effects of End of Year EPU on Growth of TFP**

	Kiviet-AH			Kiviet-AB			Kiviet-BB		
	All	Advanced	Emerging	All	Advanced	Emerging	All	Advanced	Emerging
epu_USA_t	-0.0132^{**}	-0.008	-0.0211^{**}	-0.0120^{**}	-0.0053	-0.0195^{**}	-0.0124^{**}	-0.0053	-0.0204^{**}
	(0.0061)	(0.0067)	(0.0099)	(0.0054)	(0.0051)	(0.0092)	(0.0056)	(0.0098)	(0.0096)
Neoclassical Variables									
g_tfp_{t-1}	0.3564^{***}	0.5231^{**}	0.3909^{***}	0.3712^{***}	0.5880^{***}	0.4053^{***}	0.3859^{***}	0.7155^{*}	0.4194^{***}
	(0.0354)	(0.2167)	(0.0598)	(0.0344)	(0.2189)	(0.0545)	(0.0353)	(0.4223)	(0.0563)
$tfp\_initial$	-0.0956^{***}	-0.0585	-0.0979^{***}	-0.0941^{***}	-0.0425	-0.0967^{***}	-0.0937^{***}	-0.0412	-0.0954^{***}
	(0.0124)	(0.0526)	(0.0176)	(0.0112)	(0.0324)	(0.0167)	(0.0114)	(0.0466)	(0.0168)
$g\_tfp\_USA_t$	-0.0554	0.4689^{***}	-0.4229^{*}	-0.0584	0.4515^{***}	-0.4211^{*}	-0.0561	0.4407^{**}	-0.4306^{**}
	(0.1421)	(0.1672)	(0.2374)	(0.1308)	(0.1412)	(0.2221)	(0.1326)	(0.2235)	(0.2169)
tfp_USA_t	0.0576^{*}	-0.0061	0.1032	0.0669^{**}	0.0028	0.1082^{*}	0.0716^{**}	0.0084	0.1333^{**}
	(0.0328)	(0.0706)	(0.0681)	(0.0289)	(0.0444)	(0.0594)	(0.0325)	(0.0858)	(0.0631)
inv_t	-0.0256	-0.0830^{*}	-0.0231	-0.0125	-0.0537^{*}	-0.0068	-0.0092	-0.0392	0.0019
	(0.0266)	(0.0498)	(0.0422)	(0.0239)	(0.0312)	(0.038)	(0.0252)	(0.0543)	(0.0395)
hc_t	-0.0574	-0.0705	-0.0548	-0.0548	-0.0622	-0.0594	-0.0651	-0.0594	-0.0965
	(0.0384)	(0.1185)	(0.0747)	(0.034)	(0.0767)	(0.0643)	(0.0405)	(0.0836)	(0.071)
n_t	-0.1987	-0.1343	0.3322	-0.3175	-0.3335	0.1398	-0.4130^{*}	-0.4626	-0.0469
	(0.2592)	(0.7096)	(0.4965)	(0.2371)	(0.4728)	(0.4487)	(0.2475)	(0.6064)	(0.4975)
Other Variables									
gov_t	-0.0427	-0.0041	-0.0277	-0.0354	-0.0519	-0.0181	-0.0346	-0.0541	-0.0118
	(0.0318)	(0.1441)	(0.0398)	(0.0267)	(0.0877)	(0.0348)	(0.0282)	(0.1362)	(0.037)
$trade_t$	0.0123	0.0185^{*}	0.0001	0.01	0.0117^{*}	-0.0004	0.0116	0.0154	0.0005
	(0.0082)	(0.0097)	(0.0182)	(0.0074)	(0.0068)	(0.0159)	(0.0081)	(0.0123)	(0.0168)
Institution									
$poli\_inst_t$	-0.0059^{***}	-0.0031	-0.0071^{**}	-0.0058^{***}	-0.003	-0.0070^{**}	-0.0058^{***}	-0.0031	-0.0069^{**}
	(0.0019)	(0.0024)	(0.0032)	(0.0017)	(0.0022)	(0.003)	(0.0017)	(0.003)	(0.003)
$polity_t$	-0.0003	-0.0001	-0.0006	-0.0003	0.0003	-0.0006	-0.0003	0.0001	-0.0006
	(0.0005)	(0.0017)	(0.0006)	(0.0004)	(0.0013)	(0.0005)	(0.0004)	(0.0012)	(0.0006)
Sample	1265	517	696	1265	517	696	1265	517	696

Note: 1. *, **, *** denote significance at 10%, 5% and 1% level, respectively.

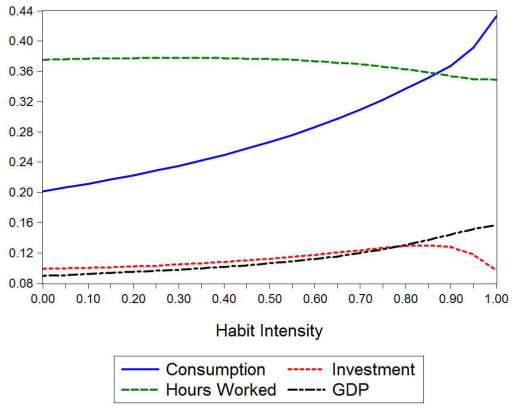
2. Standard errors are reported in the parentheses under the coefficients.

Appendix C: Chapter 3

C.1 Figures

Figure C.1: **Sensitivity of International Comovements in CAC Models Under Constant Habit Persistence ($\gamma_h = 0.4$) – External Habit Models**

With Capital Utilization



Without Capital Utilization

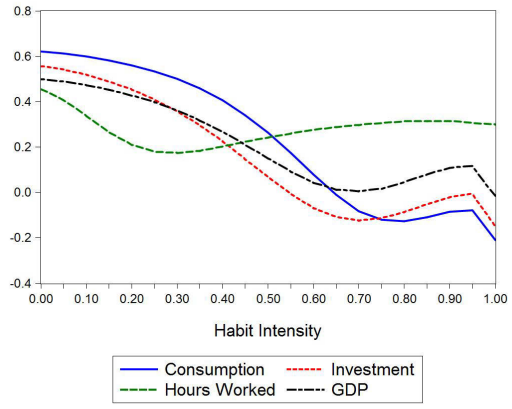
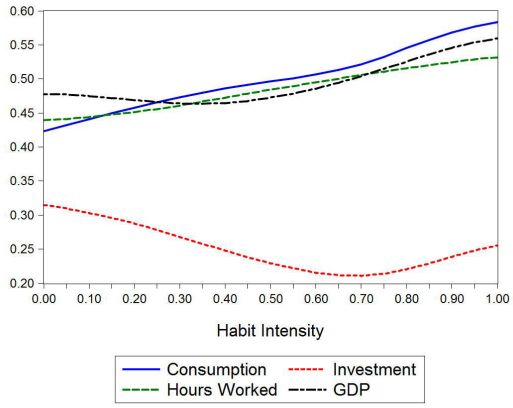


Figure C.2: **Sensitivity of International Comovements in CAC Models Under Constant Habit Persistence ($\gamma_h = 0.4$) – Internal Habit Models**

With Capital Utilization



Without Capital Utilization

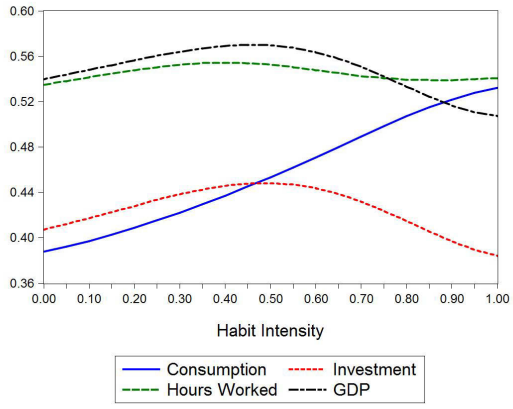
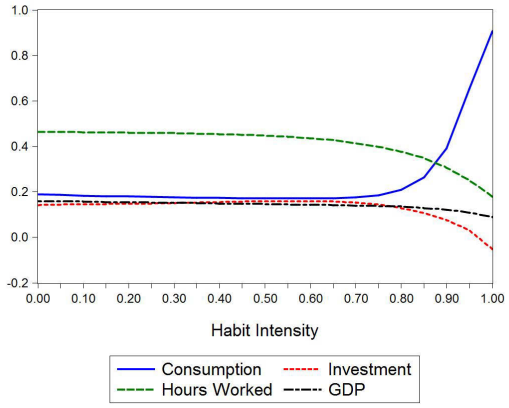


Figure C.3: **Sensitivity of International Comovements in IAC Models Under Constant Habit Persistence ($\gamma_h = 0.82$) – External Habit Models**

With Capital Utilization



Without Capital Utilization

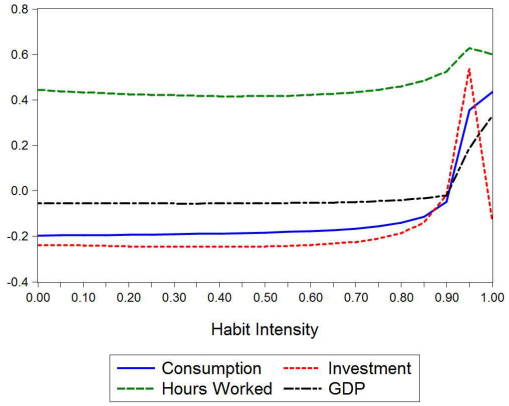
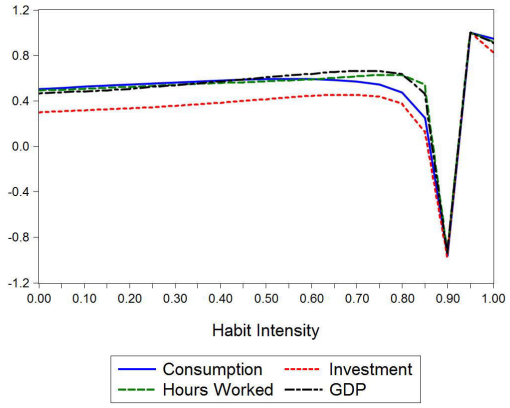


Figure C.4: **Sensitivity of International Comovements in IAC Models Under Constant Habit Persistence ($\gamma_h = 0.64$) – Internal Habit Models**

With Capital Utilization



Without Capital Utilization

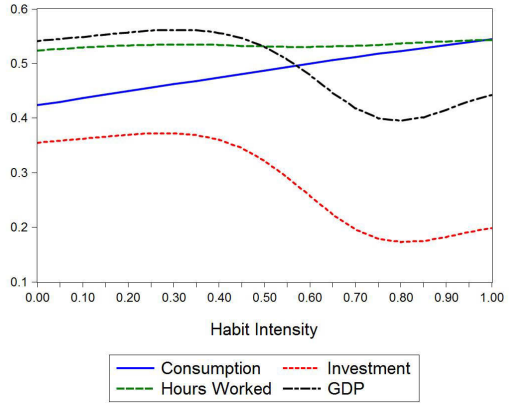
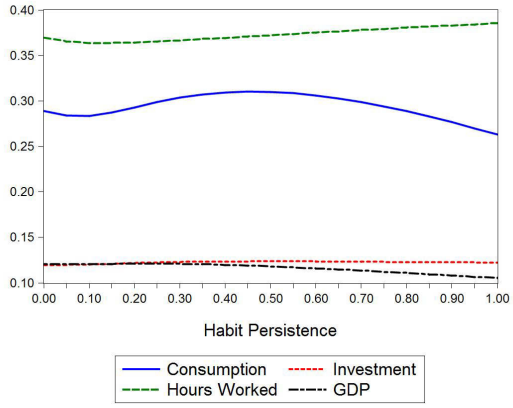


Figure C.5: **Sensitivity of International Comovements in CAC Models Under Constant Habit Intensity ($\lambda_h = 0.7$) – External Habit Models**

With Capital Utilization



Without Capital Utilization

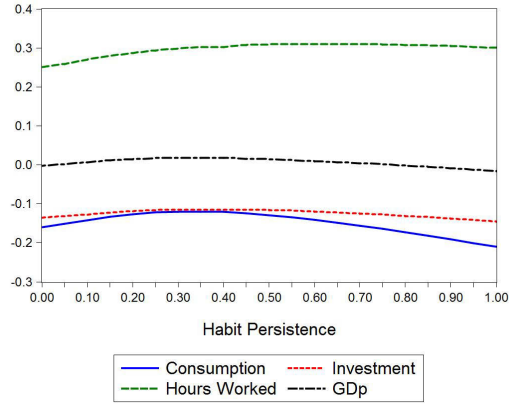
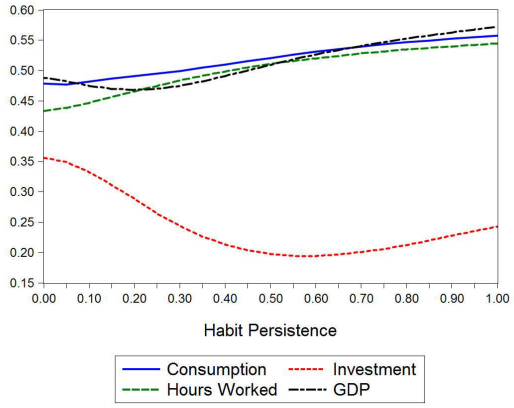


Figure C.6: **Sensitivity of International Comovements in CAC Models Under Constant Habit Intensity ($\lambda_h = 0.63$) – Internal Habit Models**

With Capital Utilization



Without Capital Utilization

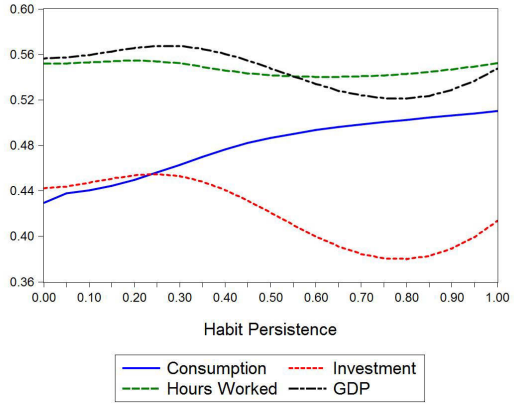
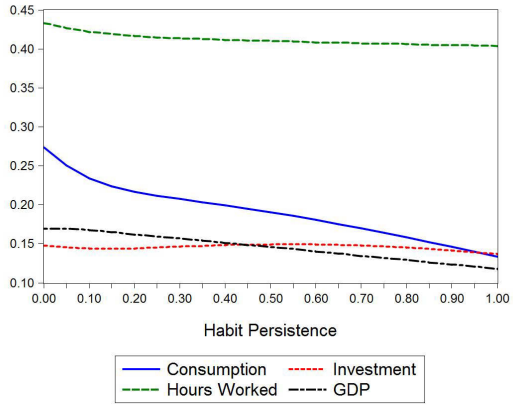


Figure C.7: **Sensitivity of International Comovements in IAC Models Under Constant Habit Intensity ($\lambda_h = 0.72$) – External Habit Models**

With Capital Utilization



Without Capital Utilization

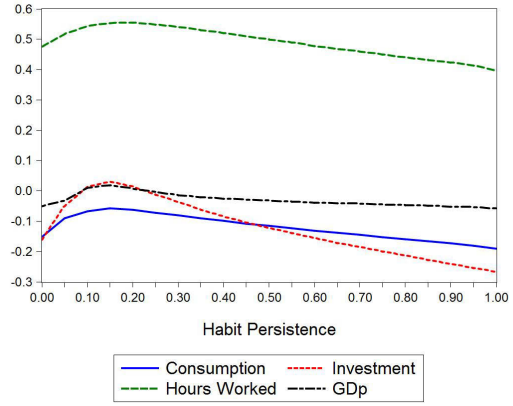
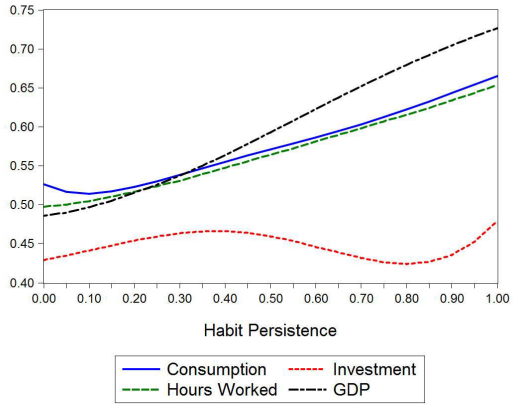


Figure C.8: **Sensitivity of International Comovements in IAC Models Under Constant Habit Intensity ($\lambda_h = 0.52$) – Internal Habit Models**

With Capital Utilization



Without Capital Utilization

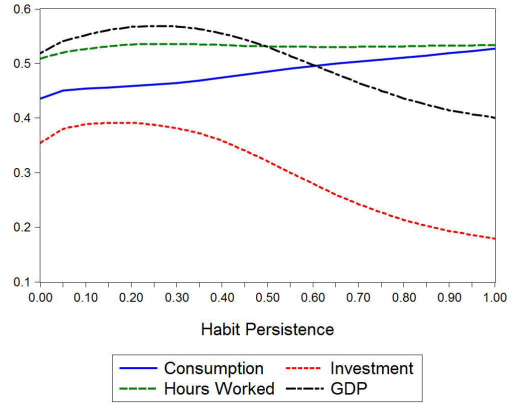
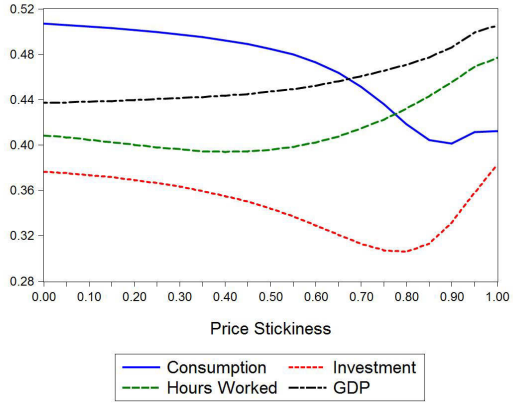
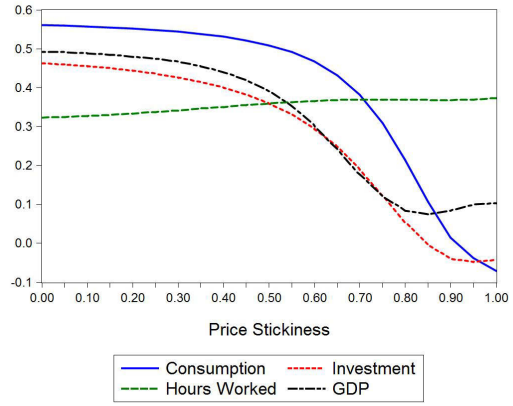


