Productivity or Demand?
Identifying Sources of Fluctuations in Small Open Economies *

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Abstract

Business cycles in emerging markets are different than in developed economies: consumption fluctuates more than output and trade balance is strongly counter-cyclical. The two leading theories to account for those differences are: (i) permanent productivity shocks and (ii) interest rate shocks. I show movements in terms of trade can distinguish between these two theories. Expansionary productivity shocks reduce the relative price of country's exports. Expansionary interest rate shocks raise the relative price of country's exports. Application of this method to Mexican fluctuations in the 1990s yields results consistent with leading methods based on Bayesian inference. The difference is that in this paper identification relies on instantaneous response of price rather than long-run properties of quantities. Identification can be based on relatively short time series and the method can be applied to real-time events. The method is best suited for cases when manufacturing constitutes large portion of both exports and imports.

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1 Introduction

Empirically, the business cycle experiences of emerging economies are very different than those of developed economies. In emerging economies the volatility of consumption is greater than the volatility of output and trade balance is strongly counter-cyclical. These two facts constitute a puzzle for standard business cycle model of a small open economy. Recent research has suggested business cycles in emerging economies are driven by fundamentally different sources than the transitory productivity shocks of the real business cycle model. The two leading theories point at two alternative sources of fluctuations: (1) persistent productivity (supply) vs. (2) interest rate (demand) shocks. Assessing relative importance of the two sources of fluctuations has proven to be difficult and remains the major question in studies of emerging markets. This paper explores the impact of the two shocks on country's terms of trade and uses cyclical behavior of terms of trade to quantify contribution of the two shocks to fluctuations in emerging economies.

Specifically, I provide the theoretical result that expansionary productivity and interest rate shocks affect country's terms of trade differently. I consider a version of the workhorse two-country international business cycle framework of Backus et al. (1994) with incomplete markets (henceforth BKK). One of the countries is small. Terms of trade is the price of country's exports relative to the price of its imports. Small country's terms of trade improve if the expansionary shock is the decline in the interest rate. Conversely, terms of trade deteriorate if the expansionary shock is to domestic productivity.

The intuition behind this result relies on the movements in relative demand and supply for domestically produced goods. Domestic productivity shocks are supply shocks: a positive shock increases supply of domestic goods. If the shock is persistent, the wealth effect increases demand for the domestic good, but the increase is limited if domestic and foreign goods are imperfect substitutes. Hence, an expansionary productivity shock will result in excess supply of domestic goods and a deterioration in terms of trade. Interest rate shocks are demand shocks: a fall in the interest rate makes today's consumption cheaper and increases country's demand for all goods. If consumers prefer domestic goods the relative demand for domestic goods will increase. Because the supply is unaffected, this will result in terms of trade improvement.

The first contribution of this paper is to propose a new method of distinguishing between two major theories of fluctuations in emerging economies. The first theory, introduced by Aguiar and Gopinath (2007), argues that the stochastic process of total factor productivity (TFP) is fundamentally different in emerging economies. They introduce shocks to *trend* growth of TFP, in addition to standard transitory shocks to its level. The second theory, put forth by Neumeyer and Perri (2005) and Uribe and Yue (2006), argues the major source of fluctuations are *interest rate* shocks. Both theories have been successful in accounting for the excess volatility of consumption and the counter-cyclicality of net exports. This paper shows the two theories differ in their predictions about the cyclicality of the terms of trade.

The second contribution is a quantitative assessment of productivity and interest rate shocks during two important business cycles events in emerging economies–the Tequila crisis in Mexico and the Asian crisis in Korea—using the behavior of the terms of trade as an important source of information. Application of this method to Mexico yields results that are very similar to the ones in Garcia-Cicco et al. (2010), while using only the data for the period 1990-2005. Major drivers of the fluctuations appear to be interest rate shocks, while the role of permanent productivity shocks is negligible. One has to be careful, however, in extending the conclusions from earlier studies to other emerging economies. The analysis of the fluctuations in Korea reveals quite the opposite: the major source of fluctuations are permanent productivity shocks. The empirical difference between the two countries is in the cyclical movements of the terms of trade.

The third contribution of this paper is to our understanding of the role of interest rate shocks in small open economies. Interest rate shocks do not generate substantial output movements in a partial equilibrium model of a small open economy (see e.g. Mendoza (1991) and Correia et al. (1995)). Researchers attempted to reconcile this result with an important role of interest rate movements in emerging markets. The most common approach was to introduce financial frictions into the model or have the country spread respond to productivity shocks[1]. This paper shows that if we allow for domestic and foreign goods to be imperfect substitutes, interest rate fluctuations can have substantial impact on movements in output in an otherwise frictionless model. The logic is the following. If interest rate declines, demand for today's consumption increases. If domestic and foreign goods are imperfect substitutes, domestic output must increase for the consumption to increase. In such framework, interest rate shocks affect output via a demand channel.

Related literature

This paper is related to a number of earlier studies that explored the role of exogenous movements in commodity prices in fluctuations in developing countries (e.g. Mendoza (1995), Kose (2002), Kraay and Ventura (2007), Broda (2004) and Hevia and Nicolini (2009)). Mendoza (1995) and Kose (2002) argued that terms of trade fluctuations account for a substantial fraction of movements in output in less developed countries. Recently, however, Kehoe and Ruhl (2008) showed that if output is measured as chain-weighted real GDP, then exogenous terms of trade movements have no first-order effects on productivity and on real GDP. This paper takes a different route - it treats export and import price deflators as endogenous and explores whether their movements can tell us something about the sources of fluctuations in open economies. Application of that approach in practice will require a decomposition of terms of trade into the component driven by exogenous movements in world prices of commodities and the residual (endogenous) term that can be used as the source of identification. In general, the approach is most appropriate for countries (and time periods), where majority of trade (both exports and imports) is in manufacturing, such as e.g. Mexico during the period 1990-2007, which is studied in Section 6.

The second line of research this paper is related to attempts to quantify the contribution of productivity and interest rate shocks to fluctuations in emerging economies. Recently, Garcia-Cicco et al. (2010) evaluated empirically the role of the two shocks in Argentina and Mexico exploiting the

[1] See e.g. Neumeyer and Perri (2005), Uribe and Yue (2006), Oviedo (2005)

long-term properties of trade balance[2]. In this paper identification relies on instantaneous response of price rather than long-run properties of quantities. Because of that, successful identification can be based on relatively short time series and the method can be applied to real-time events. However, since the method relies on endogenous movements in terms of trade, it is best suited for cases when manufacturing constitutes large portion of both exports and imports.

This paper is also related to studies that attempt to identify the non-stationary component of productivity growth. In order to identify the permanent component of the TFP process one needs in practice a very long time series (Garcia-Cicco et al. (2010), Aguiar and Gopinath (2007)). Needless to say, such series are not easily available, especially in developing countries. An alternative is to look at the data through the lenses of a structural model and use additional moments to identify permanent shocks. In a seminal paper, Cochrane (1994) showed that different (in magnitude) response of consumption can be one such moment. However, the response of consumption turns out to be very similar in models with permanent productivity shocks and in models with country risk shocks, making it hard to distinguish between the two. In this paper I showed that the responses of the terms of trade (in addition to consumption) can be used as an identifying moment which allows for distinguishing between country risk and permanent productivity shocks.