Figure C.9: **Sensitivity of International Comovements Under Price Stickiness (α_c) – CAC with Capital Utilization Models**

Without Habit Formation



With External Habit



With Internal Habit

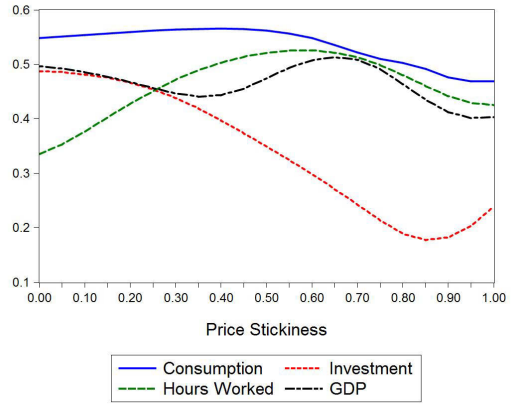
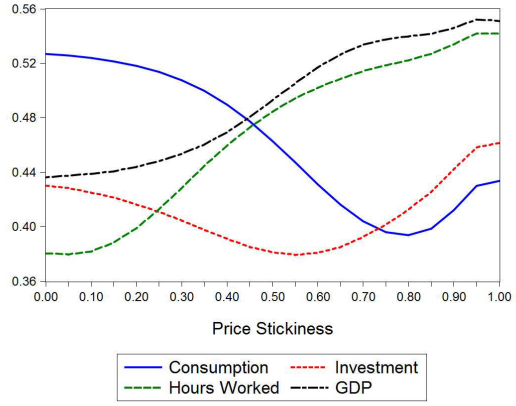
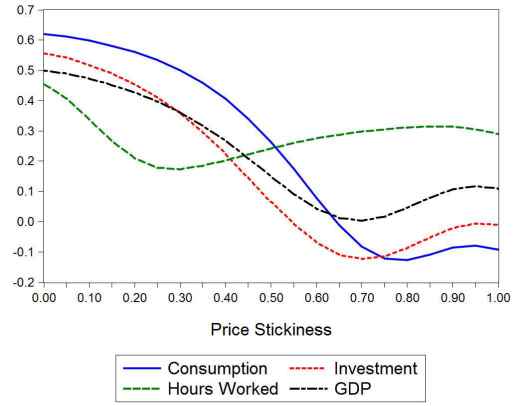


Figure C.10: **Sensitivity of International Comovements Under Price Stickiness (α_c) – CAC without Capital Utilization Models**

Without Habit Formation



With External Habit



With Internal Habit

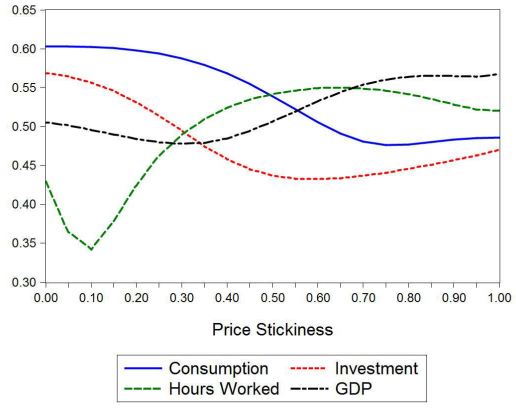
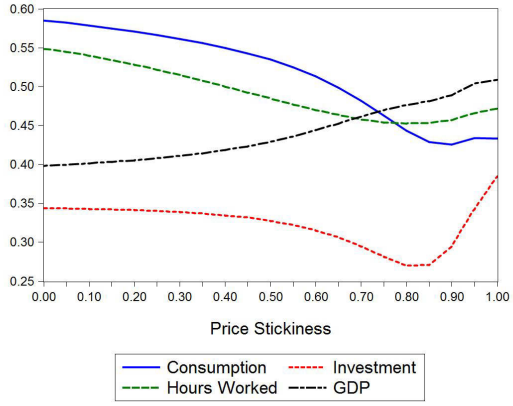
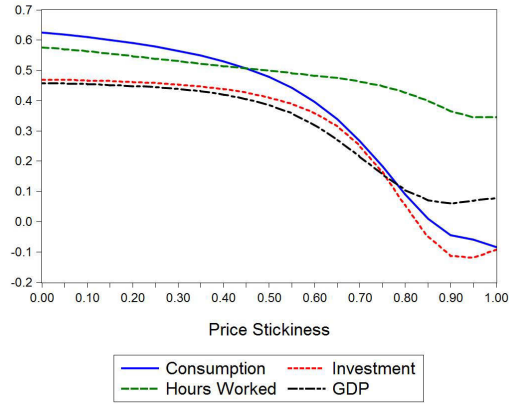


Figure C.11: **Sensitivity of International Comovements Under Price Stickiness (α_c) – IAC with Capital Utilization Models**

Without Habit Formation



With External Habit



With Internal Habit

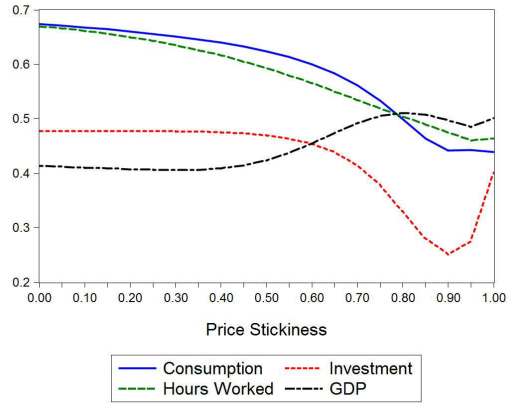
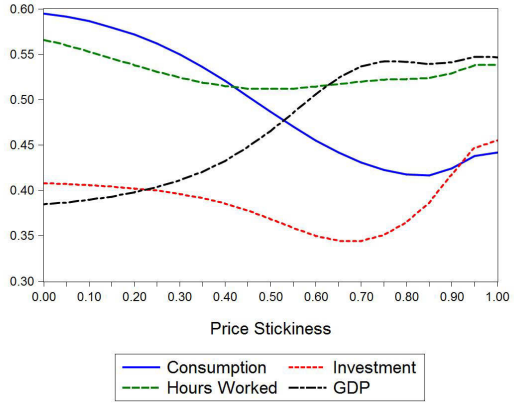
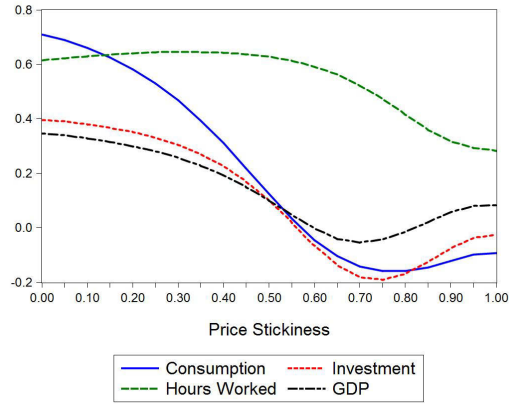


Figure C.12: **Sensitivity of International Comovements Under Price Stickiness (α_c) – IAC without Capital Utilization Models**

Without Habit Formation



With External Habit



With Internal Habit

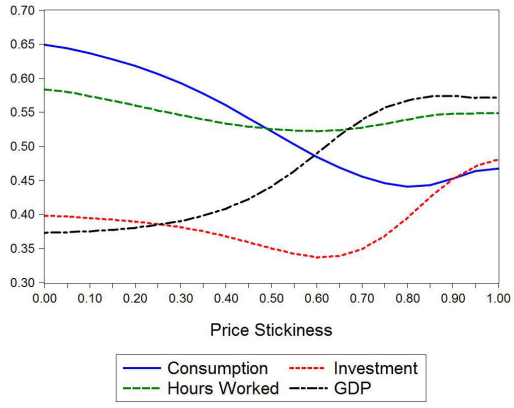


Figure C.13: **Impulse Responses in CAC Models with Capital Utilization, No Habit, External Habit and Internal Habit – A Positive TFP Shock**

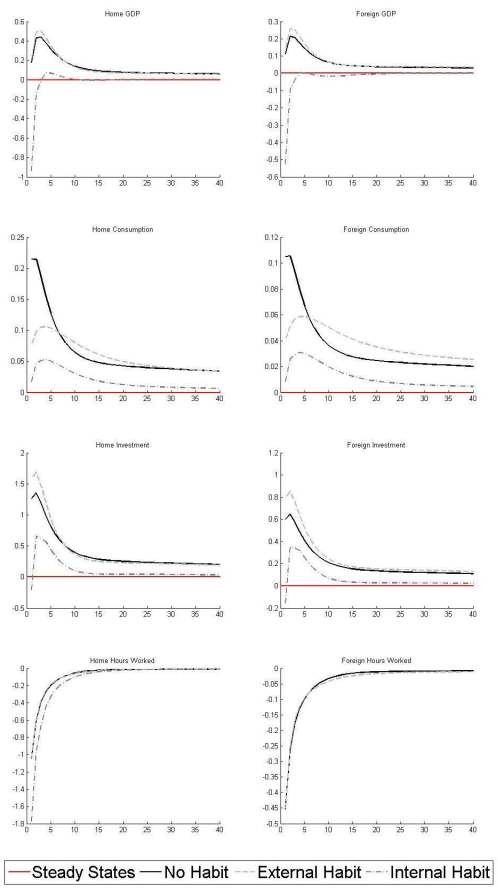


Figure C.14: **Impulse Responses in CAC Models with Capital Utilization, No Habit, External Habit and Internal Habit – A Positive Investment Efficiency Shock**

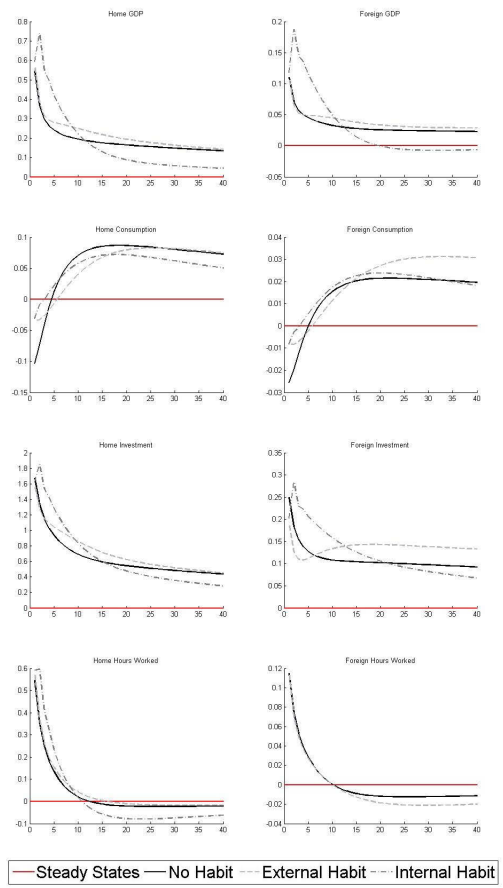


Figure C.15: **Impulse Responses in CAC Models with Capital Utilization, No Habit, External Habit and Internal Habit – A Contractionary Monetary Policy Shock**

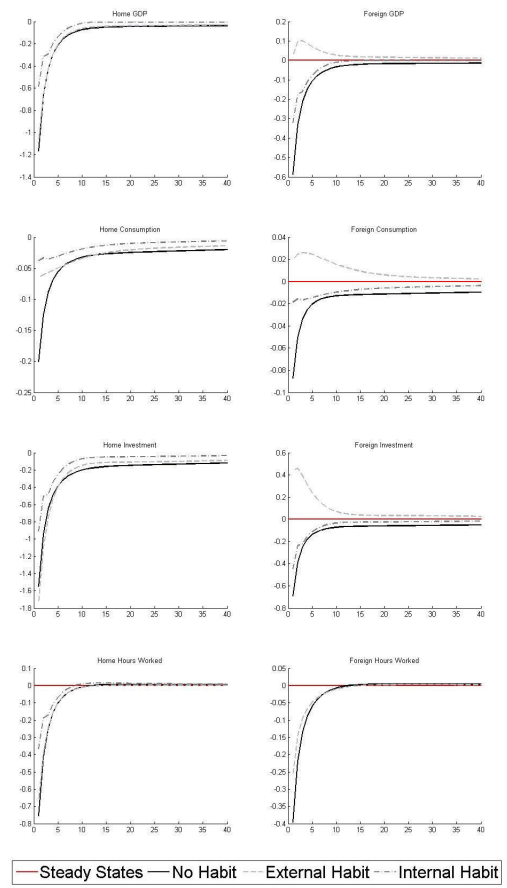


Figure C.16: **Impulse Responses in CAC Models without Capital Utilization, No Habit, External Habit and Internal Habit – A Positive TFP Shock**

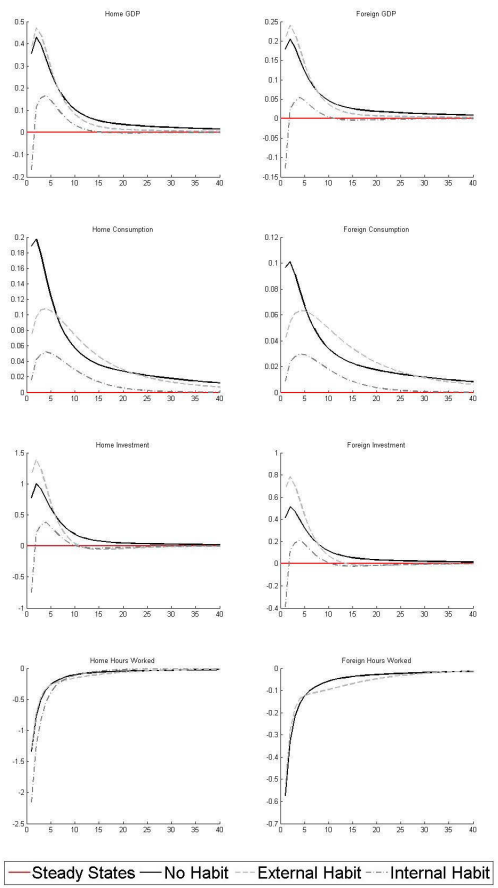


Figure C.17: **Impulse Responses in CAC Models without Capital Utilization, No Habit, External Habit and Internal Habit – A Positive Investment Efficiency Shock**

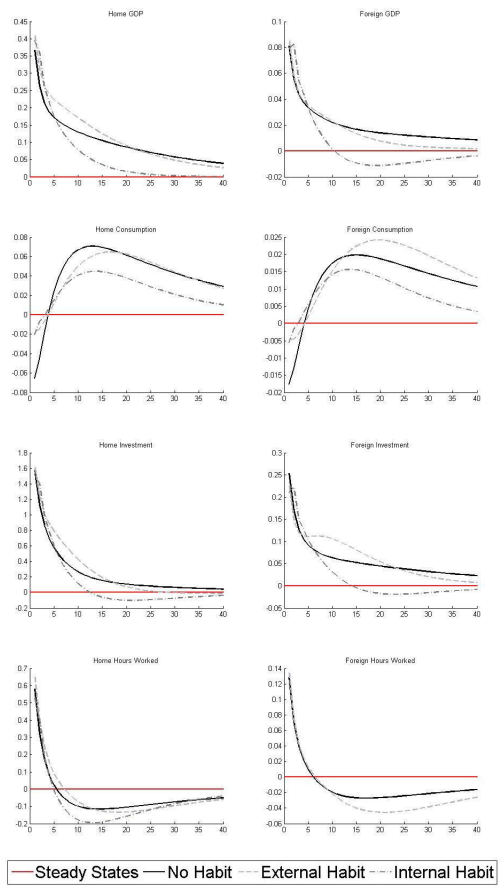


Figure C.18: **Impulse Responses in CAC Models without Capital Utilization, No Habit, External Habit and Internal Habit – A Contractionary Monetary Policy Shock**

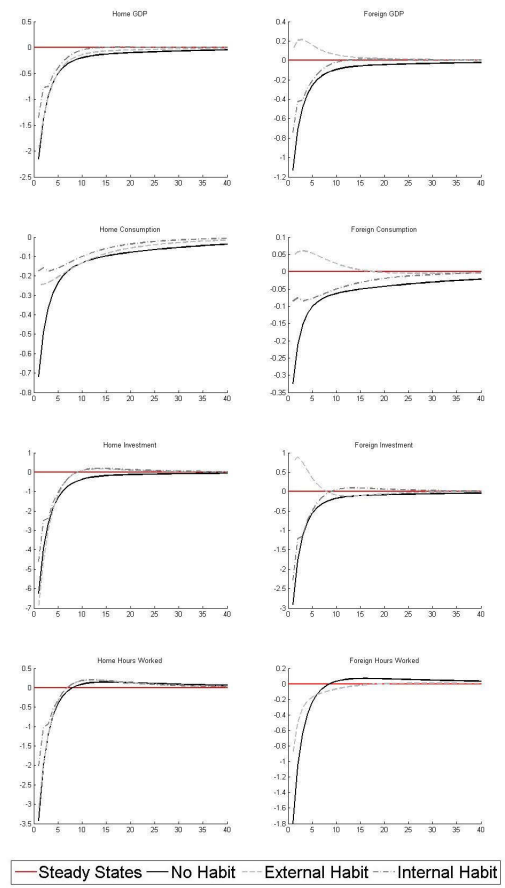


Figure C.19: **Impulse Responses in IAC Models with Capital Utilization, No Habit, External Habit and Internal Habit – A Positive TFP Shock**

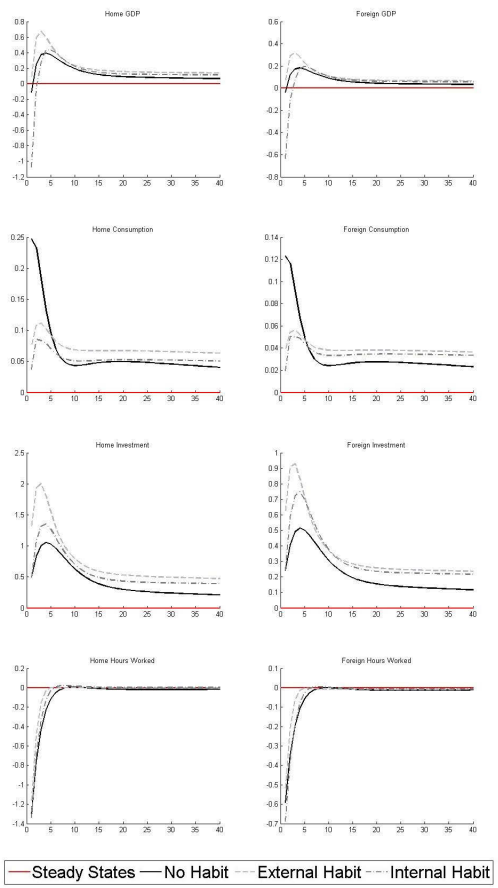


Figure C.20: **Impulse Responses in IAC Models with Capital Utilization, No Habit, External Habit and Internal Habit – A Positive Investment Efficiency Shock**

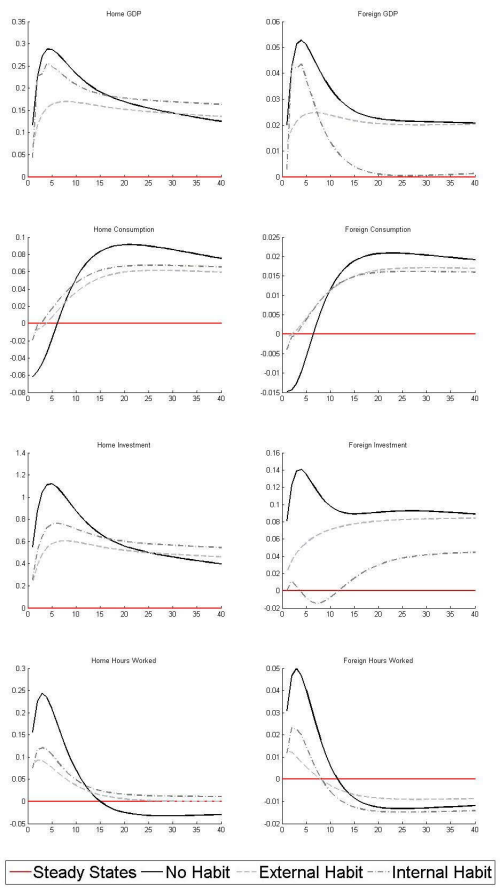


Figure C.21: **Impulse Responses in IAC Models with Capital Utilization, No Habit, External Habit and Internal Habit – A Contractionary Monetary Policy Shock**

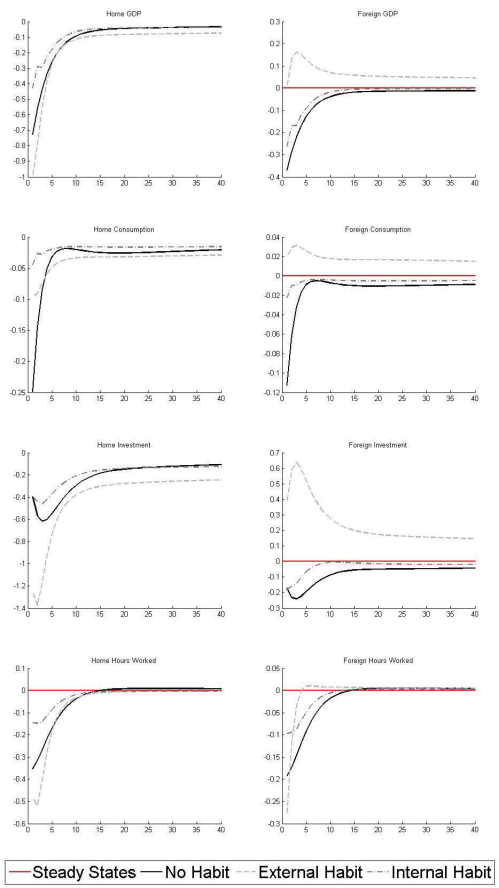


Figure C.22: **Impulse Responses in IAC Models without Capital Utilization, No Habit, External Habit and Internal Habit – A Positive TFP Shock**

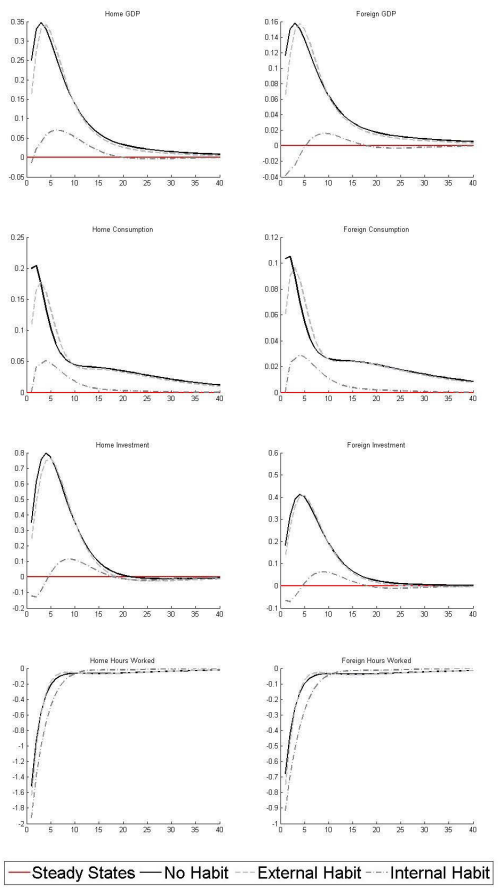


Figure C.23: **Impulse Responses in IAC Models without Capital Utilization, No Habit, External Habit and Internal Habit – A Positive Investment Efficiency Shock**

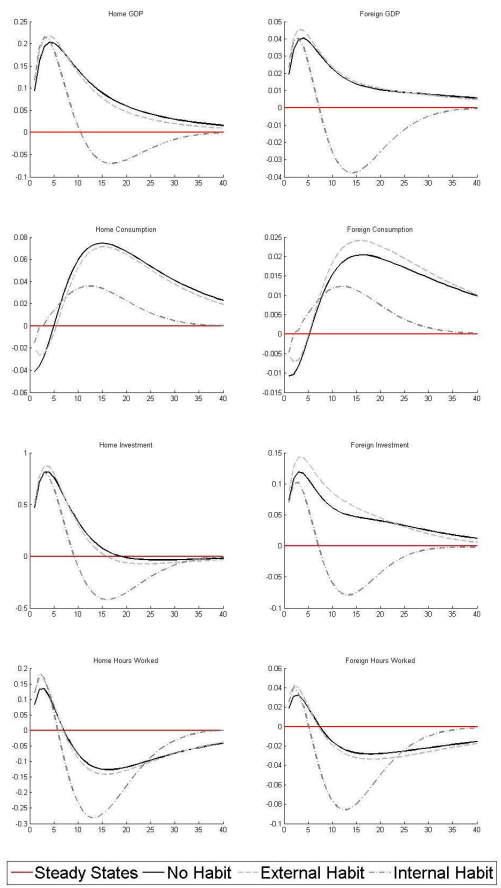


Figure C.24: **Impulse Responses in IAC Models without Capital Utilization, No Habit, External Habit and Internal Habit – A Contractionary Monetary Policy Shock**

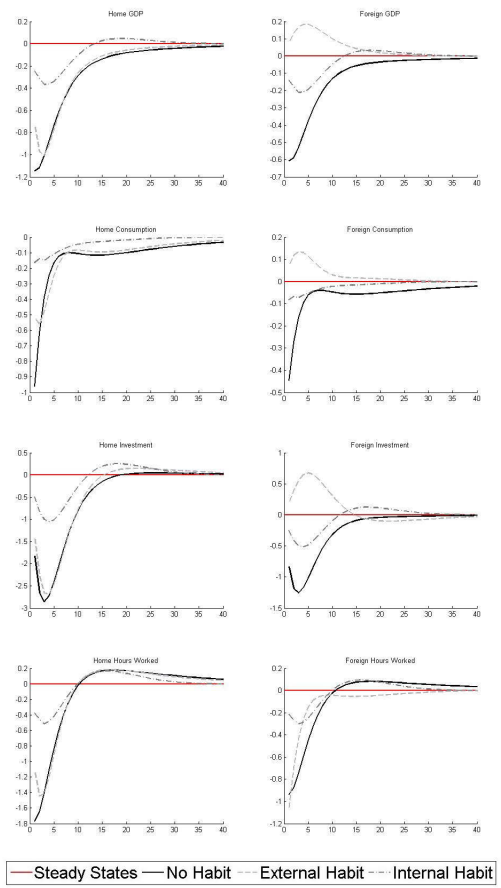
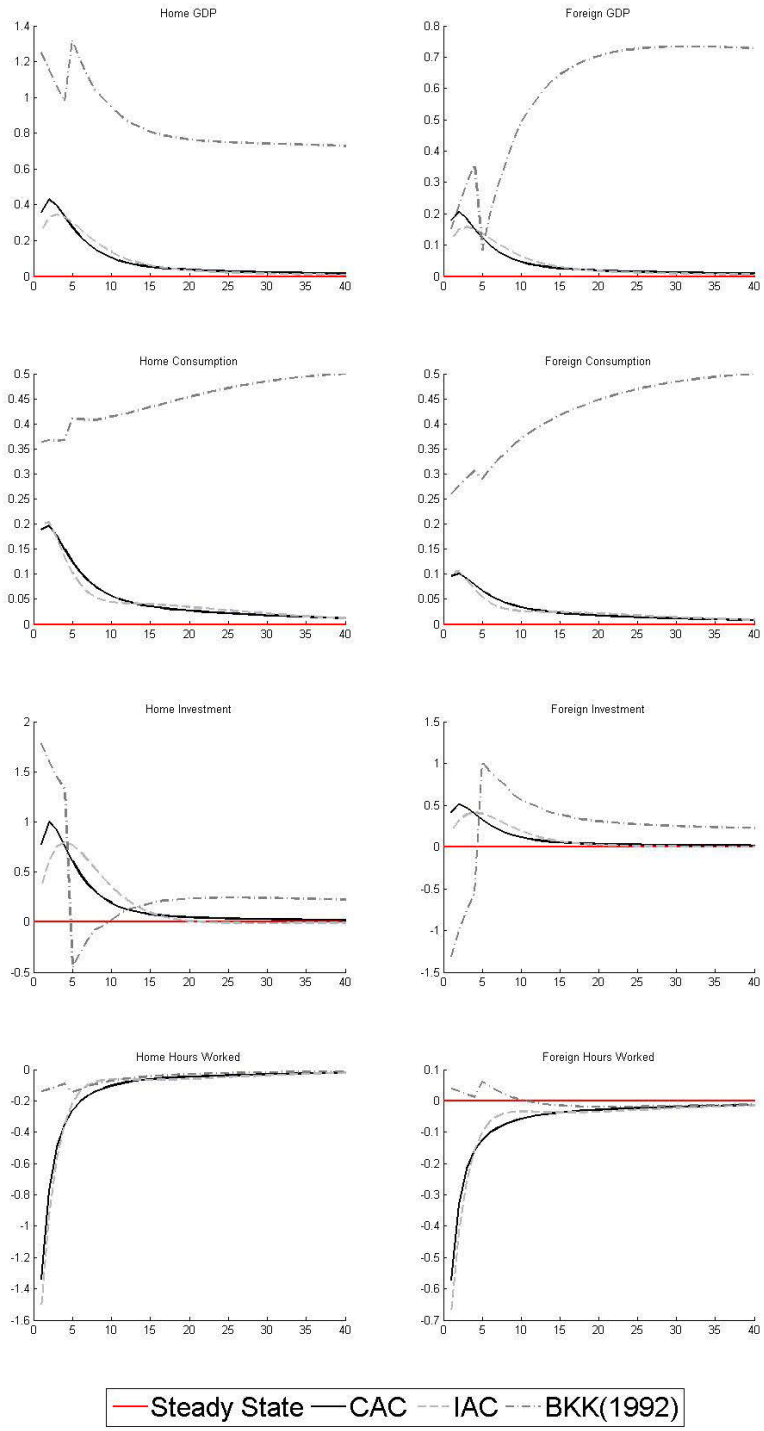


Figure C.25: **Impulse Responses to a Positive TFP Shock in Benchmark and BKK (1992) Models**



C.2 Tables

Table C.1: **International and Domestic Business Cycle Statistics of CAC Models with Capital Utilization**

				Habit				
				NO	*Externral*		*Internal*	
	Data	*BKK* (1993)	*DK* (2012)	$\lambda_h = 0$	$\lambda_h = 0.30$	$\lambda_h = 0.7$	$\lambda_h = 0.07$	$\lambda_h = 0.63$
					$\gamma_h = 1$	$\gamma_h = 0.40$	$\gamma_h = 1$	$\gamma_h = 0.4$
Cross-Country Correlations								
GDP	0.59	$0.00 \sim 0.10$	0.01	0.47	0.10	0.12	0.47	0.49
Consumption	0.41	$0.68 \sim 0.83$	0.77	0.44	0.22	0.31	0.45	0.51
Investment	0.46	$-0.58 \sim -0.76$	0.33	0.31	0.10	0.12	0.29	0.21
Hours Worked	0.40	$-0.42 \sim -0.62$	-0.68	0.42	0.38	0.37	0.45	0.50
Standard Deviation (%)								
GDP	1.45	$1.33 \sim 1.38$	0.77	1.45	1.39	1.45	1.49	1.45
Consumption	1.22	$0.64 \sim 0.82$	0.27	0.39	0.35	0.18	0.34	0.11
Investment	3.73	$4.54 \sim 6.39$	2.88	3.07	3.12	3.47	2.98	2.72
Hours Worked	0.84	$0.52 \sim 0.58$	0.4	1.48	1.47	1.45	1.69	2.02
Net Exports	0.61	$0.3 \sim 0.85$	0.69	0.72	0.67	0.67	0.84	1.00
Real Exchange Rate	4.07			2.08	2.53	2.83	1.85	1.28
Autocorrelations								
GDP	0.84	$0.63 \sim 0.65$	0.73	0.50	0.51	0.54	0.47	0.42
Consumption	0.76		0.93	0.64	0.77	0.83	0.68	0.83
Investment	0.84		0.69	0.60	0.60	0.63	0.60	0.69
Hours Worked	0.92		0.73	0.45	0.44	0.44	0.45	0.46
Net Exports	0.69		0.72	0.37	0.36	0.37	0.37	0.35
Real Exchange Rate	0.81			0.64	0.59	0.65	0.64	0.58
Correlations with Domestic GDP								
Consumption	0.74	$0.78 \sim 0.92$	0.68	0.57	0.54	0.48	0.46	-0.03
Investment	0.82	$0.00 \sim 0.16$	0.96	0.88	0.89	0.90	0.85	0.78
Hours Worked	0.88	$0.79 \sim 0.95$	0.93	0.43	0.40	0.36	0.59	0.82
Net Exports	-0.13	$-0.57 \sim -0.66$	0.69	0.75	0.73	0.77	0.80	0.87
Real Exchange Rate	-0.17			0.25	0.47	0.43	0.20	-0.01

Notes: 1. Data sources include OECD National Accounts, BIS and IFS. The real variables reported in the table are transformed to natural logarithm. All statistics are derived from Hodrick-Prescott filtered quarterly data with a smoothing parameter of 1,600.
2. In deriving the statistics of cross-country correlations, the U.S. serves as the counterpart of each of the other G7 countries; the aggregate of the G6 countries is used as the counterpart of the U.S.

Table C.2: **International and Domestic Business Cycle Statistics of CAC Models without Capital Utilization**

				Habit				
				NO	*Externral*		*Internal*	
	Data	*BKK* (1993)	*DK* (2012)	$\lambda_h = 0$	$\lambda_h = 0.30$	$\lambda_h = 0.7$	$\lambda_h = 0.07$	$\lambda_h = 0.63$
					$\gamma_h = 1$	$\gamma_h = 0.40$	$\gamma_h = 1$	$\gamma_h = 0.4$
Cross-Country Correlations								
GDP	0.59	$0.00 \sim 0.10$	0.01	0.54	−0.02	0.02	0.56	0.56
Consumption	0.41	$0.68 \sim 0.83$	0.77	0.40	−0.13	−0.12	0.41	0.48
Investment	0.46	$-0.58 \sim -0.76$	0.33	0.40	−0.08	−0.11	0.43	0.44
Hours Worked	0.40	$-0.42 \sim -0.62$	−0.68	0.52	0.22	0.31	0.55	0.55
Standard Deviation (%)								
GDP	1.45	$1.33 \sim 1.38$	0.77	2.41	2.29	2.36	2.88	1.62
Consumption	1.22	$0.64 \sim 0.82$	0.27	0.83	0.73	0.38	0.90	0.27
Investment	3.73	$4.54 \sim 6.39$	2.88	7.10	7.27	8.34	8.67	5.60
Hours Worked	0.84	$0.52 \sim 0.58$	0.4	4.03	3.84	3.86	4.64	3.28
Net Exports	0.61	$0.3 \sim 0.85$	0.69	0.24	0.30	0.28	0.28	0.16
Real Exchange Rate	4.07			4.54	6.74	7.68	5.15	3.14
Autocorrelations								
GDP	0.84	$0.63 \sim 0.65$	0.73	0.50	0.53	0.56	0.49	0.52
Consumption	0.76		0.93	0.54	0.70	0.77	0.56	0.78
Investment	0.84		0.69	0.50	0.50	0.55	0.48	0.51
Hours Worked	0.92		0.73	0.47	0.49	0.50	0.47	0.47
Net Exports	0.69		0.72	0.67	0.67	0.69	0.66	0.71
Real Exchange Rate	0.81			0.55	0.54	0.61	0.53	0.54
Correlations with Domestic GDP								
Consumption	0.74	$0.78 \sim 0.92$	0.68	0.57	0.91	0.78	0.95	0.71
Investment	0.82	$0.00 \sim 0.16$	0.96	0.95	0.99	0.99	0.99	0.99
Hours Worked	0.88	$0.79 \sim 0.95$	0.93	0.99	0.81	0.82	0.87	0.73
Net Exports	−0.13	$-0.57 \sim -0.66$	0.69	−0.43	−0.61	−0.53	−0.43	−0.34
Real Exchange Rate	−0.17			0.45	0.70	0.64	0.45	0.40

Notes: 1. Data sources include OECD National Accounts, BIS and IFS. The real variables reported in the table are transformed to natural logarithm. All statistics are derived from Hodrick-Prescott filtered quarterly data with a smoothing parameter of 1,600.
2. In deriving the statistics of cross-country correlations, the U.S. serves as the counterpart of each of the other G7 countries; the aggregate of the G6 countries is used as the counterpart of the U.S.