2 Productivity and Demand Shocks in Emerging Economies

Emerging economies are different: the volatility of consumption is greater than the volatility of output and trade balance is strongly counter-cyclical. This is different both from the behavior of developed economies and from the predictions of the standard model of business cycles in a small open economy (see e.g. Mendoza (1991), Correia et al. (1995), Schmitt-Grohe and Uribe (2003)). Aguiar and Gopinath (2007) and Neumeyer and Perri (2005) provide thorough documentation of the behavior of both consumption and trade balance in emerging markets. This section will review the information gathered in earlier studies. It will also discuss in more detail the two major views

[2] See also Chang and Fernandez (2010) for a similar analysis of fluctuations in Mexico between 1980 and 2002.

of fluctuations in emerging markets: permanent productivity shocks and interest rate shocks. In addition to that, it will document some regularities about the behavior of the terms of trade in emerging as well as developed economies which will serve as a motivation for further analysis in this paper.

2.1 Data

Appendix A describes in details the data sources, time periods covered for each country as well as the exact definition of each series. The statistics in this section are calculated using annual data from World Development Indicators.

National Accounts GDP is Gross Domestic Product in constant prices. Consumption is the households' private consumption in constant prices. The ratio of net exports to GDP has been calculated in current prices. All three series are from the World Bank's World Development Indicators.

Terms of Trade Since the focus of this paper is on cyclical movements in terms of trade, a more detailed description of the terms of trade data is in order. The most common measure of a country's terms of trade is the ratio of the exports' and imports' price deflators. Unfortunately, in some cases raw materials or commodities account for a large fraction of either exports or imports. In such cases fluctuations in the price deflators may be affected by exogenous movements in world prices of those materials (e.g. export price deflator of Russia may be affected by the movements in the world price of oil). This is a potential problem, since in the paper I focus on the *endogenous* response of terms of trade to different shocks.

Ideal solution is to use the data on terms of trade in manufacturing sector only. Since such data is not available for most countries, I construct a measure of manufacturing terms of trade using the procedure in Backus and Crucini (2000). The details of the construction of those series are provided in Appendix A. In addition to that I exclude countries where raw materials or commodities constituted on average at least 50% of exports or imports. The data on manufacturing share in trade is from the World Bank World Development Indicators.

Countries The analysis in this section covers 10 developed and 10 emerging economies. The developed economies are: Austria, Belgium, Canada, Denmark, Finland, Netherlands, Portugal, Spain, Sweden and Switzerland. The emerging economies are: Brazil, China, Israel, Korea, Malaysia, Mexico, Philippines, Singapore, South Africa and Thailand. These are the countries that met the criterion of having manufacturing be at least 50% of their exports and imports. In general, the manufacturing share is fairly large in both groups, exceeding 75% for both exports and imports (columns 6 and 7 in Tables 1 and 2 provide information about the average share of manufacturing in exports and imports for each country during the time period studied).

2.2 Business Cycle Statistics

Tables 1 and 2 present business cycle statistics for the sample of developed and emerging economies. The statistics in the first 4 columns are quite similar to those reported in earlier studies. There are a few important observations to be made. First, emerging markets are more volatile. The average standard deviation of output growth among developed countries is 1.79%, while it is 3.46% in emerging markets. This difference could be simply assigned to larger shocks, if it weren't for a different behavior of other variables: consumption, trade balance and terms of trade.

The second column in each table displays the the standard deviation of consumption growth. Consumption in emerging markets is more volatile than output. This finding is one of the most puzzling one. A consumption smoothing motive should induce household to increase consumption by less than the increase in output during expansions which would result in lower volatility. Excess volatility of consumption is a manifestation of something more than lack of access to financial instruments to smooth consumption. In an extreme case of financial autarky, movements in consumption would be of the same magnitude as movements in output, never larger. Not surprisingly, this feature of emerging markets has been the subject of numerous studies[3].

The third feature of emerging markets business cycles is that net exports are strongly counter-cyclical. In developed economies, the correlation between net exports and output also tends to be negative, but this relationship is much less pronounced. The strong counter-cyclicality of net exports is a manifestation of the fact that recessions in emerging economies are typically associated with sudden stops of capital inflows and reversals of trade balance and current account.

Table 1: Business Cycle Statistics: Emerging Economies

	Volatility		Correlations		Mnf share	
	$\sigma(\Delta y)$	$\frac{\sigma(\Delta c)}{\sigma(\Delta y)}$	$\rho(\frac{nx}{y}, \Delta y)$	$\rho(TOT, \Delta y)$	EX	IM
Brazil	2.00	1.47	0.12	0.13	0.55	0.70
Israel	2.76	0.96	-0.45	-0.56	0.88	0.81
Korea	4.15	1.54	-0.71	-0.31	0.92	0.64
Malaysia	4.67	1.19	-0.60	0.48	0.75	0.84
Mexico	3.32	1.81	-0.35	0.57	0.78	0.81
South	1.97	1.07	-0.50	0.37	0.51	0.74
Thailand	5.31	1.00	-0.67	0.33	0.73	0.77
Singapore	3.80	1.04	-0.32	0.31	0.83	0.81
Turkey	4.33	1.15	-0.65	-0.13	0.78	0.68
Philippines	2.25	0.45	-0.20	0.04	0.75	0.73
Average	3.46	1.17	-0.43	0.12	0.75	0.75
Median	3.56	1.11	-0.48	0.22	0.76	0.76

[3]A non-exclusive list includes Aguiar and Gopinath (2007), Neumeyer and Perri (2005), Uribe and Yue (2006), Mendoza and Yue (2008), Boz et al. (2008), Oviedo (2005)

Table 2: Business Cycle Statistics: Developed Economies

	Volatility		Correlations		Mnf share	
	$\sigma(\Delta y)$	$\frac{\sigma(\Delta c)}{\sigma(\Delta y)}$	$\rho(\frac{nx}{y}, \Delta y)$	$\rho(TOT, \Delta y)$	EX	IM
Austria	1.07	0.95	-0.21	-0.50	0.86	0.82
Belgium	1.34	0.68	0.02	-0.65	0.80	0.78
Canada	1.97	0.76	0.42	-0.02	0.63	0.83
Denmark	1.48	1.01	-0.42	-0.18	0.63	0.74
Finland	3.46	0.91	0.86	-0.08	0.84	0.73
Netherlands	1.39	0.88	-0.38	-0.10	0.62	0.70
Portugal	2.17	0.83	-0.37	-0.35	0.84	0.73
Spain	1.54	1.05	-0.13	-0.37	0.77	0.73
Sweden	2.25	1.02	0.75	-0.07	0.82	0.77
Switzerland	1.26	0.71	0.37	-0.55	0.93	0.84
Average	1.79	0.88	0.09	-0.29	0.77	0.77
Median	1.51	0.90	-0.05	-0.27	0.81	0.76

2.2.1 Cyclicality of terms of trade

The correlation between terms of trade and GDP is depicted in column 5 of the two tables. On average, terms of trade tend to be pro-cyclical in emerging economies and counter-cyclical in developed countries. The average correlation between GDP and terms of trade is -0.29 among the developed countries and 0.14 in emerging economies. The pro-cyclicality of terms of trade in emerging economies found in this paper is consistent with results reported in a number of previous studies[4]. Notice that those numbers are unlikely to be driven by movements in commodity prices, since for most of the countries manufacturing is a substantial portion of both exports and imports. On average, the share of manufacturing is about 77% in both emerging and in developed economies. The three notable differences are Korea, Israel and Turkey—all three with counter-cyclical terms of trade. This different behavior will be exploited in Section 6.

2.3 Productivity and interest rate shocks

The two theories of emerging markets business cycles that attracted most attention in the literature rely on (i) permanent shocks to productivity or, alternatively, on (ii) shocks to interest rates. The first one was introduced by Aguiar and Gopinath (2007) and further studied in Boz et al. (2008). They introduce exogenous shocks to the growth rate of TFP (trend shocks) in addition to the standard transitory shocks to its level. The trend shock makes a big difference, because it affects permanent income more than it affects current output. The second approach argues that external shocks to the interest rate are the major source of fluctuations. These shocks are coupled with frictions in the domestic production sector and the combination of the two acts as the propagation mechanism to the standard, transitory shocks to total factor productivity (TFP). Prominent studies in this group include Neumeyer and Perri (2005) or Uribe and Yue (2006). Both types of models were successful in accounting for the excess volatility of consumption and the counter-cyclicality of net exports (they did not address the behavior of the terms of trade).

[4] The classic reference here is Mendoza (1995)

The two approaches have been evaluated empirically by Garcia-Cicco et al. (2010) and Chang and Fernandez (2010). They used Bayesian methods to estimate parameters of a model which encompassed both the *trend* and the *interest rate* shocks. The advantage of these methods is that they use widely collected data series: consumption, output and trade balance. The disadvantage is that identification relies on long-run properties of aggregate quantities. Because of that Garcia-Cicco et al. (2010) used a century long time series for their identification combined with an implicit assumption of parameter stability. The use of shorter time period in Chang and Fernandez (2010) resulted in the likelihood function of their model being bi-modal, with each mode corresponding to a different parametrization—one consistent with the *stochastic trend*, the other consistent with the *country risk* model.

2.4 Terms of trade as the source of identification

This paper exploits the behavior of terms of trade to learn about relative importance of productivity and interest rate shocks in emerging markets. As will be shown in the next section, the two types of shocks proposed in previous studies—permanent productivity shocks and interest rate shocks—differ in the their prediction about the behavior of the terms of trade. Because of that, the identification in this paper relies on the instantaneous response of the price rather than long-run properties of quantities as in Garcia-Cicco et al. (2010) and Chang and Fernandez (2010).

Such approach has two advantages. First, since it relies on short-term properties of time series, it does not require the assumption of parameter stability applied to a model that covers a period of 100 years. One can allow, for example, for regime changes. There may be periods when the dominant source of fluctuations are productivity shocks, while in other periods the dominant source would be shocks to interest rate. The second advantage is that the behavior of terms of trade can be used as a source of identification with real-time data.

The main disadvantage is that we require additional information - the series on terms of trade. The most common measure of country's terms of trade is the ratio of the export and import price deflators. The identifying assumption behind the analysis done in this paper is that movements in terms of trade are endogenous. This is likely to be true if manufacturing accounts for a substantial fraction of both exports and imports. It is more problematic, however, if raw materials and commodities are a large portion of trade.

The empirical analysis in the paper focuses on fluctuations in two emerging economies, Mexico and Korea, between 1990 and 2005. In both countries, manufacturing has accounted for majority of trade: over 75% of both exports and imports in Mexico and over 60% of imports and over 90% of exports in Korea.

3 Model

The benchmark model is a version of the BKK framework (Backus et al. (1994)) with incomplete markets. There are two countries. Country 1 is a small open economy (e.g. Mexico) and country 2 is the composite of its trading partners. Time is discrete. In each period t, the world is hit by an exogenous shock $s_t \in S$ where S is potentially infinite. In a given time period t the state of the economy is given by the history of the exogenous shocks: $s^t := (s_1, s_2, ..., s_t)$. The unconditional probability of state s^t occurring is $\pi(s^t|s_0)$. The probability of s^t conditional on being in state s^{t-1} is $\pi(s^t|s^{t-1})$. All allocations and prices are functions of the state s^t.

Technology In each country there are two types of firms . The f-firms produce the aggregate consumption/investment good. The production of the final good requires inputs of goods a and b. Country 1 is the sole producer of good a and country 2 is the sole producer of good b. The final good technology features constant elasticity of substitution between those two intermediates:

$$G^j(A^j(s^t), B^j(s^t)) = \left[\omega_a^j A^j(s^t)^{\frac{\eta-1}{\eta}} + \omega_b^j B^j(s^t)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \qquad j = 1, 2 \tag{3.1}$$

where η is the elasticity of substitution and $j = 1, 2$ denotes a country. The weights $\omega_a^1 = 1 - \omega_b^1$ and $\omega_b^2 = 1 - \omega_a^2$ reflect home bias in each country. Country 2 is assumed to be large and will be modeled as such by assuming that ω_b^2 is close to 1 (similar way to make one of the countries large is used e.g. in Gali and Monacelli (2005)). The final goods sector is competitive. An f-firm in country 1 solves the following static profit maximization problem:

$$\max_{A^1(s^t),B^1(s^t)} G^1(A^1(s^t), B^1(s^t)) - q^a(s^t)A^1(s^t) - q^b(s^t)B^1(s^t) \tag{3.2}$$

where q^i is the price of intermediate $i \in \{a, b\}$ in units of the aggregate consumption good of country 1 (which is chosen to be the numeraire). An f-firm in country 2 solves the following profit maximization problem:

$$\max_{A^2(s^t),B^2(s^t)} p(s^t) \cdot G^2(A^2(s^t), B^2(s^t)) - q^a(s^t)A^2(s^t) - q^b(s^t)B^2(s^t) \tag{3.3}$$

where p is the price of the aggregate good in country 2 in units of the aggregate good of country 1. All of the above quantities are expressed in per capita terms.

Intermediates a and b are produced by competitive intermediate goods producers - the i-firms. The i-firms in country 1 produce good a and the i-firms in country 2 produce good b. Production requires capital and labor and uses Cobb-Douglas technology, which mimics the specification of aggregate output in Aguiar and Gopinath (2007):

$$Y^j(s^t) = e^{z_t^j} \left(K^j(s^{t-1})N_j\right)^\alpha \left(\Gamma_t^j \ell^j(s^t) \cdot N_j\right)^{1-\alpha}, \qquad j = 1, 2 \tag{3.4}$$

where z_t^j is a transitory productivity shock, Γ_t^j is the stock of labor augmenting technology and N_j is the population size of the country. N_1 is normalized to 1 while N_2 will be calibrated. The laws of motion for the exogenous productivity shocks are given by equations below.

$$\mathbf{z_t} = \mathbf{A}\mathbf{z_{t-1}} + \epsilon_\mathbf{t}^\mathbf{z}, \qquad \epsilon_\mathbf{t}^\mathbf{z} \sim N(\mathbf{0}, \mathbf{\Sigma}) \tag{3.5}$$

$$\Gamma_t^2 = e^{\mu_g} \cdot \Gamma_{t-1}^2 \tag{3.6}$$

$$\Gamma_t^1 = e^{g_t}\Gamma_{t-1}^1 \cdot \left(\frac{\Gamma_{t-1}^2}{\Gamma_{t-1}^1}\right)^\lambda, \qquad \lambda \in (0, 1] \tag{3.7}$$

$$g_t = (1 - \rho^g)\mu_g + \rho^g g_{t-1} + \epsilon^g{}_t, \qquad \epsilon^g{}_t \sim N(0, \sigma^g) \tag{3.8}$$

where $\mathbf{z} := [z^1, z^2]'$ and both eigenvalues of matrix $\mathbf{A}$ are less than 1 in absolute terms. For simplicity I assumed that the TFP in country 2 grows at a constant rate μ_g. The growth rate of TFP in country 1, in contrast, is stochastic and follows a mean reverting process with mean μ_g. In addition to the stochastic growth rate, there is also a convergence term $(\Gamma^2_{t-1}/\Gamma^1_{t-1})^\lambda$ which ensures the de-trended model is stationary. In practice, λ will be made very small, so that the g-shock has permanent effects[5]. The variables that contain the trend have been denoted with upper-case letters. The variables that do not contain the trend, have been denoted with lower-case letters.