Table C.3: **International and Domestic Business Cycle Statistics of IAC Models with Capital Utilization**

				Habit				
				NO	*Externral*		*Internal*	
	Data	*BKK* (1993)	*DK* (2012)	$\lambda_h = 0$	$\lambda_h = 0.70$	$\lambda_h = 0.72$	$\lambda_h = 0.41$	$\lambda_h = 0.59$
					$\gamma_h = 1$	$\gamma_h = 0.82$	$\gamma_h = 1$	$\gamma_h = 0.64$
Cross-Country Correlations								
GDP	0.59	$0.00 \sim 0.10$	0.01	0.56	0.12	0.13	0.65	0.62
Consumption	0.41	$0.68 \sim 0.83$	0.77	0.48	0.13	0.16	0.63	0.59
Investment	0.46	$-0.58 \sim -0.76$	0.33	0.44	0.14	0.14	0.34	0.43
Hours Worked	0.40	$-0.42 \sim -0.62$	-0.68	0.55	0.41	0.59	0.45	0.58
Standard Deviation (%)								
GDP	1.45	$1.33 \sim 1.38$	0.77	1.62	1.45	1.45	1.46	1.45
Consumption	1.22	$0.64 \sim 0.82$	0.27	0.27	0.22	0.18	0.13	0.12
Investment	3.73	$4.54 \sim 6.39$	2.88	5.60	3.13	3.25	1.98	2.09
Hours Worked	0.84	$0.52 \sim 0.58$	0.4	3.28	1.39	1.39	1.53	1.44
Net Exports	0.61	$0.3 \sim 0.85$	0.69	0.16	0.73	0.72	1.31	1.30
Real Exchange Rate	4.07			3.14	3.24	2.98	0.84	0.75
Autocorrelations								
GDP	0.84	$0.63 \sim 0.65$	0.73	0.52	0.64	0.66	0.35	0.38
Consumption	0.76		0.93	0.78	0.77	0.76	0.72	0.77
Investment	0.84		0.69	0.51	0.81	0.81	0.90	0.89
Hours Worked	0.92		0.73	0.47	0.41	0.41	0.46	0.42
Net Exports	0.69		0.72	0.71	0.35	0.36	0.29	0.28
Real Exchange Rate	0.81			0.54	0.31	0.33	0.12	0.42
Correlations with Domestic GDP								
Consumption	0.74	$0.78 \sim 0.92$	0.68	0.71	0.89	0.89	0.23	0.28
Investment	0.82	$0.00 \sim 0.16$	0.96	0.99	0.87	0.88	0.46	0.45
Hours Worked	0.88	$0.79 \sim 0.95$	0.93	0.73	0.36	0.37	0.85	0.81
Net Exports	-0.13	$-0.57 \sim -0.66$	0.69	-0.34	0.76	0.75	0.92	0.89
Real Exchange Rate	-0.17			0.40	0.54	0.56	0.15	0.11

Notes: 1. Data sources include OECD National Accounts, BIS and IFS. The real variables reported in the table are transformed to natural logarithm. All statistics are derived from Hodrick-Prescott filtered quarterly data with a smoothing parameter of 1,600.
2. In deriving the statistics of cross-country correlations, the U.S. serves as the counterpart of each of the other G7 countries; the aggregate of the G6 countries is used as the counterpart of the U.S.

Table C.4: **International and Domestic Business Cycle Statistics of IAC Models without Capital Utilization**

				Habit				
				NO	*Externral*		*Internal*	
	Data	*BKK* (1993)	*DK* (2012)	$\lambda_h = 0$	$\lambda_h = 0.70$	$\lambda_h = 0.72$	$\lambda_h = 0.41$	$\lambda_h = 0.59$
					$\gamma_h = 1$	$\gamma_h = 0.82$	$\gamma_h = 1$	$\gamma_h = 0.64$
Cross-Country Correlations								
GDP	0.59	$0.00 \sim 0.10$	0.01	0.54	−0.06	−0.05	0.50	0.52
Consumption	0.41	$0.68 \sim 0.83$	0.77	0.42	−0.19	−0.16	0.50	0.49
Investment	0.46	$-0.58 \sim -0.76$	0.33	0.35	−0.22	−0.11	0.26	0.31
Hours Worked	0.40	$-0.42 \sim -0.62$	−0.68	0.52	0.44	0.31	0.53	0.53
Standard Deviation (%)								
GDP	1.45	$1.33 \sim 1.38$	0.77	1.70	1.68	1.55	0.66	0.71
Consumption	1.22	$0.64 \sim 0.82$	0.27	1.06	0.92	0.80	0.22	0.24
Investment	3.73	$4.54 \sim 6.39$	2.88	4.55	4.85	4.44	2.22	2.37
Hours Worked	0.84	$0.52 \sim 0.58$	0.4	3.02	3.03	2.89	2.45	2.46
Net Exports	0.61	$0.3 \sim 0.85$	0.69	0.22	0.32	0.25	0.13	0.13
Real Exchange Rate	4.07			5.68	15.53	14.79	1.57	1.65
Autocorrelations								
GDP	0.84	$0.63 \sim 0.65$	0.73	0.75	0.84	0.85	0.89	0.90
Consumption	0.76		0.93	0.48	0.75	0.75	0.69	0.73
Investment	0.84		0.69	0.88	0.90	0.90	0.92	0.92
Hours Worked	0.92		0.73	0.66	0.71	0.70	0.62	0.63
Net Exports	0.69		0.72	0.86	0.92	0.92	0.91	0.91
Real Exchange Rate	0.81			0.50	0.38	0.41	0.15	0.36
Correlations with Domestic GDP								
Consumption	0.74	$0.78 \sim 0.92$	0.68	0.82	0.87	0.86	0.63	0.67
Investment	0.82	$0.00 \sim 0.16$	0.96	0.92	0.94	0.95	0.96	0.96
Hours Worked	0.88	$0.79 \sim 0.95$	0.93	0.69	0.69	0.65	0.40	0.41
Net Exports	−0.13	$-0.57 \sim -0.66$	0.69	−0.40	−0.53	−0.48	−0.23	−0.25
Real Exchange Rate	−0.17			0.40	0.36	0.42	0.21	0.22

Notes: 1. Data sources include OECD National Accounts, BIS and IFS. The real variables reported in the table are transformed to natural logarithm. All statistics are derived from Hodrick-Prescott filtered quarterly data with a smoothing parameter of 1,600.
2. In deriving the statistics of cross-country correlations, the U.S. serves as the counterpart of each of the other G7 countries; the aggregate of the G6 countries is used as the counterpart of the U.S.

C.3 Technical Appendix

C.3.1 Preference

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_{i,t} - \lambda_h H_{i,t})^{1-\sigma}}{1-\sigma} + \chi ln \frac{M_{i,t}}{P_{i,t}} - \eta \frac{\ell_{i,t}^{1+\psi}}{1+\psi} \right], \tag{C.1}$$

where $M_{i,t}$ is the money demand, ℓ_t is the labour supply, and $H_{i,t}$ denotes habit stock that follows the specification by Ferson and Constantinides (1991) as $H_{i,t+1} = \gamma_h C_{i,t} + (1-\gamma_h) H_{i,t}$, $i \in H, F$. The parameters, $\lambda_h \in [0,1]$ and $\gamma_h \in [0,1]$ represent habit intensity and habit persistence, respectively. This specification allows more flexibilities, such that a future habit stock can be solely determined by current consumption or current habit stock level. If the habit persistence is at its maximum, then the habit formation simply becomes the more general case where habit depends on past consumption.[1] $H_{i,t} = 0$ is assumed in the benchmark model with no habit. Past consumption is exogenously determined by the aggregate consumption level in external habit models and individual past consumption is used in the internal habit models.

The composite consumption is given as:

$$C_{i,t} = \left[\alpha^{\frac{1}{\phi}} (C_{i,t}^i)^{\frac{\phi-1}{\phi}} + (1-\alpha)^{\frac{1}{\phi}} (C_{j,t}^i)^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}}, \tag{C.2}$$

and the composite consumption of goods produced by country j and consumed by country i is defined as:

$$C_{j,t}^i = \left[\int_0^1 c_t^i(m_j)^{\frac{\varepsilon-1}{\varepsilon}} dm_j \right]^{\frac{\varepsilon}{\varepsilon-1}}, \; i,j = H,F \; and \; m_j \in [0,1], \tag{C.3}$$

where $c_t^i(m_j)$ stands for a differentiated good within a continuum of goods produced by a firm of country j, α presents the home bias in consumption, ϕ is the elasticity of substitution between home and foreign goods, and ε is the elasticity of substitution among the varieties of goods within a country.

[1] See Dynan (2000) for example.

Accordingly, the composite price index is

$$P_{i,t} = \left[\alpha(P^i_{i,t})^{1-\phi} + (1-\alpha)(P^i_{j,t})^{1-\phi}\right]^{\frac{1}{1-\phi}}, \tag{C.4}$$

and the price sub-index is

$$P^i_{j,t} = [\int_0^1 p^i_t(m_j)^{1-\varepsilon} dm_j]^{\frac{1}{1-\varepsilon}},\ \forall i,j = H,F\ and\ m_j \in [0,1], \tag{C.5}$$

where $p^i_t(m_j)$ denotes the price of a differentiated good m_j produced by a firm of country j but sold in country i.

C.3.2 Technologies and Firms

There are a large number of homogeneous monopolistically competitive firms in the market. A firm that produces a differentiated good m_i employs the following production technology,

$$y_t(m_i) = \theta_{i,t} k^s_t(m_i)^{\kappa} \ell_t(m_i)^{1-\kappa} = \theta_{i,t}[Z_{i,t} k_{t-1}(m_i)]^{\kappa} \ell_t(m_i)^{1-\kappa},\ i = H,F\ and\ m_i \in [0,1], \tag{C.6}$$

where the service capital follows $k^s_t(m_i) = Z_{i,t} k_{t-1}(m_i)$, $Z_{i,t}$ is the rate of capital utilization, and $\theta_{i,t}$ is the TFP shock. $Z_{i,t}$ and $\theta_{i,t}$ are common within a country but are allowed to vary from their foreign counterparts.

The labour markets are assumed perfectly competitive, and labour force is homogeneous within a country but can be different from labour force in the other country. As a result, the wage rate $w_{i,t}$ is same within each country.

Price stickiness specified by Calvo (1983) is introduced to the price setting of monopolistic firms. In a period t, a firm is able to optimally reset its price with a probability of $(1-\alpha_c)$, and to maintain its price at the period $t-1$ with a probability α_c.

The price sub-index $P^i_{j,t}$ evolves as:

$$P^i_{j,t} = [(1-\alpha_c)(\tilde{p}^i_t(m_j))^{1-\varepsilon} + \alpha_c(P^i_{j,t-1})^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}},\ i,j = H,F.^2 \tag{C.7}$$

The cost minimization problem of a firm is

$$\min w_{i,t}\ell_t(m_i) + R^K_{i,t} Z_{i,t} k_{t-1}(m_i), \tag{C.8}$$

s.t.

$$y_t(m_i) = \theta_{i,t}[Z_{i,t}k_{t-1}(m_i)]^{\kappa}\ell_t(m_i)^{1-\kappa}, \tag{C.9}$$

where $R^K_{i,t}$ is the rental rate of capital, and is common for firms within country i.

Solving the problem yields the nominal marginal cost as:

$$MC_t(m_i) = MC_{i,t} = \frac{1}{\theta_{i,t}} \frac{1}{\kappa^{\kappa}(1-\kappa)^{(1-\kappa)}} w^{(1-\kappa)}_{i,t} {R^K_{i,t}}^{\kappa}, \tag{C.10}$$

which implies that the equivalence of the firm's and market marginal cost.

The first order conditions also suggest the following capital-labour ratio:

$$\frac{k_{t-1}(m_i)}{\ell_t(m_i)} = \frac{\kappa}{1-\kappa} \frac{w_{i,t}}{R^K_{i,t} Z_{i,t}}, \tag{C.11}$$

[2]Due to symmetry assumption, $P^i_{j,t-1}$ is common for all firms.

which indicates a constant capital-labour ratio across the monopolistic firms within a country, thus,

$$\frac{k_{i,t-1}}{\ell_{i,t}} = \frac{\kappa}{1-\kappa}\frac{w_{i,t}}{R^K_{i,t}Z_{i,t}}. \tag{C.12}$$

Furthermore, the production function can be rewritten as:

$$y_t(m_i) = \theta_{i,t}(\frac{Z_{i,t}k_{i,t-1}}{\ell_{i,t}})^{\kappa}\ell_t(m_i), \tag{C.13}$$

which implies

$$y_{i,t} = \int_0^1 y_t(m_i)dm_i = \theta_{i,t}(Z_{i,t}k_{i,t-1})^{\kappa}(\ell_{i,t})^{1-\kappa}. \tag{C.14}$$

Similar to consumption, composite investment is assumed to follow a CES functional form as:

$$I_{i,t} = \left[\alpha^{\frac{1}{\phi}}(I^i_{i,t})^{\frac{\phi-1}{\phi}} + (1-\alpha)^{\frac{1}{\phi}}(I^i_{j,t})^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}, \tag{C.15}$$

and the composite investment goods produced by country j and consumed by country i are

$$I^i_{j,t} = \left[\int_0^1 i^i_t(m_j)^{\frac{\varepsilon-1}{\varepsilon}}dm_j\right]^{\frac{\varepsilon}{\varepsilon-1}},\ i,j = H,F\ and\ m_j \in [0,1], \tag{C.16}$$

where $i_t(m_j)$ represents a differentiated investment good m_j produced by a firm in country j.[3]

In this study, both the capital adjustment costs and investment adjustment costs are examined and specified as CKM (2002) and CEE (2005), respectively.

Under CAC, the law of motion for capital stock is modified from the CKM (2002) specification such that an investment efficiency shock $\varepsilon_{i,t}$ makes a product with investment, and is specified as

$$k_{i,t} = (1-\delta)k_{i,t-1} + \varepsilon_{i,t}I_{i,t} - \left[B(\frac{I_{i,t}}{k_{i,t-1}})\right]k_{i,t-1}, \tag{C.17}$$

[3]The home biases in consumption and investment are assumed to be same.

where $B(\cdot)$ is a convex CAC function with $B(\delta) = B'(\delta) = 0$ and $B'' > 0$ at steady states.

Under IAC, the law of motion for capital stock is

$$k_{i,t} = (1-\delta)k_{i,t-1} + \varepsilon_{i,t}\left[1 - A(\frac{I_{i,t}}{I_{i,t-1}})\right] I_{i,t}, \tag{C.18}$$

where $\varepsilon_{i,t}$ is the investment efficiency shock, and $A(\cdot)$ is a convex IAC function with $A(1) = A'(1) = 0$ and $A'' > 0$ at steady states.

The demands for both home and foreign investment goods are determined by minimizing the cost of generating an investment $I_{i,t}$, and are described as below:

$$I^i_{j,t} = (1-\alpha)(\frac{P^i_{j,t}}{P_{i,t}})^{-\phi} I_{i,t}, \quad I^i_{i,t} = \alpha(\frac{P^i_{i,t}}{P_{i,t}})^{-\phi} I_{i,t}, \quad i,j = H,F; \tag{C.19}$$

similarly, given $I^i_{i,t}$ and $I^i_{j,t}$, the investment demands for each variety are given as:

$$i^i_t(m_j) = \left[\frac{p^i_t(m_j)}{P^i_{j,t}}\right]^{-\varepsilon} I^i_{j,t}, \quad i^i_t(m_i) = \left[\frac{p^i_t(m_i)}{P^i_{i,t}}\right]^{-\varepsilon} I^i_{i,t}, \quad i,j = H,F. \tag{C.20}$$

A monopolistic firm of home country (H) maximizes the expected profit according to

$$\max_{\tilde{p}^H_t(m_H), \tilde{p}^F_t(m_H)} \sum_{\tau=0}^{\infty} E_t {\alpha_c}^{\tau} \rho_{t,t+\tau} \left\{ \begin{array}{l} [\tilde{c}^H_{t,t+\tau}(m_H) + \tilde{i}^H_{t,t+\tau}(m_H)][\tilde{p}^H_t(m_H) - MC_{H,t+\tau}] + \ldots \\ [\tilde{c}^F_{t,t+\tau}(m_H) + \tilde{i}^F_{t,t+\tau}(m_H)][er_{t+\tau}\tilde{p}^F_t(m_H) - MC_{H,t+\tau}] \end{array} \right\}, \tag{C.21}$$

s.t.

$$\tilde{c}^H_{t,t+\tau}(m_H) + \tilde{i}^H_{t,t+\tau}(m_H) = \left[\frac{\tilde{p}^H_t(m_H)}{P^H_{H,t+\tau}}\right]^{-\varepsilon} (C^H_{H,t+\tau} + I^H_{H,t+\tau}), \tag{C.22}$$

$$\tilde{c}^F_{t,t+\tau}(m_H) + \tilde{i}^F_{t,t+\tau}(m_H) = \left[\frac{\tilde{p}^F_t(m_H)}{P^F_{H,t+\tau}}\right]^{-\varepsilon} (C^F_{H,t+\tau} + I^F_{H,t+\tau}), \tag{C.23}$$

where $\tilde{c}^i_{t,t+\tau}(m_j)$ and $\tilde{i}^i_{t,t+\tau}(m_j)$ are the consumption and investment demands for the differentiated

good m_j produced by country j given the fact that $\tilde{p}_t^i(m_j)$ is unchanged during the periods t and $t+\tau$, and $\rho_{t,t+\tau}$ is the stochastic discount factor which is discussed in the next section.[4]

The first order conditions imply that

$$\sum_{\tau=0}^{\infty} E_t \left\{ {\alpha_c}^{\tau} \rho_{t,t+\tau} [\tilde{c}_{t,t+\tau}^H(m_H) + \tilde{i}_{t,t+\tau}^H(m_H)][\tilde{p}_t^H(m_H) + \frac{\varepsilon}{1-\varepsilon} MC_{H,t+\tau}] \right\} = 0, \tag{C.24}$$

$$\sum_{\tau=0}^{\infty} E_t \left\{ {\alpha_c}^{\tau} \rho_{t,t+\tau} [\tilde{c}_{t,t+\tau}^F(m_H) + \tilde{i}_{t,t+\tau}^F(m_H)][er_{t+\tau}\tilde{p}_t^F(m_H) + \frac{\varepsilon}{1-\varepsilon} MC_{H,t+\tau}] \right\} = 0. \tag{C.25}$$

Similarly, the FOCs of a foreign firm give

$$\sum_{\tau=0}^{\infty} E_t \left\{ {\alpha_c}^{\tau} \rho_{t,t+\tau} [\tilde{c}_{t,t+\tau}^F(m_F) + \tilde{i}_{t,t+\tau}^F(m_F)][\frac{\tilde{p}_t^F(m_F)}{er_{t+\tau}} + \frac{\varepsilon}{1-\varepsilon} MC_{F,t+\tau}] \right\} = 0, \tag{C.26}$$

$$\sum_{\tau=0}^{\infty} E_t \left\{ {\alpha_c}^{\tau} \rho_{t,t+\tau} [\tilde{c}_{t,t+\tau}^H(m_F) + \tilde{i}_{t,t+\tau}^H(m_F)][\tilde{p}_t^H(m_F) + \frac{\varepsilon}{1-\varepsilon} MC_{F,t+\tau}] \right\} = 0. \tag{C.27}$$

The wage bill of country i is

$$w_{i,t}\ell_{i,t} = (1-\kappa)P_{i,t}y_{i,t}. \tag{C.28}$$

The dividend paid to shareholders is

$$d_{i,t} = \kappa P_{i,t}y_{i,t} - P_{i,t}^i I_{i,t}^i - P_{j,t}^i I_{j,t}^j = P_{i,t}(\kappa y_{i,t} - I_{i,t}). \tag{C.29}$$

C.3.3 Exchange Rate and Terms of Trade

Through out the models, the real exchange rate (rer_t) is defined as:

$$rer_t = \frac{er_t P_{F,t}}{P_{H,t}}, \tag{C.30}$$

[4]The constraints are derived by combining equations (C.19) and (C.33).

and the home terms of trade is specified as:

$$tot_t = \frac{P^F_{H,t}}{P^H_{F,t}}, \tag{C.31}$$

where er_t is the nominal exchange rate.