The i-firms rent capital and labor services from the households. The profit maximization of an intermediate good producer in country 1 is:

$$\max q^a(s^t)Y^1(s^t) - r^1_t(s^t)K^1(s^{t-1}) - W^1_t(s^t)\ell^1(s^t)$$

subject to:

$$Y^1(s^t) \leq e^{z^1_t} K^1(s^{t-1})^\alpha \left(\Gamma^1_t \ell^1(s^t)\right)^{1-\alpha}$$

The profit maximization of an intermediate good producer in country 2 is identical, except that the typical firm produces good b:

$$\max q^b(s^t)Y^2(s^t) - \left[r^2_t(s^t)K^2(s^{t-1}) - W^2_t(s^t)\ell^2(s^t)\right] \cdot N_2$$

subject to:

$$Y^2(s^t) \leq e^{z^2_t} \left(K^2(s^{t-1})N_2\right)^\alpha \left(\Gamma^2_t \ell^2(s^t)N_2\right)^{1-\alpha}$$

Both the rental rates and wages are in units of the country 1 aggregate good.

Preferences and budget constraint Each country is inhabited by a stand-in household with preferences over consumption and hours worked having the following utility representation:

$$U = \sum_t \sum_{s^t} \prod_{i=1}^{t} \beta(s_i)\pi(s^t)u(C^j(s^t), \ell^j(s^t)), \tag{3.9}$$

where s^t is the history of the aggregate state of the world up to and including time t, C^j is the consumption, ℓ^j is the household's labor supply in country j, all per capita. Household provides capital and labor services to the i-firms. The discount rate is allowed to be stochastic. In the

[5] See Nguyen (2011) for a similar way to ensure stationarity in a 2-country model with trend shocks.

quantitative analysis, country 2 will be assumed large and fluctuations in its discount rate will result in the movements in interest rate (exogenous, from the point of view of country 1 - the emerging economy).

The two countries can trade a non-contingent bond with each other. The bond is denominated in units of good b, which is the good produced in country 2. The budget constraint for the household in country 1 is:

$$\begin{aligned} C^1(s^t) + I^1(s^t) \leq\, & r^1(s^t)K^1(s^{t-1}) + W^1(s^t)\ell^1(s^t) \\ & + q^b(s^t)D^1(s^t) - R^1(s^{t-1})q^b(s^t)D^1(s^{t-1}) + T^1(s^t) \end{aligned} \tag{3.10}$$

where $R^1(s^{t-1})$ is the gross interest rate the household in country 1 pays on the debt issued in period $t-1$, W denotes the wage, r denotes rental rate on capital, D denotes the stock of debt and T is the lump-sum transfer the stand-in household receives from the government. The constraint for the household in country 2 is very similar:

$$\begin{aligned} p(s^t)C^2(s^t) + p(s^t)I^2(s^t) \leq\, & r^2(s^t)K^2(s^{t-1}) + W^2(s^t)\ell^2(s^t) \\ & + q^b(s^t)D^2(s^t) - R^2(s^{t-1})q^b(s^t)D^2(s^{t-1}) \end{aligned} \tag{3.11}$$

Interest rate and country risk shocks Interest rate movements are endogenous in the model. However, because country 1 is small, essentially all the movements in the interest rate result from the shocks in country 2. Hence, from the perspective of country 1, these movements are exogenous. There are two exogenous shocks in country 2: (i) the productivity shock z and (ii) preference shock β. A positive productivity shocks will raise the interest rate as it increases the marginal product of capital. A positive preference shock, makes the stand-in household more patient, which will drive down the equilibrium interest rate.

The interest rate that agents in country 1 face is the product of the world (i.e. country 2) interest rate and the country risk. Country risk is introduced by assuming the government in country 1 can randomly "steals" part of the debt repayment and give it back to the household in a lump-sum fashion:

$$T^1(s^t) = R^1(s^{t-1})q^b(s^t)D^1(s^{t-1}) \cdot \tau(s^t)$$

The country spread is defined as:

$$CS(s^{t-1}) = E_t \frac{1}{1-\tau(s^t)}$$

so that $R^1(s^t) = R^2(s^t) \cdot CS(s^t)$.

Resource constraints The accumulation of capital stock incurs adjustment cost of the standard quadratic form:

$$K^j(s^t) = (1-\delta)K^j(s^{t-1}) + I^j(s^t) - \frac{\phi}{2}\left(\frac{K^j(s^t)}{K^j(s^{t-1})} - e^{\mu_g}\right)^2 K^j(s^{t-1}),$$

Investment and consumption good are obtained from the production of the final good:

$$G^j(A^j(s^t), B^j(s^t)) = C^j(s^t) + I^j(s^t)$$

The interest rate in the model is endogenously determined by the market clearing condition for debt:

$$D^1(s^t) + N_2 \cdot D^2(s^t) = 0 \tag{3.12}$$

The final condition is that the world demand for the intermediates equals the world supply of the intermediates:

$$\begin{aligned} A^1(s^t) + A^2(s^t) \cdot N_2 &= Y^1(s^t) && \text{(intermediates produced in country 1)} \\ B^1(s^t) + B^2(s^t) \cdot N_2 &= Y^2(s^t) && \text{(intermediates produced in country 2)} \end{aligned}$$

3.1 Stationary version of the model

Introduction of the trend growth makes the model non-stationary. In order to solve it we need to make it stationary. We can do that by de-trending appropriate variables. As in Aguiar and Gopinath (2007), a de-trended variable X_t will be defined as:

$$x_t := \frac{X_t}{\Gamma_{t-1}^2}$$

In general we can de-trend all the variables by the cumulative stock of labor-augmenting technology either in country 1 (Γ^1_{t-1}) or in country 2 (Γ^2_{t-1}). I chose to de-trend using the latter one. This choice is both arbitrary and innocuous and the major benefit of de-trending by Γ^2_{t-1} is that 3 inter-temporal Euler conditions will be easier to work with. For notational simplicity, in the remainder of the paper I will drop the dependence of allocations on the exogenous state s^t. The stand-in household's utility maximization problem in country 1 is now:

$$\max E_0 \sum_t \beta^t \cdot f(\Gamma^2_{t-1}) \cdot u(c^1_t, 1-\ell^1_t)$$

subject to:

$$\begin{aligned} c^1_t + i^1_t &\leq r^1_t k^1_t + w^1_t \ell_t + e^{\mu_g} q^b_t d^1_{t+1} - R^1_t q^b_t d^1_t \\ e^{\mu_g} k^1_{t+1} &= (1-\delta)k^1_t + i^1_t - \frac{\phi}{2}\left(e^{\mu_g}\frac{k^1_{t+1}}{k^1_t} - e^{\mu_g}\right)^2 k^1_t \end{aligned}$$

The function $f(\cdot)$ will depend on the specification of the utility function[6]. In order to ensure that the law of motion for debt in the linearized version of the model does not exhibit a unit root I will assume a small quadratic adjustment cost on debt[7].

The outputs of the i-firms in a normalized form in the two countries are as follows.

$$y^1_t = e^{z^1_t}\left(k^1_t\right)^{\alpha}\left(e^{\pi_t} e^{g_t} \ell^1_t\right)^{1-\alpha} \tag{3.13}$$

$$y^2_t = e^{z^2_t}\left(k^2_t \cdot N_2\right)^{\alpha}\left(e^{\mu_g} \ell^2_t \cdot N_2\right)^{1-\alpha} \tag{3.14}$$

where $\pi_t := \log\left(\Gamma^1_{t-1}/\Gamma^2_{t-1}\right)$ is a new state variable in the stationary economy. The law of motion for π_t is:

$$\pi_t = g_t - \mu_g + (1-\lambda)\,\pi_{t-1} \tag{3.15}$$

[6]For example, if utility is a standard CRRA over a Cobb-Douglas composite between consumption and leisure, $u(c, 1-\ell) = \frac{1}{1-\sigma} \cdot [c^{\eta}(1-\ell)^{1-\eta}]^{1-\sigma}$, then $f(\Gamma) = \Gamma^{\eta(1-\sigma)}$. If we assume the household has preferences represented by a quasi-linear utility of Greenwood et al. (1988) (often referred to as GHH preferences), $u(C_t, 1-\ell_t) = \frac{1}{1-\sigma} \cdot [C_t - \psi\Gamma_{t-1}\ell_t\nu]^{1-\sigma}$, then $f(\Gamma) = \Gamma^{1-\sigma}$

[7]This specification follows Neumeyer and Perri (2005). See Schmitt-Grohe and Uribe (2003) for different ways to ensure stationarity in the law of motion for external debt in small open economy models.

The expression above makes it clear that in order for the model to be stationary we need $\lambda > 0$. In practice λ will be set to a very small number, effectively making the trend shocks permanent. Market clearing conditions for the intermediates a and b are:

$$y_t^1 = a_t^1 + a_t^2 \cdot N_2 \tag{3.16}$$

$$y_t^2 = b_t^1 + b_t^2 \cdot N_2 \tag{3.17}$$

The definition of the competitive equilibrium in this economy is standard.

Definition 3.1 (Equilibrium)**.** An equilibrium consists of prices $(q^a(s^t),\ q^b(s^t),\ p(s^t))$, $(R^j(s^t),\ w^j(s^t),\ r^j(s^t))_{j=1,2}$ and allocations $(c^j(s^t),\ i^j(s^t),\ k^j(s^t),\ d^j(s^t),\ \ell^j(s^t),\ a^j(s^t),\ b^j(s^t),\ y^j(s^t))$, such that

1. Given prices, allocations solve the households' and firms' maximization problems

2. Goods markets clear

3. Bond market clears

3.2 Solution Method

The system is solved using linear approximation of equilibrium conditions around the steady state. Note that one of the state variables—π_t—is close to having a unit root for small values of λ. In order for the trend shock to have permanent effects, λ must be set to a very small number (in practice around 0.001). For such a small value of λ there is a risk that the approximation error associated with local solution may be substantial if we simulate the model, because the system will tend to be far away from the steady state. For that reason, all the moments are calculated using analytical formulas based on the technical appendix in Aguiar and Gopinath (2007) and on Burnside (1998).

4 Parameter values and characterization of equilibrium

4.1 National Accounts and Prices

National Accounts The total absorption in country j, in period t, can be expressed as a function of A_t^j and B_t^j. Since the Armington aggregator $G(\cdot)$ in (3.1) is homogenous of degree one, we will have the following equality holding in equilibrium in country 1:

$$C_t^1 + I_t^1 = q_t^a A_t^1 + q_t^b B_t^1$$

Net exports of country 1 in units of the aggregate consumption are given by:

$$NX_t^1 = q_t^a A_t^2 \cdot N_2 - q_t^b B_t^1$$

Adding net exports on both sides of the previous equation we get the national accounts identity in units of the aggregate consumption good:

$$C_t^1 + I_t^1 + NX_t^1 = q_t^a (A_t^1 + A_t^2 \cdot N_2) = q_t^a Y_t^1$$

Real GDP in country j is $Y_t^j = e^{z_t^j} K_t^{j\,\alpha} \left(\Gamma_t^j \ell_t^j\right)^{1-\alpha}$, while real consumption and investment expenditures are C_t^j and I_t^j. Trade balance as a fraction of GDP is calculated in constant prices (just as it was in the data). In country 1, it is:

$$\frac{NX_t^1}{GDP_t^1} = \frac{q_t^a A_t^2 \cdot N_2 - q_t^b B_t^1}{q_t^a Y_t^1}$$

Table below summarizes the mapping between national accounts in the data and in the model in country 1.

Terms of trade and real exchange rate Terms of trade of country j is defined as the price of its export good relative to the price of its import good. The terms of trade in the two countries are given by:

$$TOT^1 = \frac{q^a}{q^b}, \qquad TOT^2 = 1/TOT^1$$

Table 3: Mapping between the model and the data

Variable	**Model**	**Data**
Output	Y_t^1	GDP in constant prices
Consumption	C_t^1	C in constant prices
Investment	I_t^1	I in constant prices
Net Exports / GDP	$\frac{q_t^a A_t^2 \cdot N_2 - q_t^b B_t^1}{q_t^a Y_t^1}$	NX/GDP, both in current prices

Real exchange rate is the price of foreign aggregate good in units of domestic aggregate good (an increase in real exchange rate corresponds to real appreciation). Since the aggregate good in country 1 is the numeraire, the real exchange rates are simply:

$$rx^1 = p, \qquad rx^2 = 1/p$$

Import ratio First order condition from the profit maximization of the final good producers yields the following relationship between terms of trade and the ratio of imports to domestic non-traded production:

$$TOT^1 = \frac{\omega_a^1}{\omega_b^1}\left(\frac{b_t^1}{a_t^1}\right)^{1-\rho} = \frac{\omega_a^1}{\omega_b^1}\left(\frac{b_t^1}{y_t^1 - a_t^2 \cdot N_2}\right)^{1-\rho} = \frac{\omega_a^1}{\omega_b^1} ir_t^{1-\rho} \tag{4.1}$$

where $ir_t := b_t^1/(y_t^1 - a_t^2)$ is the import ratio. This condition will help us pin down the home bias parameter for the quantitative analysis.

4.2 Preferences and parameter values

In the benchmark analysis I use GHH preferences (Greenwood et al. (1988)) with the following functional form in the de-trended economy[8]:

$$u(c, \ell) = \frac{(c - \psi \ell^\nu)^{1-\sigma}}{1-\sigma}$$

[8] In the original problem the utility function takes the form $U = \frac{1}{1-\sigma}[C_t - \psi \Gamma_{t-1}^{usa} \ell_t^\nu]^{1-\sigma}$.

Two reasons motivate this choice. First, both Garcia-Cicco et al. (2010) and Chang and Fernandez (2010) use GHH preferences in their studies, hence the results will be more comparable. Second, for the model with Cobb-Douglas preferences to generate excess relative volatility of consumption, labor must be negatively correlated with output, which makes this specification less appealing.

The model is quarterly and the discount factor β is set to 0.98. The risk aversion parameter σ is set to 2. The parameter ν determines the elasticity of labor supply given by $\frac{1}{\nu-1}$. Following Neumeyer and Perri (2005) I set $\nu = 1.6$. The value of ψ and N_2 are set jointly so that $\bar{\ell} = 0.33$ in both countries: $\psi = 1.45$ and $N_2 = 47$.