Under the local currency pricing (LCP) assumption in this study, the law of one price (LOP) does not hold. In the producer currency pricing (PCP), a perfect nominal exchange rate pass-through is associated with the price changes in the counterpart country. In the LCP, home producers set optimal prices in the currency of each country. Given the price stickiness assumption, foreign price responses slowly to nominal exchange rate, which implies an imperfect nominal exchange rate pass-through consequently.

C.3.4 Household Decision Problem

Two stage maximization for consumption

First Stage: maximizing the composite consumption for goods produced within a country given the composite consumption ($C_{i,t}$), and the results are

$$C^i_{j,t} = (1-\alpha)(\frac{P^i_{j,t}}{P_{i,t}})^{-\phi} C_{i,t}, \quad C^i_{i,t} = \alpha(\frac{P^i_{i,t}}{P_{i,t}})^{-\phi} C_{i,t}, \quad i,j = H,F. \tag{C.32}$$

Similarly, given $C^i_{i,t}$ and $C^i_{j,t}$, the demands for each variety are given as:

$$c^i_t(m_j) = \left[\frac{p^i_t(m_j)}{P^i_{j,t}}\right]^{-\varepsilon} C^i_{j,t}, \quad c^i_t(m_i) = \left[\frac{p^i_t(m_i)}{P^i_{i,t}}\right]^{-\varepsilon} C^i_{i,t}, \quad i,j = H,F. \tag{C.33}$$

Second Stage: a representative household maximizes the following problem:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_{i,t} - \lambda_h H_{i,t})^{1-\sigma}}{1-\sigma} + \chi ln \frac{M_{i,t}}{P_{i,t}} - \eta \frac{\ell^{1+\psi}_{i,t}}{1+\psi}\right], \tag{C.34}$$

s.t.

$$\begin{cases} P_{i,t}C_{i,t} + M_{i,t} + P_{i,t}I_{i,t} + \sum S^m_{i,t} \leq w_{i,t}\ell_{i,t} + M_{i,t-1} + Tr_{i,t} + \ldots \\ \qquad R^K_{i,t}k_{i,t-1} + \sum R^m_{i,t}S^m_{i,t-1}, \text{ with no capital utilization} \\ P_{i,t}C_{i,t} + M_{i,t} + P_{i,t}I_{i,t} + \sum S^m_{i,t} \leq w_{i,t}\ell_{i,t} + M_{i,t-1} + Tr_{i,t} + \ldots \\ \qquad R^K_{i,t}Z_{i,t}k_{i,t-1} - P_{i,t}a(Z_{i,t})k_{i,t-1} + \sum R^m_{i,t}S^m_{i,t-1}, \text{ with capital utilization} \end{cases} \tag{C.35}$$

and

$$\begin{cases} k_{i,t} = (1-\delta)k_{i,t-1} + \varepsilon_{i,t}I_{i,t} - \left[B(\frac{I_{i,t}}{k_{i,t-1}})\right]k_{i,t-1}, \text{ under CAC} \\ k_{i,t} = (1-\delta)k_{i,t-1} + \varepsilon_{i,t}\left[1 - A(\frac{I_{i,t}}{I_{i,t-1}})\right]I_{i,t}, \text{ under IAC} \end{cases} \tag{C.36}$$

where $a(Z_{i,t})$ is the cost of capital utilization, and $S^m_{i,t}$ is the holding of asset m by country i with a return to asset m as $R^m_{i,t}$. $a(Z_{i,t})$ satisfies $a(1) = 0$ and $Z = 1$ at steady states. Households can purchase both domestic and foreign assets.[5] Households make investment decisions and get return to capital $R^K_{i,t}$. The two corresponding Lagrangian multipliers are λ_t and v_t.[6] It is assumed that there is a lump-sum transfer from government (Tr) to balance the demand for money (M) such that

$$M_{i,t} = M_{i,t-1} + Tr_{i,t}. \tag{C.37}$$

The Lagrangian multipliers associated with the two constraints are assumed to be λ_t and v_t (subscript i is ignored due to symmetry of the two countries), respectively; the price of capital or the shadow value of installed capital in consumption units (q_t) is defined as a ratio of the two shadow prices ($\frac{v_t}{\lambda_t P_{i,t}}$), and FOCs are

[5]Under complete asset market that is arbitrage-free (no price differential), the return to capital $R^K_{i,t}$ is equal to return to assets $R^m_{i,t}$.

[6]Due to the symmetry assumption, the two multipliers are same for both countries and the subscript "i" is ignored.

$$\frac{\partial \mathcal{L}}{\partial C_{i,t}} = \begin{cases} C_{i,t}^{-\sigma} - \lambda_t P_{i,t} = 0, \text{ No Habit,} \\ (C_{i,t} - \lambda_h H_{i,t})^{-\sigma} - \lambda_t P_{i,t} = 0, \text{ External Habit,} \\ (C_{i,t} - \lambda_h H_{i,t})^{-\sigma} - h\beta E_t (C_{i,t+1} - \lambda_h H_{i,t+1})^{-\sigma} - \lambda_t P_{i,t} = 0, \text{ Internal Habit,} \end{cases} \tag{C.38}$$

where $h = \lambda_h \gamma_h$.

$$\frac{\partial \mathcal{L}}{\partial \ell_{i,t}} = -\eta \ell_{i,t}^{\psi} + \lambda_t w_{i,t} = 0, \tag{C.39}$$

$$\frac{\partial \mathcal{L}}{\partial S_{m,t}^{i}} = -\lambda_t + \beta E_t \lambda_{t+1} R_{m,t+1}^{i} = 0, \tag{C.40}$$

$$\frac{\partial \mathcal{L}}{\partial M_{i,t}} = \chi \frac{1}{M_{i,t}} - \lambda_t + \beta E_t \lambda_{t+1} = 0, \tag{C.41}$$

$$\frac{\partial \mathcal{L}}{\partial Z_{i,t}} = \frac{R_{i,t}^{K}}{P_{i,t}} - a'(Z_{i,t}) = 0, \tag{C.42}$$

$$\begin{cases} \frac{\partial \mathcal{L}}{\partial k_{i,t}} = v_t - \beta E_t \Big\{ \lambda_{t+1} R_{i,t+1}^{K} + \dots \\ \qquad v_{t+1} \left[(1-\delta) + B'(\frac{I_{i,t+1}}{k_{i,t}}) \frac{I_{i,t+1}}{k_{i,t}} - B(\frac{I_{i,t+1}}{k_{i,t}}) \right] \Big\} = 0, \text{ under CAC without CU,} \\ \frac{\partial \mathcal{L}}{\partial k_{i,t}} = v_t - \beta E_t \Big\{ \lambda_{t+1} R_{i,t+1}^{K} + v_{t+1}(1-\delta) \Big\} = 0, \text{ under IAC without CU,} \\ \frac{\partial \mathcal{L}}{\partial k_{i,t}} = v_t - \beta E_t \Big\{ \lambda_{t+1} [R_{i,t+1}^{K} Z_{i,t+1} - P_{i,t+1} a(Z_{i,t+1})] + \dots \\ \qquad v_{t+1} \left[(1-\delta) + B'(\frac{I_{i,t+1}}{k_{i,t}}) \frac{I_{i,t+1}}{k_{i,t}} - B(\frac{I_{i,t+1}}{k_{i,t}}) \right] \Big\} = 0, \text{ under CAC with CU,} \\ \frac{\partial \mathcal{L}}{\partial k_{i,t}} = v_t - \beta E_t \Big\{ \lambda_{t+1} [R_{i,t+1}^{K} Z_{i,t+1} - P_{i,t+1} a(Z_{i,t+1})] + \dots \\ \qquad v_{t+1}(1-\delta) \} = 0, \text{ under IAC with CU,} \end{cases} \tag{C.43}$$

$$\begin{cases} \dfrac{\partial \mathcal{L}}{\partial I_{i,t}} = \lambda_t P_{i,t} - v_t \left[\varepsilon_{i,t} - B'(\dfrac{I_{i,t}}{k_{i,t-1}}) \right] = 0, \text{ under CAC,} \\ \dfrac{\partial \mathcal{L}}{\partial I_{i,t}} = \lambda_t P_{i,t} - v_t \varepsilon_{i,t} \left[1 - A(\dfrac{I_{i,t}}{I_{i,t-1}}) - A'(\dfrac{I_{i,t}}{I_{i,t-1}}) \dfrac{I_{i,t}}{I_{i,t-1}} \right] - \dots \\ \qquad \beta E_t \left[v_{t+1} \varepsilon_{i,t+1} A'(\dfrac{I_{i,t+1}}{I_{i,t}})(\dfrac{I_{i,t+1}}{I_{i,t}})^2 \right] = 0, \text{ under IAC.} \end{cases} \tag{C.44}$$

The labour supply is determined as:

$$\eta \ell_{i,t}^{\psi} = \begin{cases} C_{i,t}^{-\sigma} \dfrac{w_{i,t}}{P_{i,t}}, \text{ No Habit,} \\ (C_{i,t} - \lambda_h H_{i,t})^{-\sigma} \dfrac{w_{i,t}}{P_{i,t}}, \text{ External Habit,} \\ [(C_{i,t} - \lambda_h H_{i,t})^{-\sigma} - h\beta E_t (C_{i,t+1} - \lambda_h H_{i,t+1})^{-\sigma}] \dfrac{w_{i,t}}{P_{i,t}}, \text{ Internal Habit.} \end{cases} \tag{C.45}$$

The pricing kernel is defined as:

$$\rho_{t,t+1} = \beta \frac{\lambda_{t+1}}{\lambda_t} = \dots.$$

$$\begin{cases} \beta \dfrac{P_{i,t}}{P_{i,t+1}} \dfrac{E_t (C_{i,t+1})^{-\sigma}}{(C_{i,t})^{-\sigma}}, \text{ No Habit,} \\ \beta \dfrac{P_{i,t}}{P_{i,t+1}} \dfrac{E_t (C_{i,t+1} - \lambda_h H_{i,t+1})^{-\sigma}}{(C_{i,t} - \lambda_h H_{i,t})^{-\sigma}}, \text{ External Habit,} \\ \beta \dfrac{P_{i,t}}{P_{i,t+1}} \dfrac{E_t (C_{i,t+1} - \lambda_h H_{i,t+1})^{-\sigma} - h\beta E_{t+1} (C_{i,t+2} - \lambda_h H_{i,t+2})^{-\sigma}}{(C_{i,t} - \lambda_h H_{i,t})^{-\sigma} - h\beta E_t (C_{i,t+1} - \lambda_h H_{i,t+1})^{-\sigma}}, \text{ Internal Habit,} \end{cases} \tag{C.46}$$

and a more general pricing kernel that links periods t and $t+\tau$ is given as:

$$\rho_{t,t+\tau} = \beta^{\tau} \frac{\lambda_{t+\tau}}{\lambda_t}. \tag{C.47}$$

Combining equations (C.42), (C.43) & (C.44) implies

$$\begin{cases} q_t - E_t\left\{\rho_{t,t+1}\frac{P_{i,t+1}}{P_{i,t}}\left[\frac{R^K_{i,t+1}}{P_{i,t+1}} + \dots \right.\right. \\ \qquad \left.\left. q_{t+1}\left(1-\delta - B(\frac{I_{i,t+1}}{k_{i,t}}) + B'(\frac{I_{i,t+1}}{k_{i,t}})\frac{I_{i,t+1}}{k_{i,t}}\right)\right]\right\} = 0, \text{ under CAC without CU,} \\ q_t - E_t\left\{\rho_{t,t+1}\frac{P_{i,t+1}}{P_{i,t}}[\frac{R^K_{i,t+1}}{P_{i,t+1}} + q_{t+1}(1-\delta)]\right\} = 0, \text{ under IAC without CU,} \\ q_t - E_t\left\{\rho_{t,t+1}\frac{P_{i,t+1}}{P_{i,t}}\left[a'(Z_{i,t+1})Z_{i,t+1} - a(Z_{i,t+1}) + \dots \right.\right. \\ \qquad \left.\left. q_{t+1}\left(1-\delta - B(\frac{I_{i,t+1}}{k_{i,t}}) + B'(\frac{I_{i,t+1}}{k_{i,t}})\frac{I_{i,t+1}}{k_{i,t}}\right)\right]\right\} = 0, \text{ under CAC with CU,} \\ q_t - E_t\left\{\rho_{t,t+1}\frac{P_{i,t+1}}{P_{i,t}}[a'(Z_{i,t+1})Z_{i,t+1} - a(Z_{i,t+1}) + q_{t+1}(1-\delta)]\right\} = 0, \text{ under IAC with CU,} \end{cases} \tag{C.48}$$

and

$$\begin{cases} \frac{1}{q_t} + B'(\frac{I_{i,t}}{k_{i,t-1}}) - \varepsilon_{i,t} = 0, \text{ under CAC,} \\ 1 - q_t\varepsilon_{i,t}\left[1 - A(\frac{I_{i,t}}{I_{i,t-1}}) - A'(\frac{I_{i,t}}{I_{i,t-1}})\frac{I_{i,t}}{I_{i,t-1}}\right] - \dots \\ \qquad E_t\rho_{t,t+1}\frac{P_{i,t+1}}{P_{i,t}}\left[q_{t+1}\varepsilon_{i,t+1}A'(\frac{I_{i,t+1}}{I_{i,t}})(\frac{I_{i,t+1}}{I_{i,t}})^2\right] = 0, \text{ under IAC.} \end{cases} \tag{C.49}$$

The FOCs under the case with no capital utilization are very similar to the case where capital utilization is included such that all FOC equations that contain $Z_{i,t}$, $a(Z_{i,t})$ and $a'(Z_{i,t})$ are dropped.

Rewriting the real rental cost of capital in terms of consumption, production, TFP shocks and service capital by combining equations (C.12), (C.14) and (C.45) gives

$$\frac{R^K_{i,t}}{P_{i,t}} = \begin{cases} \frac{\kappa\eta}{1-\kappa}C^{\sigma}_{i,t}y^{\frac{1+\psi}{1-\kappa}}\theta_{i,t}^{-\frac{1+\psi}{1-\kappa}}k_{i,t-1}^{-\frac{1+\psi\kappa}{1-\kappa}}, \text{ with no capital utilization,} \\ \frac{\kappa\eta}{1-\kappa}C^{\sigma}_{i,t}y^{\frac{1+\psi}{1-\kappa}}\theta_{i,t}^{-\frac{1+\psi}{1-\kappa}}(Z_{i,t}k_{i,t-1})^{-\frac{1+\psi\kappa}{1-\kappa}}, \text{ with capital utilization,} \end{cases} \tag{C.50}$$

and similarly, rewriting the real wage provides

$$\frac{w_{i,t}}{P_{i,t}} = (\frac{1-\kappa}{\kappa})^{\frac{\psi\kappa}{1+\psi\kappa}}(\frac{R^K_{i,t}}{P_{i,t}})^{\frac{\psi\kappa}{1+\psi\kappa}}\eta^{\frac{1}{1+\psi\kappa}}C_{i,t}^{\frac{\sigma}{1+\psi\kappa}}y_{i,t}^{\frac{\psi}{1+\psi\kappa}}\theta_{i,t}^{-\frac{\psi}{1+\psi\kappa}}. \tag{C.51}$$

The Euler equation for assets is

$$1 = E_t \rho_{t,t+1} R^m_{i,t+1}. \tag{C.52}$$

Market clearing conditions in goods and assets markets ($i \neq j$) are given as:

$$\begin{cases} C^i_{i,t} + C^j_{i,t} + I^i_{i,t} + I^j_{i,t} = y_{i,t}, \text{ with no capital utilization,} \\ C^i_{i,t} + C^j_{i,t} + I^i_{i,t} + I^j_{i,t} + a(Z_{i,t})k_{i,t-1} = y_{i,t}, \text{ with capital utilization,} \end{cases} \tag{C.53}$$

$$S^m_{i,t} + S^m_{i,t} = 0. \tag{C.54}$$

C.3.5 Monetary Policy and Price Dynamics

The risk-free nominal interest rate is given as:

$$\frac{1}{ir_{i,t}} = \beta E_t \left[\frac{U_{C_{i,t+1}}}{U_{C_{i,t}}} \frac{1}{\pi_{i,t+1}} \right], \tag{C.55}$$

where $\pi_{i,t+1}$ is the inflation rate which is defined as $\pi_{i,t+1} = \frac{P_{i,t+1}}{P_{i,t}}$.

The monetary authority utilizes a Taylor rule as follows:

$$log(\frac{ir_{i,t}}{ir}) = \rho_{ir} log(\frac{ir_{i,t-1}}{ir}) + (1 - \rho_{ir}) \left[\gamma_\pi log(\frac{\pi_{i,t}}{\pi}) + \gamma_y log(\frac{Y_{i,t}}{Y}) \right] + \varepsilon^{ir}_{i,t}, \tag{C.56}$$

where $Y_{i,t} = P_{i,t} y_{i,t}$, and ir, π and Y are the steady state values of interest rate, inflation and GDP, respectively.

C.3.6 Steady States

The steady states of variables are symmetric across home and foreign countries, and are solved by substituting the steady state variables into key equations. All prices are equal to 1, $\overline{er} = \overline{rer} = 1$,

$\overline{Q_H} = \overline{Q_F} = 1$, $\overline{\varepsilon_H} = \overline{\varepsilon_F} = 1$, $\overline{Z_H} = \overline{Z_F} = 1$ and $\overline{\theta_H} = \overline{\theta_F} = 1$. Some of the key relationships used in the log-linearization section are illustrated below.

The laws of motion for capital stock − equations (C.17) and (C.18) both imply

$$\overline{k} = (1-\delta)\overline{k} + \overline{I}, \tag{C.57}$$

the capital-labour ratio − equation (C.12) suggests

$$\frac{\overline{k}}{\overline{\ell}} = \frac{\kappa}{1-\kappa}\frac{\overline{w}}{\overline{R^K}}, \tag{C.58}$$

and the production function − equation (C.14) indicates

$$\overline{y} = \overline{k}^{\kappa}\overline{\ell}^{1-\kappa}. \tag{C.59}$$

Combining the three equations, I find the steady state investment-output ratio as:

$$\Lambda = \frac{\overline{I}}{\overline{y}} = \frac{\delta\overline{k}}{\overline{y}} = \left(\frac{\kappa}{1-\kappa}\right)^{1-\kappa}\overline{R^K}^{\kappa-1}\overline{w}^{1-\kappa}. \tag{C.60}$$

Next, I substitute steady state variables into equation (C.48) to get

$$1 = \beta[a'(1) + (1-\delta)] \Rightarrow \overline{R^K} = a'(1) = \frac{1}{\beta} - 1 + \delta. \tag{C.61}$$

Equation (C.10) yields the steady state relationship as:

$$\overline{MC} = \frac{1}{\kappa^{\kappa}(1-\kappa)^{1-\kappa}}\overline{w}^{1-\kappa}\overline{R^K}^{\kappa}. \tag{C.62}$$

equations (C.24) through (C.27) require that the formulas in the second brackets are equal to

zero at steady states, thus, substituting equation (C.62) delivers the following relationship,

$$1 = \frac{\varepsilon}{\varepsilon - 1} \frac{1}{\kappa^{\kappa}(1-\kappa)^{1-\kappa}} \overline{w}^{1-\kappa} \overline{R^K}^{\kappa}, \tag{C.63}$$

furthermore, dividing equation (C.60) by equation (C.63) and substituting equation (C.62) imply the investment share Λ as:

$$\Lambda = \delta\kappa \frac{\varepsilon - 1}{\varepsilon} \frac{\beta}{1 - \beta + \beta\delta}. \tag{C.64}$$

C.3.7 Log-linearization

The "hat" variables stand for the relative deviation from their steady states, and variables with no super-/subscript represent the corresponding steady states.

C.3.7.1 Monetary Policy

Log-linearizing equation (C.56) implies the following Taylor rule:

$$\widehat{ir_{i,t}} = \rho_{ir} \widehat{ir_{i,t-1}} + (1 - \rho_{ir})[\gamma_{\pi} \widehat{\pi_{i,t}} + \gamma_y \widehat{y_{i,t}}] + \widehat{\varepsilon^{ir}_{i,t}}, \tag{C.65}$$

and the risk-free interest rate − equation (C.55) gives the following Euler consumption equations:

$$\begin{cases} \widehat{C_{i,t}} = E_t \widehat{C_{i,t+1}} - \frac{1}{\sigma}(\widehat{ir_{i,t}} - E_t \widehat{\pi_{i,t+1}}), \text{ No Habit,} \\ \widehat{C_{i,t}} = \frac{1}{1+h} E_t \widehat{C_{i,t+1}} + \frac{h}{1+h} \widehat{C_{i,t-1}} - \frac{\lambda_h - h}{1+h}(\widehat{H_{i,t}} - \widehat{H_{i,t-1}}) - \frac{1-\lambda_h}{\sigma(1+h)}(\widehat{ir_{i,t}} - E_t \widehat{\pi_{i,t+1}}), \text{ External Habit,} \\ \widehat{C_{i,t}} = -\frac{h\beta}{1+h-h^2\beta} E_t \widehat{C_{i,t+2}} + \frac{1-h\beta-h^2\beta}{1+h-h^2\beta} E_t \widehat{C_{i,t+1}} - \frac{h}{1+h-h^2\beta} \widehat{C_{i,t-1}} + \dots \\ \qquad \frac{h\beta(\lambda_h - h)}{1+h-h^2\beta} \widehat{H_{i,t+1}} - \frac{(\lambda_h - h)(1+h\beta)}{1+h-h^2\beta} \widehat{H_{i,t}} + \frac{\lambda_h - h}{1+h-h^2\beta} \widehat{H_{i,t-1}} - \dots \\ \qquad \frac{(1-\lambda_h)(1-h\beta)}{\sigma(1+h-h^2\beta)}(\widehat{ir_{i,t}} - E_t \widehat{\pi_{i,t+1}}), \text{ Internal Habit.} \end{cases} \tag{C.66}$$

C.3.7.2 Money Demand

Equation (C.37) implies that at steady states, government transfer is 0. As a result, I find that $E_t M_{i,t+1} = M_{i,t}$ and $E_t\left(\frac{1}{M_{i,t+1}}\right) = \frac{1}{M_{i,t}}$.

The FOC − equation (C.41) can be rewritten as $\lambda_t = \chi \frac{1}{M_{i,t}} + \beta E_t \lambda_{t+1}$, and the iteration process implies

$$\lambda_t = \frac{\chi}{1-\beta}\frac{1}{M_{i,t}}. \tag{C.67}$$

Thus, the log-linearization of the money demand is given as:

$$\widehat{m_{i,t}} = \begin{cases} \frac{1-\beta}{\chi}\sigma\widehat{C_{i,t}}, \text{ No Habit,} \\ \frac{1-\beta}{\chi}\sigma\left(\frac{1}{1-\lambda_h}\widehat{C_{i,t}} - \frac{h}{1-\lambda_h}\widehat{C_{i,t-1}} - \frac{\lambda_h - h}{1-\lambda_h}\widehat{H_{i,t-1}}\right), \text{ External Habit,} \\ \frac{1-\beta}{\chi}\frac{\sigma}{1-\lambda_h - h\beta + h\lambda_h\beta}\Big[h\beta E_t\widehat{C_{i,t+1}} - (1+h^2\beta)\widehat{C_{i,t}} + h\widehat{C_{i,t-1}} - \dots \\ \qquad h\beta(\lambda_h - h)\widehat{H_{i,t}} + (\lambda_h - h)\widehat{H_{i,t-1}}\Big], \text{ Internal Habit,} \end{cases} \tag{C.68}$$

where $m_{i,t} = \frac{M_{i,t}}{P_{i,t}}$ is the real money demand.

C.3.7.3 Household decisions

The derivations on household and firms' decisions are based on the case of no habit persistence.

Log-linearizing equations (C.17) and (C.18) give

$$\widehat{k_{i,t}} = (1-\delta)\widehat{k_{i,t-1}} + \delta(\widehat{\varepsilon_{i,t}} + \widehat{I_{i,t}}), \text{ under CAC and IAC,} \tag{C.69}$$

and the capital utilization equation implies

$$\widehat{k^s_{i,t}} = \widehat{Z_{i,t}} + \widehat{k_{i,t-1}}. \tag{C.70}$$

Capital and investment decisions derived from equations (C.48) and (C.49) are

$$\begin{cases} \widehat{q_{i,t}} = E_t \left[-\sigma(\widehat{C_{i,t+1}} - \widehat{C_{i,t}}) + (1-\beta+\beta\delta)\widehat{r^K_{i,t+1}} + \beta(1-\delta)\widehat{q_{i,t+1}} + \dots \right. \\ \qquad \left. \beta B''(\delta)\delta^2(\widehat{I_{i,t+1}} - \widehat{k_{i,t}}) \right], \text{ under CAC,} \\ \widehat{q_{i,t}} = E_t \left[-\sigma(\widehat{C_{i,t+1}} - \widehat{C_{i,t}}) + (1-\beta+\beta\delta)\widehat{r^K_{i,t+1}} + \beta(1-\delta)\widehat{q_{i,t+1}} \right], \text{ under IAC,} \end{cases} \tag{C.71}$$

and

$$\begin{cases} 0 = \widehat{q_{i,t}} + \widehat{\varepsilon_{i,t}} - B''(\delta)\delta(\widehat{I_{i,t}} - \widehat{k_{i,t-1}}), \text{ under CAC,} \\ 0 = \widehat{q_{i,t}} + \widehat{\varepsilon_{i,t}} - A''(1)(\widehat{I_{i,t}} - \widehat{I_{i,t-1}}) + \beta A''(1)E_t \left[\widehat{I_{i,t+1}} - \widehat{I_{i,t}} \right], \text{ under IAC,} \end{cases} \tag{C.72}$$

where $r^K_{i,t} = R^K_{i,t}/P_{i,t}$ is the real rental cost and $\widehat{r^K_{i,t}} = \widehat{R^K_{i,t}} - \widehat{P_{i,t}}$.

The log-linearization of capital utilization − equation (C.42) is given as:

$$\widehat{r^K_{i,t}} = \frac{a''(1)}{a'(1)}\widehat{Z_{i,t}}. \tag{C.73}$$

C.3.7.4 Frims' Decisions

First, I define two sets of variables, namely, the world and relative variables. For example, variables $X^W_{i,t}$ and $X^R_{i,t}$ are defined as follows:

$$X^{i,W}_{i,t} = {X^i_{i,t}}^{\alpha} {X^j_{i,t}}^{1-\alpha}, \tag{C.74}$$

and

$$X^{i,R}_{i,t} = \frac{X^i_{i,t}}{X^j_{i,t}}. \tag{C.75}$$

Thus, log-linearizations of $X^W_{i,t}$ and $X^R_{i,t}$ imply

$$\widehat{X^{i,W}_{i,t}} = \alpha\widehat{X^i_{i,t}} + (1-\alpha)\widehat{X^j_{i,t}}, \tag{C.76}$$

and

$$\widehat{X_{i,t}^{i,R}} = \widehat{X_{i,t}^{i}} - \widehat{X_{i,t}^{j}}. \tag{C.77}$$

Log-linearizing the production function equation (C.9) leads to the following equation:

$$\widehat{y_{i,t}} = \widehat{\theta_{i,t}} + \kappa \widehat{k_{i,t}^{s}} + (1-\kappa)\widehat{\ell_{i,t}}. \tag{C.78}$$

The log-linearization of equation (C.50) − real rental cost gives

$$\widehat{r_{i,t}^{K}} = \begin{cases} \sigma\widehat{C_{i,t}} + \dfrac{1+\psi}{1-\kappa}\widehat{y_{i,t}} - \dfrac{1+\psi}{1-\kappa}\widehat{\theta_{i,t}} - \dfrac{1+\psi\kappa}{1-\kappa}\widehat{k_{i,t-1}}, \text{ with no capital utilization,} \\ \sigma\widehat{C_{i,t}} + \dfrac{1+\psi}{1-\kappa}\widehat{y_{i,t}} - \dfrac{1+\psi}{1-\kappa}\widehat{\theta_{i,t}} - \dfrac{1+\psi\kappa}{1-\kappa}(\widehat{Z_{i,t}} + \widehat{k_{i,t-1}}). \text{ with capital utilization.} \end{cases} \tag{C.79}$$

Applying the concepts of world and relative variables, the home and foreign consumption and income imply the following relationships:

$$\widehat{C_{H,t}} = \widehat{C_{H,t}^{W}} + (1-\alpha)\widehat{C_{t}^{R}} = \widehat{C_{H,t}^{W}} + (1-\alpha)\frac{1}{\sigma}\widehat{rer_{t}}, \tag{C.80}$$

$$\widehat{C_{F,t}} = \widehat{C_{F,t}^{W}} - (1-\alpha)\widehat{C_{t}^{R}} = \widehat{C_{F,t}^{W}} - (1-\alpha)\frac{1}{\sigma}\widehat{rer_{t}}, \tag{C.81}$$

$$\widehat{y_{H,t}} = \begin{cases} -\phi(\widehat{P_{H,t}^{H,W}} - \widehat{P_{H,t}^{W}}) + (1-\Lambda)\widehat{C_{H,t}^{W}} + \Lambda\widehat{I_{H,t}^{W}}, \text{ with no capital utilization,} \\ \dfrac{\Lambda}{\delta}(\dfrac{1}{\beta} - 1 + \delta)\widehat{Z_{H,t}} - \phi(\widehat{P_{H,t}^{H,W}} - \widehat{P_{H,t}^{W}}) + (1-\Lambda)\widehat{C_{H,t}^{W}} + \Lambda\widehat{I_{H,t}^{W}}, \text{ with capital utilization,} \end{cases} \tag{C.82}$$

$$\widehat{y_{F,t}} = \begin{cases} -\phi(\widehat{P_{F,t}^{F,W}} - \widehat{P_{F,t}^{W}}) + (1-\Lambda)\widehat{C_{F,t}^{W}} + \Lambda\widehat{I_{F,t}^{W}}, \text{ with no capital utilization,} \\ \dfrac{\Lambda}{\delta}(\dfrac{1}{\beta} - 1 + \delta)\widehat{Z_{F,t}} - \phi(\widehat{P_{F,t}^{F,W}} - \widehat{P_{F,t}^{W}}) + (1-\Lambda)\widehat{C_{F,t}^{W}} + \Lambda\widehat{I_{F,t}^{W}}, \text{ with capital utilization.} \end{cases} \tag{C.83}$$

The main difference between the models with and without capital utilization lies on the service

capital $k^s_{i,t}$ and capital utilization rate $Z_{i,t}$ contained in the budget constraint − equation (C.35) and the market clearing condition − equation (C.53). Thus, in the following derivations, I only demonstrate the case where capital utilization is included and provide the New Keynesian Phillips Curves with no capital utilization in the end due to similarities of the two cases.

I next rewrite equation (C.79) in terms of world prices, world consumption, world investment, real exchange rate and TFP as:

$$\widehat{r^K_{H,t}} = \begin{cases} \left[\sigma + (1-\Lambda)\frac{1+\psi}{1-\kappa}\right]\widehat{C^W_{H,t}} + \Lambda\frac{1+\psi}{1-\kappa}\widehat{I^W_{H,t}} + (1-\alpha)\widehat{rer_t} - \dots \\ \phi\frac{1+\psi}{1-\kappa}(\widehat{P^{H,W}_{H,t}} - \widehat{P^W_{H,t}}) - \frac{1+\psi}{1-\kappa}\widehat{\theta_{H,t}} - \frac{1+\psi\kappa}{1-\kappa}\widehat{k_{H,t-1}}, \text{ with no capital utilization,} \\ \left[\sigma + (1-\Lambda)\frac{1+\psi}{1-\kappa}\right]\widehat{C^W_{H,t}} + \Lambda\frac{1+\psi}{1-\kappa}\widehat{I^W_{H,t}} + (1-\alpha)\widehat{rer_t} - \phi\frac{1+\psi}{1-\kappa}(\widehat{P^{H,W}_{H,t}} - \dots \\ \widehat{P^W_{H,t}}) - \frac{1+\psi}{1-\kappa}\widehat{\theta_{H,t}} - \frac{1+\psi\kappa}{1-\kappa}\widehat{k_{H,t-1}} + \frac{1+\psi}{1-\kappa}\frac{\Lambda}{\delta}(\frac{1}{\beta} - 1 + \delta)\widehat{Z_{H,t}}, \text{ with capital utilization,} \end{cases} \tag{C.84}$$

$$\widehat{r^K_{F,t}} = \begin{cases} \left[\sigma + (1-\Lambda)\frac{1+\psi}{1-\kappa}\right]\widehat{C^W_{F,t}} + \Lambda\frac{1+\psi}{1-\kappa}\widehat{I^W_{F,t}} - (1-\alpha)\widehat{rer_t} - \dots \\ \phi\frac{1+\psi}{1-\kappa}(\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}) - \frac{1+\psi}{1-\kappa}\widehat{\theta_{F,t}} - \frac{1+\psi\kappa}{1-\kappa}\widehat{k_{F,t-1}}, \text{ with no capital utilization,} \\ \left[\sigma + (1-\Lambda)\frac{1+\psi}{1-\kappa}\right]\widehat{C^W_{F,t}} + \Lambda\frac{1+\psi}{1-\kappa}\widehat{I^W_{F,t}} - (1-\alpha)\widehat{rer_t} - \phi\frac{1+\psi}{1-\kappa}(\widehat{P^{F,W}_{F,t}} - \dots \\ \widehat{P^W_{F,t}}) - \frac{1+\psi}{1-\kappa}\widehat{\theta_{F,t}} - \frac{1+\psi\kappa}{1-\kappa}\widehat{k_{F,t-1}} + \frac{1+\psi}{1-\kappa}\frac{\Lambda}{\delta}(\frac{1}{\beta} - 1 + \delta)\widehat{Z_{F,t}}, \text{ with capital utilization,} \end{cases} \tag{C.85}$$

where Λ is the investment-income ratio at steady states.