Table 4: Benchmark parameter values

Preferences	
Discount factor	$\beta = 0.98$
Risk aversion parameter	$\sigma = 2.50$
Labor weight (GHH preferences)	$\psi = 1.45$
Labor curvature (GHH preferences)	$\nu = 1.60$
Technology	
Elasticity of substitution	$\eta = 1.5$
Depreciation	$\delta = 0.025$
Capital share	$\alpha = 0.32$
Steady state growth	$\mu_g = 0.006$
Import ratio	$ir^1 = 0.45$
	$ir^2 = 0.01$
Debt adjustment cost	$\kappa = 0.00001$
Investment adjustment cost	$\phi = 10.0$

NOTES: Import ratios, for a given η, will have implications for the home bias parameters ω_a^1 and ω_b^1, from (4.1), assuming the terms of trade in steady state is 1. Smaller import ratio will correspond to a larger home bias. The values in the table (given the value of $\eta = 1.5$) correspond to $\omega_a^1 = 0.63$ and $\omega_b^2 = 0.98$.

An important parameter is η—the elasticity of substitution between domestic and foreign inputs. There is some dispute in the literature about the most appropriate value for that elasticity. In general, the values suggested for the United States vary between 1 and 2 (see Backus et al. (1994)), but Heathcote and Perri (2002) use an even smaller value of 0.9. In the benchmark analysis I set $\eta = 1.5$[9]. This parameter, together with the average ratio of imports to domestic non-traded production will determine the value of the home bias parameter. For Mexico that ratio is on average 0.45 and implies that $\omega_a^1 = 0.63$[10]. Because Mexican exports are a very small fraction of the World's output, I set the import ratio in country 2 to be 0.01, implying $\omega_b^2 = 0.96$. Finally, depreciation rate is set to 0.025 and capital share in the production function is set to $\alpha = 0.32$.

4.3 Impulse response analysis

First, let's look at impulse responses to exogenous shocks to total factor productivity and to the country spread. Figures 1 and 2 plot responses of $\frac{C}{GDP}$ and $\frac{NX}{GDP}$ to 1% expansionary deviation in each of the three exogenous shocks in the small country. The figures are both in spirit and in magnitude very similar to Figure 3 on page 88 in Aguiar and Gopinath (2007). Consumption responds stronger than GDP both to permanent productivity shock and to the country spread shock. Trade balance deteriorates in response to both permanent productivity shock and to country spread shock. These two results simply confirm the success of the two types of shocks in accounting for the two salient features of fluctuations in emerging economies: (i) excess volatility of consumption and (ii) counter-cyclicality of trade balance. Figure 3, however, plots the response of the terms of trade to the same three exogenous shocks. It is the behavior of the terms of trade that can distinguish between trend shocks and interest rate shocks. Terms of trade deteriorate in response to expansionary trend shock and improve in response to expansionary shock to the country spread.

4.3.1 Intuition behind different effects of trend and interest rate shocks

The intuition behind these different responses can be gained by looking at Figure 4. The top row plots responses to an expansionary trend shocks. The bottom row plots responses to an

[9]This is the value used in Backus et al. (1994) Results are also provided for the elasticity of substitution equal to $\eta = 0.9$, the same used in Heathcote and Perri (2002), and for the "upper bound" of $\eta = 2$.

[10]Import ratio specified in (4.1) is calculated in the data as Imports / (GDP - Exports), all at constant prices.

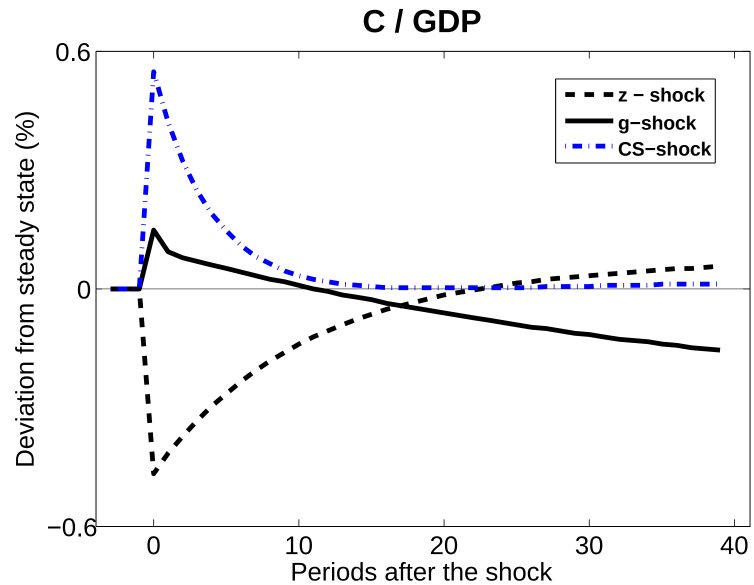

Figure 1: Impulse responses from the model - C/GDP
NOTES: Y-axis denotes % deviation from the steady state following a 1% (expansionary) deviation in each of the exogenous shocks

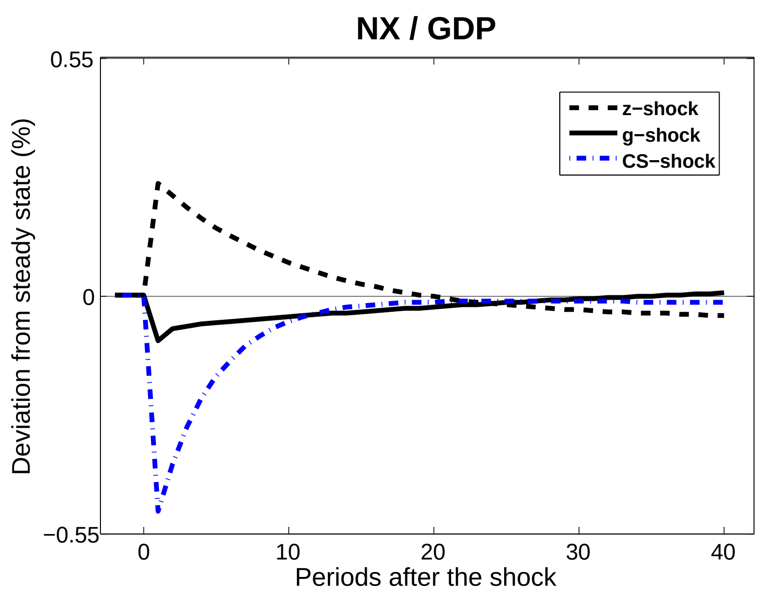

Figure 2: Impulse responses from the model - NX/GDP
NOTES: Y-axis denotes deviation from the steady state following a 1% (expansionary) deviation in each of the exogenous shocks

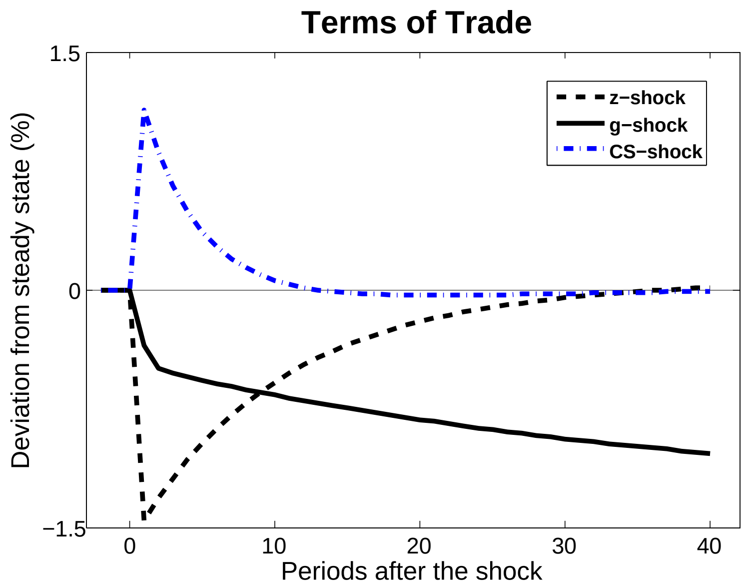

Figure 3: Impulse responses from the model - Terms of Trade
NOTES: Y-axis denotes % deviation from the steady state following a 1% (expansionary) deviation in each of the exogenous shocks

expansionary shock to country spread. Both shocks have been normalized so that on impact the response of output in the small country is 1%. The graphs in the first column plot the responses of the two intermediates—domestic and foreign—used in the production of aggregate good in the small country. The graphs in the middle column plot the responses of the two intermediates used in the production of aggregate good in the large country. The graphs in the third column plot the responses of the outputs of the two intermediates (i.e. of GDPs in the two countries).