I next log-linearize the marginal cost − equation (C.10) and real wage − equation (C.51) to have

$$\widehat{MC_{i,t}} = -\widehat{\theta_{i,t}} + (1-\kappa)\widehat{w_{i,t}} + \kappa\widehat{R^K_{i,t}}, \tag{C.86}$$

and

$$\widehat{w_{i,t}} = \frac{\psi\kappa}{1+\psi\kappa}\widehat{R^K_{i,t}} + \frac{1}{1+\psi\kappa}\widehat{P_{i,t}} + \frac{\sigma}{1+\psi\kappa}\widehat{C_{i,t}} + \frac{\psi}{1+\psi\kappa}\widehat{y_{i,t}} - \frac{\psi}{1+\psi\kappa}\widehat{\theta_{i,t}}. \tag{C.87}$$

Thus, substituting equation (C.87) to equation (C.86) gives

$$\widehat{MC_{i,t}} = \frac{\kappa(1+\psi)}{1+\psi\kappa}\widehat{R^K_{i,t}} + \frac{1-\kappa}{1+\psi\kappa}\widehat{P_{i,t}} + \frac{\sigma(1-\kappa)}{1+\psi\kappa}\widehat{C_{i,t}} + \frac{\psi(1-\kappa)}{1+\psi\kappa}\widehat{y_{i,t}} - \frac{1+\psi}{1+\psi\kappa}\widehat{\theta_{i,t}}. \tag{C.88}$$

Log-linearizing equations (C.24) $\sim$ (C.27), I get

$$\widehat{\tilde{p}^H_t(m_H)} - \widehat{P_{H,t}} = E_t\left[\sum_{\tau=1}^{\infty}(\alpha_c\beta)^\tau\widehat{\pi_{H,t+\tau}}\right] + (1-\alpha_c\beta)E_t\left[\sum_{\tau=0}^{\infty}(\alpha_c\beta)^\tau(\widehat{MC_{H,t+\tau}} - \widehat{P_{H,t+\tau}})\right], \tag{C.89}$$

$$\widehat{\tilde{p}^F_t(m_H)} - \widehat{P_{F,t}} = E_t\left[\sum_{\tau=1}^{\infty}(\alpha_c\beta)^\tau\widehat{\pi_{F,t+\tau}}\right] + (1-\alpha_c\beta)E_t\left[\sum_{\tau=0}^{\infty}(\alpha_c\beta)^\tau(\widehat{MC_{H,t+\tau}} - \widehat{P_{H,t+\tau}} - \widehat{rer_{t+\tau}})\right], \tag{C.90}$$

$$\widehat{\tilde{p}^H_t(m_F)} - \widehat{P_{H,t}} = E_t\left[\sum_{\tau=1}^{\infty}(\alpha_c\beta)^\tau\widehat{\pi_{H,t+\tau}}\right] + (1-\alpha_c\beta)E_t\left[\sum_{\tau=0}^{\infty}(\alpha_c\beta)^\tau(\widehat{MC_{F,t+\tau}} - \widehat{P_{F,t+\tau}} + \widehat{rer_{t+\tau}})\right], \tag{C.91}$$

$$\widehat{\tilde{p}^F_t(m_F)} - \widehat{P_{F,t}} = E_t\left[\sum_{\tau=1}^{\infty}(\alpha_c\beta)^\tau\widehat{\pi_{F,t+\tau}}\right] + (1-\alpha_c\beta)E_t\left[\sum_{\tau=0}^{\infty}(\alpha_c\beta)^\tau(\widehat{MC_{F,t+\tau}} - \widehat{P_{F,t+\tau}})\right]. \tag{C.92}$$

Log-linearization of equation (C.7) $-$ the price sub-index indicates

$$\widehat{\tilde{p}^i_t(m_j)} - \widehat{P_{j,t}} = \widehat{P^i_{j,t}} - \widehat{P_{j,t}} + \frac{\alpha_c}{1-\alpha_c}\widehat{\pi^i_{j,t}},\ i,j = H,F. \tag{C.93}$$

I subtract both sides of equation (C.88) by $\widehat{P_{i,t}}$, substitute $\widehat{C_{i,t}}$ $\widehat{y_{i,t}}$ by world consumption and income and replace the left hand sides of equations (C.89) $\sim$ (C.92) by the right hand side of

equation (C.93) to have

$$\frac{1-\alpha_c}{\alpha_c}(\widehat{P^H_{H,t}}-\widehat{P_{H,t}})+\widehat{\pi^H_{H,t}}=\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\frac{1-\kappa}{1+\kappa\psi}\times\ldots$$

$$\sum_{\tau=0}^{\infty}(\alpha_c\beta)^\tau E_t\left\{\begin{array}{l}[\sigma+(1-\Lambda)\psi]\widehat{C^W_{H,t+\tau}}+\psi\Lambda\widehat{I^W_{H,t+\tau}}+(1-\alpha)\widehat{rer_{t+\tau}}-\ldots\\ \psi\phi(\widehat{P^{H,W}_{H,t+\tau}}-\widehat{P^W_{H,t+\tau}})-\frac{1+\psi}{1-\kappa}\widehat{\theta_{H,t+\tau}}+\frac{\kappa(1+\psi)}{1-\kappa}\widehat{r^K_{H,t+\tau}}\end{array}\right\}+\ldots \tag{C.94}$$

$$\frac{1-\alpha_c}{\alpha_c}E_t\left[\sum_{\tau=1}^{\infty}(\alpha_c\beta)^\tau\widehat{\pi_{H,t+\tau}}\right],$$

$$\frac{1-\alpha_c}{\alpha_c}(\widehat{P^F_{H,t}}-\widehat{P_{F,t}})+\widehat{\pi^F_{H,t}}=\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\frac{1-\kappa}{1+\kappa\psi}\times\ldots$$

$$\sum_{\tau=0}^{\infty}(\alpha_c\beta)^\tau E_t\left\{\begin{array}{l}[\sigma+(1-\Lambda)\psi]\widehat{C^W_{H,t+\tau}}+\psi\Lambda\widehat{I^W_{H,t+\tau}}-[\alpha+\frac{\kappa}{1-\kappa(1+\psi)}]\widehat{rer_{t+\tau}}-\ldots\\ \psi\phi(\widehat{P^{H,W}_{H,t+\tau}}-\widehat{P^W_{H,t+\tau}})-\frac{1+\psi}{1-\kappa}\widehat{\theta_{H,t+\tau}}+\frac{\kappa(1+\psi)}{1-\kappa}\widehat{r^K_{H,t+\tau}}\end{array}\right\}+\ldots \tag{C.95}$$

$$\frac{1-\alpha_c}{\alpha_c}E_t\left[\sum_{\tau=1}^{\infty}(\alpha_c\beta)^\tau\widehat{\pi_{F,t+\tau}}\right],$$

$$\frac{1-\alpha_c}{\alpha_c}(\widehat{P^H_{F,t}}-\widehat{P_{F,t}})+\widehat{\pi^H_{F,t}}=\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\frac{1-\kappa}{1+\kappa\psi}\times\ldots$$

$$\sum_{\tau=0}^{\infty}(\alpha_c\beta)^\tau E_t\left\{\begin{array}{l}[\sigma+(1-\Lambda)\psi]\widehat{C^W_{F,t+\tau}}+\psi\Lambda\widehat{I^W_{F,t+\tau}}+[\alpha+\frac{\kappa}{1-\kappa(1+\psi)}]\widehat{rer_{t+\tau}}-\ldots\\ \psi\phi(\widehat{P^{H,W}_{F,t+\tau}}-\widehat{P^W_{F,t+\tau}})-\frac{1+\psi}{1-\kappa}\widehat{\theta_{F,t+\tau}}+\frac{\kappa(1+\psi)}{1-\kappa}\widehat{r^K_{F,t+\tau}}\end{array}\right\}+\ldots \tag{C.96}$$

$$\frac{1-\alpha_c}{\alpha_c}E_t\left[\sum_{\tau=1}^{\infty}(\alpha_c\beta)^\tau\widehat{\pi_{H,t+\tau}}\right],$$

$$\frac{1-\alpha_c}{\alpha_c}(\widehat{P^F_{F,t}}-\widehat{P_{F,t}})+\widehat{\pi^F_{F,t}}=\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\frac{1-\kappa}{1+\kappa\psi}\times\ldots$$

$$\sum_{\tau=0}^{\infty}(\alpha_c\beta)^\tau E_t\left\{\begin{array}{l}[\sigma+(1-\Lambda)\psi]\widehat{C^W_{F,t+\tau}}+\psi\Lambda\widehat{I^W_{F,t+\tau}}-(1-\alpha)\widehat{rer_{t+\tau}}-\ldots\\ \psi\phi(\widehat{P^{H,W}_{F,t+\tau}}-\widehat{P^W_{F,t+\tau}})-\frac{1+\psi}{1-\kappa}\widehat{\theta_{F,t+\tau}}+\frac{\kappa(1+\psi)}{1-\kappa}\widehat{r^K_{F,t+\tau}}\end{array}\right\}+\ldots \tag{C.97}$$

$$\frac{1-\alpha_c}{\alpha_c}E_t\left[\sum_{\tau=1}^{\infty}(\alpha_c\beta)^\tau\widehat{\pi_{F,t+\tau}}\right].$$

By discounting one period ahead of equations (C.94) $\sim$ (C.97) and subtracting from these

equations, I obtain

$$\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}(\widehat{P^H_{H,t}}-\widehat{P_{H,t}})+\widehat{\pi^H_{H,t}}-\beta E_t\left(\widehat{\pi^H_{H,t+1}}\right)=\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\frac{1-\kappa}{1+\kappa\psi}\times\dots$$

$$\left\{\begin{array}{l}[\sigma+(1-\Lambda)\psi]\widehat{C^W_{H,t}}+\psi\Lambda\widehat{I^W_{H,t}}+(1-\alpha)\widehat{rer_t}+\frac{\psi\Lambda}{\delta}(\frac{1}{\beta}-1+\delta)\widehat{Z_{H,t}}-\dots\\ \psi\phi(\widehat{P^{H,W}_{H,t}}-\widehat{P^W_{H,t}})-\frac{1+\psi}{1-\kappa}\widehat{\theta_{H,t}}+\frac{\kappa(1+\psi)}{1-\kappa}\widehat{r^K_{H,t}}\end{array}\right\}, \tag{C.98}$$

$$\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}(\widehat{P^F_{H,t}}-\widehat{P_{F,t}})+\widehat{\pi^F_{H,t}}-\beta E_t\left(\widehat{\pi^F_{H,t+1}}\right)=\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\frac{1-\kappa}{1+\kappa\psi}\times\dots$$

$$\left\{\begin{array}{l}[\sigma+(1-\Lambda)\psi]\widehat{C^W_{H,t}}+\psi\Lambda\widehat{I^W_{H,t}}-[\alpha+\frac{\kappa}{1-\kappa(1+\psi)}]\widehat{rer_t}+\frac{\psi\Lambda}{\delta}(\frac{1}{\beta}-1+\delta)\widehat{Z_{H,t}}-\dots\\ \psi\phi(\widehat{P^{H,W}_{H,t}}-\widehat{P^W_{H,t}})-\frac{1+\psi}{1-\kappa}\widehat{\theta_{H,t}}+\frac{\kappa(1+\psi)}{1-\kappa}\widehat{r^K_{H,t}}\end{array}\right\}, \tag{C.99}$$

$$\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}(\widehat{P^H_{F,t}}-\widehat{P_{H,t}})+\widehat{\pi^H_{F,t}}-\beta E_t\left(\widehat{\pi^H_{F,t+1}}\right)=\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\frac{1-\kappa}{1+\kappa\psi}\times\ldots$$

$$\left\{\begin{array}{l}[\sigma+(1-\Lambda)\psi]\widehat{C^W_{F,t}}+\psi\Lambda\widehat{I^W_{F,t}}+[\alpha+\frac{\kappa}{1-\kappa(1+\psi)}]\widehat{rer_t}+\frac{\psi\Lambda}{\delta}(\frac{1}{\beta}-1+\delta)\widehat{Z_{F,t}}-\ldots\\ \psi\phi(\widehat{P^{H,W}_{H,t}}-\widehat{P^W_{H,t}})-\frac{1+\psi}{1-\kappa}\widehat{\theta_{F,t}}+\frac{\kappa(1+\psi)}{1-\kappa}\widehat{r^K_{F,t}}\end{array}\right\}, \tag{C.100}$$

$$\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}(\widehat{P^F_{F,t}}-\widehat{P_{F,t}})+\widehat{\pi^F_{F,t}}-\beta E_t\left(\widehat{\pi^F_{F,t+1}}\right)=\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\frac{1-\kappa}{1+\kappa\psi}\times\ldots$$

$$\left\{\begin{array}{l}[\sigma+(1-\Lambda)\psi]\widehat{C^W_{F,t}}+\psi\Lambda\widehat{I^W_{F,t}}-(1-\alpha)\widehat{rer_t}+\frac{\psi\Lambda}{\delta}(\frac{1}{\beta}-1+\delta)\widehat{Z_{F,t}}-\ldots\\ \psi\phi(\widehat{P^{H,W}_{H,t}}-\widehat{P^W_{H,t}})-\frac{1+\psi}{1-\kappa}\widehat{\theta_{H,t}}+\frac{\kappa(1+\psi)}{1-\kappa}\widehat{r^K_{H,t}}\end{array}\right\}. \tag{C.101}$$

I then substitute $(\widehat{P^j_{i,t}}-\widehat{P_{i,t}})$ by the corresponding world and relative price differences along

with equations (C.84) and (C.85), and rewrite equations (C.98) $\sim$ (C.101) as:

$$\widehat{\pi^{H}_{H,t}} = \beta E_t\left(\widehat{\pi^{H}_{H,t+1}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c} \times \dots$$

$$\left\{\begin{array}{l} \left[\sigma + (1-\Lambda)\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\right]\widehat{C^{W}_{H,t}} + \Lambda\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\widehat{I^{W}_{H,t}} + \dots \\ (1-\alpha)\widehat{rer_t} - \left[1+\phi\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\right](\widehat{P^{H,W}_{H,t}} - \widehat{P^{W}_{H,t}}) - (1-\alpha)(\widehat{P^{H,R}_{H,t}} - \dots \\ \widehat{P^{R}_{t}}) - \frac{1+\psi}{1-\kappa}\widehat{\theta_{H,t}} - \frac{\kappa(1+\psi)}{1-\kappa}\widehat{k_{H,t-1}} + \frac{\Lambda}{\delta}(\frac{1}{\beta}-1+\delta)\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\widehat{Z_{H,t}} \end{array}\right\}, \tag{C.102}$$

$$\widehat{\pi^{F}_{H,t}} = \beta E_t\left(\widehat{\pi^{F}_{H,t+1}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c} \times \dots$$

$$\left\{\begin{array}{l} \left[\sigma + (1-\Lambda)\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\right]\widehat{C^{W}_{H,t}} + \Lambda\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\widehat{I^{W}_{H,t}} - \dots \\ \alpha\widehat{rer_t} - \left[1+\phi\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\right](\widehat{P^{H,W}_{H,t}} - \widehat{P^{W}_{H,t}}) + \dots \\ \alpha(\widehat{P^{H,R}_{H,t}} - \widehat{P^{R}_{t}}) - \frac{1+\psi}{1-\kappa}\widehat{\theta_{H,t}} - \frac{\kappa(1+\psi)}{1-\kappa}\widehat{k_{H,t-1}} + \frac{\Lambda}{\delta}(\frac{1}{\beta}-1+\delta)\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\widehat{Z_{H,t}} \end{array}\right\}, \tag{C.103}$$

$$\widehat{\pi^H_{F,t}} = \beta E_t\left(\widehat{\pi^H_{F,t+1}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c} \times \dots$$

$$\left\{\begin{array}{l} \left[\sigma + (1-\Lambda)\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\right]\widehat{C^W_{F,t}} + \Lambda\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\widehat{I^W_{F,t}} + \dots \\ \alpha\widehat{rer_t} - \left[1+\phi\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\right](\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}) - \dots \\ \alpha(\widehat{P^{F,R}_{F,t}} - \widehat{P^R_t}) - \frac{1+\psi}{1-\kappa}\widehat{\theta_{F,t}} - \frac{\kappa(1+\psi)}{1-\kappa}\widehat{k_{F,t-1}} + \frac{\Lambda}{\delta}(\frac{1}{\beta}-1+\delta)\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\widehat{Z_{F,t}} \end{array}\right\}, \quad \text{(C.104)}$$

$$\widehat{\pi^F_{F,t}} = \beta E_t\left(\widehat{\pi^F_{F,t+1}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c} \times \dots$$

$$\left\{\begin{array}{l} \left[\sigma + (1-\Lambda)\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\right]\widehat{C^W_{F,t}} + \Lambda\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\widehat{I^W_{F,t}} - \dots \\ (1-\alpha)\widehat{rer_t} - \left[1+\phi\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\right](\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}) + \dots \\ (1-\alpha)(\widehat{P^{F,R}_{F,t}} - \widehat{P^R_t}) - \frac{1+\psi}{1-\kappa}\widehat{\theta_{F,t}} - \frac{\kappa(1+\psi)}{1-\kappa}\widehat{k_{F,t-1}} + \frac{\Lambda}{\delta}(\frac{1}{\beta}-1+\delta)\frac{1-\kappa}{1+\kappa\psi}[\psi+\kappa(\frac{1+\psi}{1-\kappa})^2]\widehat{Z_{F,t}} \end{array}\right\}. \quad \text{(C.105)}$$

Given $\widehat{P^{H,W}_{H,t}} = \alpha\widehat{P^H_{H,t}} + (1-\alpha)\widehat{P^F_{H,t}}$, $\widehat{P^{F,W}_{F,t}} = \alpha\widehat{P^F_{F,t}} + (1-\alpha)\widehat{P^H_{F,t}}$, $\widehat{P^{H,R}_{H,t}} = \widehat{P^H_{H,t}} - \widehat{P^F_{H,t}}$, $\widehat{P^{F,R}_{F,t}} = \widehat{P^H_{F,t}} - \widehat{P^F_{F,t}}$, $\widehat{P^R_t} = \widehat{P^H_t} - \widehat{P^F_t}$ and the corresponding inflations $\widehat{\pi^j_{i,t}}$, I simplify equations (C.102) $\sim$ (C.105) into the following two the New Keynesian Phillips curves with capital utilization:

$$\widehat{\pi_{H,t}} = \beta E_t\left(\widehat{\pi_{H,t+1}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c} \times \dots$$

$$\left\{\begin{array}{l} \left[\sigma + (1-\Lambda)\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}\right][\alpha\widehat{C^W_{H,t}} + (1-\alpha)\widehat{C^W_{F,t}}] + \dots \\ \Lambda\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}[\alpha\widehat{I^W_{H,t}} + (1-\alpha)\widehat{I^W_{F,t}}] + \dots \\ 2\alpha(1-\alpha)\widehat{rer_t} + (2\alpha-1)\phi\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}(\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}) - \dots \\ \frac{1+\psi}{1-\kappa}[\alpha\widehat{\theta_{H,t}} + (1-\alpha)\widehat{\theta_{F,t}}] - \frac{\kappa(1+\psi)}{1-\kappa}\widehat{k^W_{H,t-1}} + \dots \\ \frac{\Lambda}{\delta}(\frac{1}{\beta} - 1 + \delta)\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}[\alpha\widehat{Z_{H,t}} + (1-\alpha)\widehat{Z_{F,t}}] \end{array}\right\}, \tag{C.106}$$

$$\widehat{\pi_{F,t}} = \beta E_t\left(\widehat{\pi_{F,t+1}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c} \times \dots$$

$$\left\{\begin{array}{l} \left[\sigma + (1-\Lambda)\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}\right][\alpha\widehat{C^W_{F,t}} + (1-\alpha)\widehat{C^W_{H,t}}] + \dots \\ \Lambda\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}[\alpha\widehat{I^W_{F,t}} + (1-\alpha)\widehat{I^W_{H,t}}] - \dots \\ 2\alpha(1-\alpha)\widehat{rer_t} + (2\alpha-1)\phi\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}(\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}) - \dots \\ \frac{1+\psi}{1-\kappa}[\alpha\widehat{\theta_{F,t}} + (1-\alpha)\widehat{\theta_{H,t}}] - \frac{\kappa(1+\psi)}{1-\kappa}\widehat{k^W_{F,t-1}} + \dots \\ \frac{\Lambda}{\delta}(\frac{1}{\beta} - 1 + \delta)\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}[\alpha\widehat{Z_{F,t}} + (1-\alpha)\widehat{Z_{H,t}}] \end{array}\right\}. \tag{C.107}$$

The dynamics of $\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}$ are discussed in the following subsection.

Similarly, the New Keynesian Phillips curves under the case where no capital utilization is included are

$$\widehat{\pi_{H,t}} = \beta E_t\left(\widehat{\pi_{H,t+1}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c} \times \ldots$$

$$\left\{\begin{array}{l} \left[\sigma + (1-\Lambda)\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}\right][\alpha\widehat{C^W_{H,t}} + (1-\alpha)\widehat{C^W_{F,t}}] + \ldots \\ \Lambda\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}[\alpha\widehat{I^W_{H,t}} + (1-\alpha)\widehat{I^W_{F,t}}] + \ldots \\ 2\alpha(1-\alpha)\widehat{rer_t} + (2\alpha-1)\phi\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}(\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}) - \ldots \\ \frac{1+\psi}{1-\kappa}[\alpha\widehat{\theta_{H,t}} + (1-\alpha)\widehat{\theta_{F,t}}] - \frac{\kappa(1+\psi)}{1-\kappa}\widehat{k^W_{H,t-1}} + \ldots \end{array}\right\}, \tag{C.108}$$

$$\widehat{\pi_{F,t}} = \beta E_t\left(\widehat{\pi_{F,t+1}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c} \times \ldots$$

$$\left\{\begin{array}{l} \left[\sigma + (1-\Lambda)\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}\right][\alpha\widehat{C^W_{F,t}} + (1-\alpha)\widehat{C^W_{H,t}}] + \ldots \\ \Lambda\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}[\alpha\widehat{I^W_{F,t}} + (1-\alpha)\widehat{I^W_{H,t}}] - \ldots \\ 2\alpha(1-\alpha)\widehat{rer_t} + (2\alpha-1)\phi\psi\frac{\psi(1-\kappa)^2+\kappa(1+\psi)^2}{(1-\kappa)\psi+\kappa(1-\kappa)\psi^2}(\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}) - \ldots \\ \frac{1+\psi}{1-\kappa}[\alpha\widehat{\theta_{F,t}} + (1-\alpha)\widehat{\theta_{H,t}}] - \frac{\kappa(1+\psi)}{1-\kappa}\widehat{k^W_{F,t-1}} + \ldots \end{array}\right\}. \tag{C.109}$$

C.3.7.5 Exchange Rate and Prices

equations (C.4) and (C.29) imply the following log-linearizing relationships:

$$\widehat{P_{H,t}} = \alpha \widehat{P^H_{H,t}} + (1-\alpha)\widehat{P^H_{F,t}},\ \widehat{P_{F,t}} = \alpha \widehat{P^F_{F,t}} + (1-\alpha)\widehat{P^F_{H,t}}, \tag{C.110}$$

$$\widehat{rer_t} = -\widehat{er_t} + \widehat{P_{H,t}} - \widehat{P_{F,t}}. \tag{C.111}$$

Given the definitions of the world and relative prices in equations (C.76) & (C.77), I derive the following relationships:

$$\begin{aligned}
\widehat{P^H_{H,t}} &= \widehat{P^{H,W}_{H,t}} + (1-\alpha)\widehat{P^{H,R}_{H,t}}, \\
\widehat{P^F_{H,t}} &= \widehat{P^{H,W}_{H,t}} - \alpha\widehat{P^{H,R}_{H,t}}, \\
\widehat{P^H_{F,t}} &= \widehat{P^{F,W}_{F,t}} + \alpha\widehat{P^{F,R}_{F,t}}, \\
\widehat{P^F_{F,t}} &= \widehat{P^{F,W}_{F,t}} - (1-\alpha)\widehat{P^{F,R}_{F,t}}, \\
\widehat{P_{H,t}} &= \widehat{P^W_{H,t}} + (1-\alpha)\widehat{P^R_t} = \widehat{P^W_{F,t}} + \alpha\widehat{P^R_t}, \\
\widehat{P_{F,t}} &= \widehat{P^W_{F,t}} - (1-\alpha)\widehat{P^R_t} = \widehat{P^W_{H,t}} - \alpha\widehat{P^R_t}.
\end{aligned}$$

Based on these relationships, I then have the following derivations:

$$\alpha(\widehat{P^H_{H,t}} - \widehat{P_{H,t}}) + (1-\alpha)(\widehat{P^H_{F,t}} - \widehat{P_{H,t}}) = 0, \tag{C.112}$$

$$\alpha(\widehat{P^F_{F,t}} - \widehat{P_{F,t}}) + (1-\alpha)(\widehat{P^F_{H,t}} - \widehat{P_{F,t}}) = 0, \tag{C.113}$$

and furthermore,

$$\alpha\left[(\widehat{P^{H,W}_{H,t}} - \widehat{P^W_{H,t}}) + (1-\alpha)(\widehat{P^{H,R}_{H,t}} - \widehat{P^R_t})\right] + (1-\alpha)\left[(\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}) + \alpha(\widehat{P^{F,R}_{F,t}} - \widehat{P^R_t})\right] = 0, \tag{C.114}$$

$$\alpha\left[(\widehat{P^{F,W}_{F,t}} - \widehat{P^W_{F,t}}) - (1-\alpha)(\widehat{P^{F,R}_{F,t}} - \widehat{P^R_t})\right] + (1-\alpha)\left[(\widehat{P^{H,W}_{H,t}} - \widehat{P^W_{H,t}}) - \alpha(\widehat{P^{H,R}_{H,t}} - \widehat{P^R_t})\right] = 0. \tag{C.115}$$

Next I find the relationships between $(\widehat{P_{H,t}^{H,W}} - \widehat{P_{H,t}^{W}})$ and $(\widehat{P_{F,t}^{F,W}} - \widehat{P_{F,t}^{W}})$ as:

$$
\begin{aligned}
&(\widehat{P_{H,t}^{H,W}} - \widehat{P_{H,t}^{W}}) + (\widehat{P_{F,t}^{F,W}} - \widehat{P_{F,t}^{W}}) = \dots \\
&\left[\alpha(\widehat{P_{H,t}^{H}} - \widehat{P_{H,t}}) + (1-\alpha)(\widehat{P_{F,t}^{H}} - \widehat{P_{H,t}})\right] + \left[\alpha(\widehat{P_{F,t}^{F}} - \widehat{P_{F,t}}) + (1-\alpha)(\widehat{P_{H,t}^{F}} - \widehat{P_{F,t}})\right] = 0,
\end{aligned}
\tag{C.116}
$$

which implies that $-(\widehat{P_{H,t}^{H,W}} - \widehat{P_{H,t}^{W}}) = (\widehat{P_{F,t}^{F,W}} - \widehat{P_{F,t}^{W}})$.

Regrouping either equation (C.114) or (C.115) gives

$$
\alpha(1-\alpha)\left[(\widehat{P_{H,t}^{H,R}} - \widehat{P_{t}^{R}}) + (\widehat{P_{F,t}^{F,R}} - \widehat{P_{t}^{R}})\right] = (2\alpha-1)(\widehat{P_{F,t}^{F,W}} - \widehat{P_{F,t}^{W}})
$$

$$
\Downarrow
$$

$$
\widehat{P_{F,t}^{F,W}} - \widehat{P_{F,t}^{W}} = \frac{\alpha(1-\alpha)}{2\alpha-1}\left[(\widehat{P_{H,t}^{H,R}} - \widehat{P_{t}^{R}}) + (\widehat{P_{F,t}^{F,R}} - \widehat{P_{t}^{R}})\right]. \tag{C.117}
$$

I next subtract equation (C.103) from (C.102) as well as (C.105) from (C.104) to get

$$
\widehat{\pi_{H,t}^{H,R}} - \beta E_t(\widehat{\pi_{H,t+1}^{H,R}}) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}(\widehat{P_{H,t}^{H,R}} - \widehat{P_{t}^{R}}) = \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\widehat{rer_t}, \tag{C.118}
$$

$$
\widehat{\pi_{F,t}^{F,R}} - \beta E_t(\widehat{\pi_{F,t+1}^{F,R}}) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}(\widehat{P_{F,t}^{F,R}} - \widehat{P_{t}^{R}}) = \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\widehat{rer_t}, \tag{C.119}
$$

and combine the two equations to have

$$
\begin{aligned}
&\left[(\widehat{\pi_{H,t}^{H,R}} - \widehat{\pi_{t}^{R}}) + (\widehat{\pi_{F,t}^{F,R}} - \widehat{\pi_{t}^{R}})\right] - \beta E_t\left[(\widehat{\pi_{H,t+1}^{H,R}} - \widehat{\pi_{t+1}^{R}}) + (\widehat{\pi_{F,t+1}^{F,R}} - \widehat{\pi_{t+1}^{R}})\right] + \dots \\
&\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\left[(\widehat{P_{H,t}^{H,R}} - \widehat{P_{t}^{R}}) + (\widehat{P_{F,t}^{F,R}} - \widehat{P_{t}^{R}})\right] = \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\widehat{rer_t} - 2\widehat{\pi_{t}^{R}} + 2\beta E_t\widehat{\pi_{t+1}^{R}}.
\end{aligned}
\tag{C.120}
$$

Substituting equation (C.117) into (C.120) generates a dynamic relationship as:

$$
\begin{aligned}
&\Delta\left(\widehat{P_{F,t}^{F,W}} - \widehat{P_{F,t}^{W}}\right) - \beta E_t\Delta\left(\widehat{P_{F,t+1}^{F,W}} - \widehat{P_{F,t+1}^{W}}\right) + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\left(\widehat{P_{F,t}^{F,W}} - \widehat{P_{F,t}^{W}}\right) \\
&= \frac{\alpha(1-\alpha)}{2\alpha-1}\left[\frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\widehat{rer_t} - \widehat{\pi_{t}^{R}} + \beta E_t\widehat{\pi_{t+1}^{R}}\right].
\end{aligned}
\tag{C.121}
$$

Given the symmetry assumption across the monopolistic firms, using equations (C.20), (C.22), (C.23) and (C.33), I then derive the log-linearization of the income identity equation as:

$$\widehat{y_{H,t}} = \begin{cases} \phi(\widehat{P^{F,W}_{F,t}} - \widehat{P^{W}_{F,t}}) + (1-\Lambda)\widehat{C^{W}_{H,t}} + \Lambda\widehat{I^{W}_{H,t}}, \text{ with no capital utilization,} \\ \phi(\widehat{P^{F,W}_{F,t}} - \widehat{P^{W}_{F,t}}) + (1-\Lambda)\widehat{C^{W}_{H,t}} + \Lambda\widehat{I^{W}_{H,t}} + \frac{\Lambda}{\delta}(\frac{1}{\beta} - 1 + \delta)Z_{H,t}, \text{ with capital utilization,} \end{cases} \tag{C.122}$$

$$\widehat{y_{F,t}} = \begin{cases} -\phi(P^{F,W}_{F,t} - P^{W}_{F,t}) + (1-\Lambda)\widehat{C^{W}_{F,t}} + \Lambda\widehat{I^{W}_{F,t}}, \text{ with no capital utilization,} \\ -\phi(P^{F,W}_{F,t} - P^{W}_{F,t}) + (1-\Lambda)\widehat{C^{W}_{F,t}} + \Lambda\widehat{I^{W}_{F,t}} + \frac{\Lambda}{\delta}(\frac{1}{\beta} - 1 + \delta)Z_{F,t}, \text{ with capital utilization.} \end{cases} \tag{C.123}$$

C.3.7.6 International Risk Sharing

Under complete asset market assumption, the risk sharing condition (Backus-Smith condition 1993) suggests that

$$\frac{U'_{F,t}}{U'_{H,t}} = rer_t, \tag{C.124}$$

thus,

$$\begin{cases} (\frac{C_{F,t}}{C_{H,t}})^{-\sigma} = rer_t, \text{ No Habit,} \\ (\frac{C_{F,t} - \lambda_h H_{F,t}}{C_{H,t} - \lambda_h H_{H,t}})^{-\sigma} = rer_t, \text{ External Habit,} \\ \frac{(C_{F,t} - \lambda_h H_{F,t})^{-\sigma} - h\beta E_t(C_{F,t+1} - \lambda_h H_{F,t+1})^{-\sigma}}{(C_{H,t} - \lambda_h H_{H,t})^{-\sigma} - h\beta E_t(C_{H,t+1} - \lambda_h H_{H,t+1})^{-\sigma}} = rer_t, \text{ Internal Habit.} \end{cases} \tag{C.125}$$

Log-linearizing equation (C.125) implies:

$$\begin{cases} \sigma(\widehat{C_{H,t}} - \widehat{C_{F,t}}) = \widehat{rer_t}, \text{ No Habit,} \\ \frac{\sigma}{1-\lambda_h}(\widehat{C_{H,t}} - \widehat{C_{F,t}}) - \frac{h\sigma}{1-\lambda_h}(\widehat{C_{H,t-1}} - \widehat{C_{F,t-1}}) - \frac{\lambda_h - h}{1-\lambda_h}(\widehat{H_{H,t-1}} - \widehat{H_{F,t-1}}) = \widehat{rer_t}, \text{ External Habit,} \\ \frac{\sigma}{(1-h\beta)(1-\lambda_h)}\Big[(1+h^2\beta)(\widehat{C_{H,t}} - \widehat{C_{F,t}}) - h\beta E_t(\widehat{C_{H,t+1}} - \widehat{C_{F,t+1}}) - h(\widehat{C_{H,t-1}} - \widehat{C_{F,t-1}}) + \dots \\ \qquad h\beta(\lambda_h - h)(\widehat{H_{H,t}} - \widehat{H_{F,t}}) - (\lambda_h - h)(\widehat{H_{H,t-1}} - \widehat{H_{F,t-1}})\Big] = \widehat{rer_t}, \text{ Internal Habit.} \end{cases} \tag{C.126}$$

C.3.8 Shocks

Both the TFP and investment efficiency shocks are assumed to respectively follow an AR(1) process as:

$$\widehat{\theta_{i,t}} = \rho^A \widehat{\theta_{i,t-1}} + \widehat{\epsilon^A_{i,t}}, \tag{C.127}$$

and

$$\widehat{\varepsilon_{i,t}} = \rho^I \widehat{\varepsilon_{i,t-1}} + \widehat{\epsilon^I_{i,t}}, \tag{C.128}$$

where $\widehat{\epsilon^A_{i,t}} \sim N(0, \sigma^A_{i,t})$ and $\widehat{\epsilon^I_{i,t}} \sim N(0, \sigma^I_{i,t})$. Following CKM (2010), I set $\rho^A = 0.75$, $\sigma^A_{i,t} = 0.012$, $corr(\widehat{\epsilon^A_{H,t}}, \widehat{\epsilon^A_{F,t}}) = 0.45$, and $\rho^I = 0.79$, $\sigma^I_{i,t} = 0.0173$, $corr(\widehat{\epsilon^I_{H,t}}, \widehat{\epsilon^I_{F,t}}) = 0.19$. The TFP and investment efficiency shocks are assumed to be independent.

The monetary shock in the Taylor rule has an AR(1) representation as:

$$\widehat{\varepsilon^{ir}_{i,t}} = \rho^{ir} \widehat{\varepsilon^{ir}_{i,t}} + \widehat{\epsilon^{ir}_{i,t}}, \tag{C.129}$$

where $\widehat{\epsilon^{ir}_{i,t}} \sim N(0, \sigma^{ir}_{i,t})$. During calibration, I follow the method proposed by CKM (2002) to allow variations in the standard deviation of monetary shocks to match the empirical volatility of income. Meanwhile, I set $\rho^{ir} = 0.7$ and $corr(\widehat{\epsilon^{ir}_{H,t}}, \widehat{\epsilon^{ir}_{F,t}}) = 0.5$. Monetary shock is also assumed to be independent from other shocks.

The calibrated model consists of equations (C.65), (C.66), (C.68) $\sim$ (C.73), (C.78) $\sim$ (C.81), (C.106) $\sim$ (C.109), (C.120) $\sim$ (C.123) and (C.126) $\sim$ (C.129).