First note that none of the shocks in the small country has any quantitative effect on neither the production of the good produced in the large country nor on its use in the large country. This is the manifestation of the fact that shocks in the small country will not affect the world-wide demand for nor the supply of the good produced in large country.

What about the world-wide demand for and supply of the good produced in the small country? Consider first the expansionary country spread shock in the small country. A fall in the country spread reduces today's price of consumption, which increases the small country's demand for the two intermediates. While the impact on the aggregate demand for the large country good is negligible,

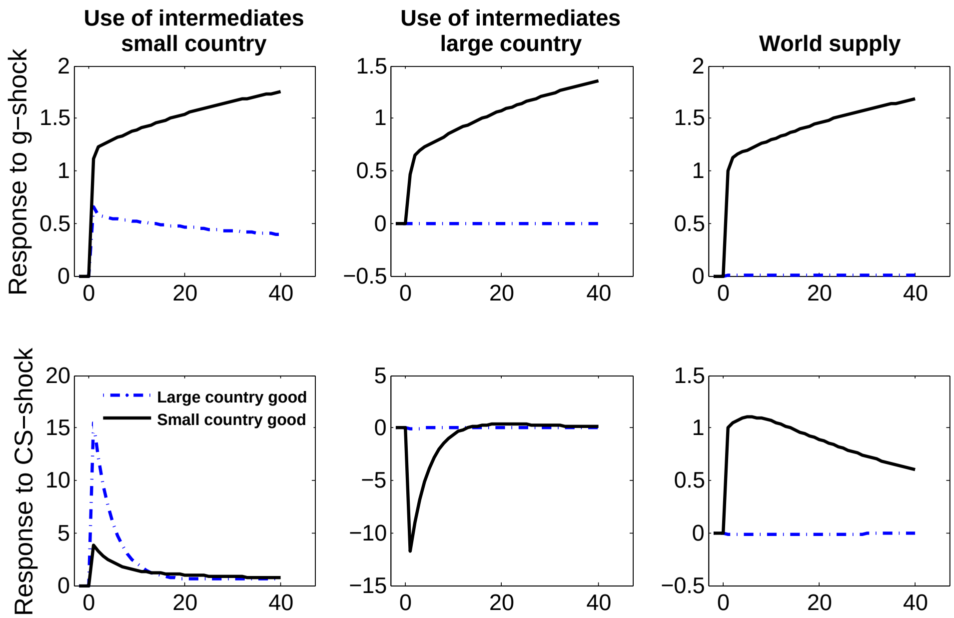

Figure 4: Impulse responses from the model - production and use of the intermediate goods
NOTES: Y-axis denotes log-deviation from the steady state. Magnitude of each shock has been normalized so that on impact the response of GDP in the small country is 1.

the impact on the aggregate demand for domestic good is substantial. As a result, relative demand for the domestic good rises. Next, consider the supply effects. Country spread shock does not increase productivity. Since capital is pre-installed, the only way for the output to increase on impact is to increase the labor supply. With GHH preferences, labor supply depends only on wage. But wage will only increase, if the price of the good produced increases. Hence, the relative price of the local good must increase in response to a fall in the small country spread.

Next consider the expansionary trend shock. First, it is a productivity shock. Second, a positive trend shocks raises permanent income, which increases the demand for the final consumption/investment good. The impact it will have on the relative demand for domestic good, however, depends on the elasticity of substitution. The larger is the complementarity between the two intermediates, the more limited is the resulting increase in demand for the domestic good. In practice, as Figures 3 and 4 suggest, even if the two goods are gross substitutes, the relative price of the domestic good may decline on impact (all the figures in this section are drawn assuming the elasticity of substitution $\eta = 1.5$).

5 Business cycles in Mexico and Korea: 1990-2005

Figure 5 plots the series of GDP growth, consumption growth and the ratio of trade balance to GDP in Mexico and Korea during the time period 1990-2005. In both countries the fluctuations in the growth rate of GDP are substantial with a distinct crisis episode in each case: the Tequila crisis in 1995 in Mexico and the Asian crisis in Korea in 1998.

Fluctuations in Mexico and Korea also have two features that are quite common in emerging economies and constitute a puzzle for standard models of business cycle fluctuations. The first is excess volatility of consumption. Tequila crisis in Mexico featured a 6% drop in output and a 10% drop in private consumption. The Asian crisis in Korea featured a 7% drop in output and a 14% drop in private consumption. The second distinct characteristic of fluctuations in emerging markets that is present both in Mexico and in Korea is strong counter-cyclicality of trade balance. This counter-cyclicality is mostly driven by reversals of trade balance during crisis. During the Tequila crisis in Mexico, trade balance to GDP ratio turned from -5% in 1994 to +3% in 1995. During the Asian crisis in Korea, that ratio turned from -3% in 1996 to 0 in 1997 and to +12% in 1998. Hence, the behavior of aggregate quantities was very similar in the two countries. Next section will explore the behavior of an important international price - the country's terms of trade.

5.1 Terms of Trade in Mexico and in Korea

The framework described in Section 3 treats terms of trade movements as endogenous. When taking the model to the data we must be careful about the measure of terms of trade used. The most common measure of terms of trade is the ratio of export and import price deflators. However, these price deflators can be substantially affected by exogenous movements in prices of commodities, if such commodities constitute a substantial fraction of trade. In general, the larger is the share of manufacturing in exports and imports, the more relevant are the export and import price deflators

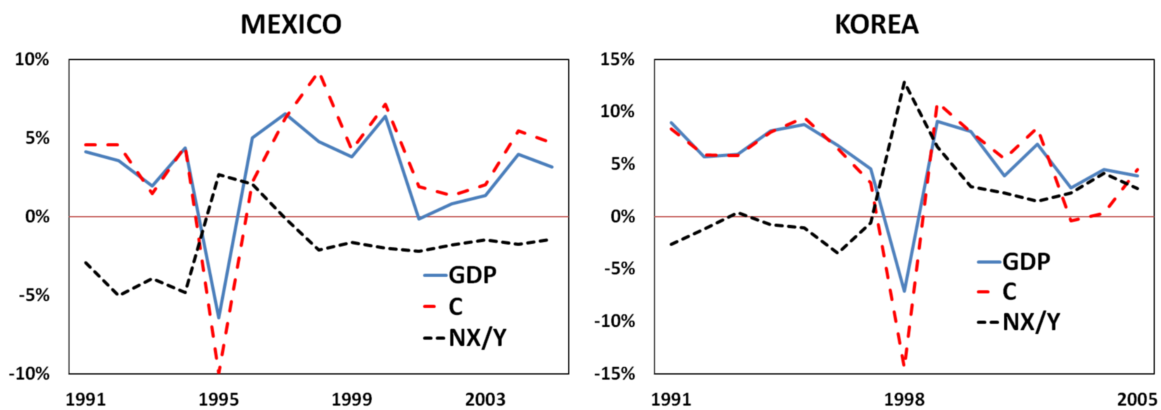

Figure 5: Business cycles in Mexico and Korea: 1990-2005.

Source: WDI.

for the analysis done in this paper. This section will describe the behavior of the Mexican and Korean terms of trade as well as construction of the series used for quantitative analysis.

Figure 6 plots the importance of manufacturing in Mexican and Korean imports and exports since 1990. In Mexico, the share of manufacturing in imports is fairly stable, around 75 % during the whole time period studied. The share of manufacturing in exports is initially lower, but stabilizes at around 75 % since 1992. In Korea, the share of manufacturing in exports and imports are fairly stable. Manufacturing accounts for about 90% of exports and about 65% of imports.

5.1.1 Manufacturing Terms of Trade

The series for manufacturing terms of trade are constructed using the procedure in Backus and Crucini (2000). Following their notation, let P_t^m be the price index of imports at time t, and let $P_t^{m,mf}$, $P^{m,nmf}$, $Q^{m,mf}$, $Q^{m,nmf}$ be the prices and quantities of manufacturing and non-manufacturing imports. The current price of imports, relative to a base period price can be written as:

$$\frac{P_t^m}{P_0^m} = \frac{P_t^{m,mf} Q_t^{m,mf} + P_t^{m,nmf} Q_t^{m,nmf}}{P_0^{m,mf} Q_t^{m,mf} + P_0^{m,nmf} Q_t^{m,nmf}} = \frac{P_t^{m,mf}}{P_0^{m,mf}} \cdot \frac{1}{S^{m,mf}} \cdot \frac{P_0^{m,mf} Q_t^{m,mf}}{P_0^{m,mf} Q_t^{m,mf} + P_0^{m,nmf} Q_t^{m,nmf}}$$

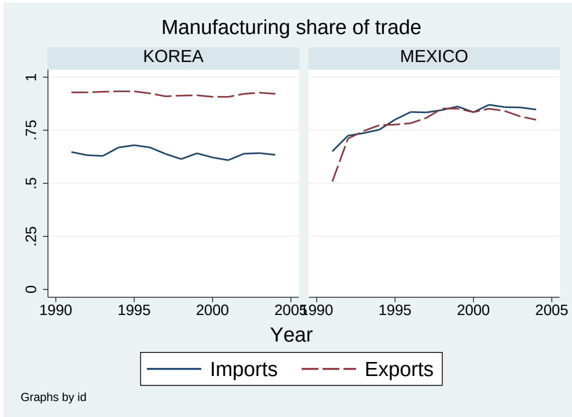

Figure 6: Share of manufacturing in imports and exports

Source: WDI

where $S^{m,mf}$ is the share of manufacturing imports. Notice, the expression on the LHS is simply the Paasche price index. The expression on the RHS is obtained by multiplying and dividing the LHS by $P_0^{m,mf} S^{m,mf}$. The above expression can be written succinctly as:

$$\frac{P_t^m}{P_0^m} = \frac{P_t^{m,mf}}{P_0^{m,mf}} \cdot \frac{1}{S^{m,mf}} \cdot Q_t^m$$

where Q_t^m is the ratio of the quantity of manufacturing imports to total quantity of imports, evaluated at base year prices. Following the same procedure for exports, we will arrive at the following expression for the manufacturing terms of trade:

$$P_t^{mf} = \frac{P_t^{x,mf}}{P_t^{m,mf}} = \frac{P_t^x}{P_t^m} \cdot \frac{S_t^{x,mf}}{S_t^{m,mf}} \cdot \frac{Q_t^x}{Q_t^m} \tag{5.1}$$

Due to data limitations (and similarly to Backus and Crucini (2000)), I must set $Q_t^i = Q^i$, $i = x, m$, i.e. the ratio of physical quantities of manufacturing to non-manufacturing imports and exports is assumed fixed.

Manufacturing Terms of Trade in Mexico and Korea during the crises Figure 7 shows the difference in the behavior of manufacturing terms of trade during the Tequila crisis in Mexico and during the Asian crisis in Korea. In each case we have observed substantial drop in GDP (6%

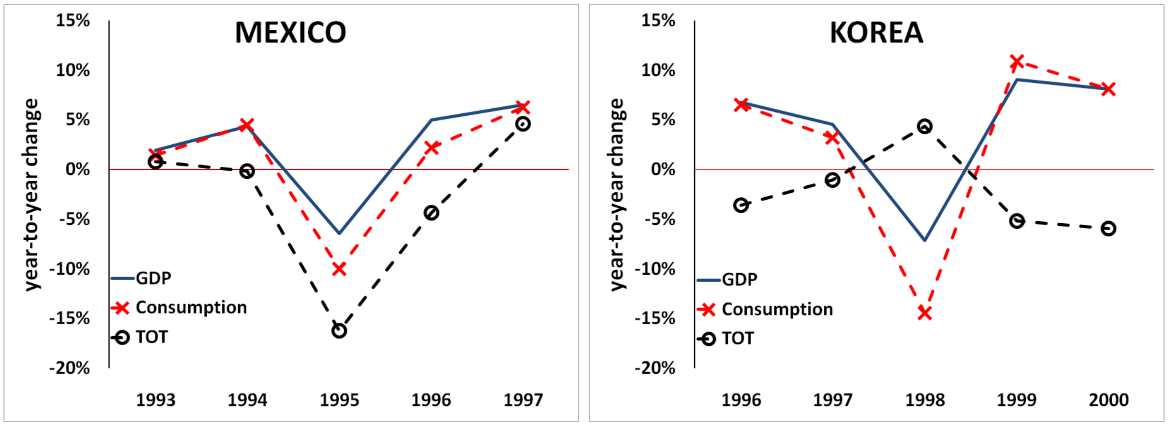

Figure 7: Terms of trade during the crisis. Left panel - Tequila crisis in Mexico. Right panel - Asian crisis in Korea
Source: WDI.

in Mexico and 7% in Korea). In each case, the consumption dropped more than output (11% in Mexico and 14% in Korea). Based on the behavior of these two variables the two crises look very much alike. What is different is the behavior of the terms of trade in each case. In Mexico, the terms of trade deteriorated. In Korea, the terms of trade improved.

Figure 8 plots the cyclical behavior of terms of trade in Korea and in Mexico during the whole period 1990-2005. Terms of trade are pro-cyclical in Mexico and counter-cyclical in Korea. Based on the analysis in Section 3, the pro-cyclicality of the terms of trade in Mexico suggests fluctuations in that country were mostly demand driven. The counter-cycliality of the terms of trade in Korea suggests the productivity shocks was the important driver of fluctuations. Next section will quantify the contribution of the two shocks to output fluctuations using the structural model presented in Section 3.

Table 5 summarizes 4 business cycle statistics for Korea and Mexico. The statistics have been calculated using quarterly data. All series (except for trade balance) are in logs and the cyclical component has been extracted using a Hodrick-Prescott filter with $\lambda = 1600$. The time period covered is 1990:Q1-2005:Q4. Next section will use those business cycle moments to assess relative importance of productivity and interest rate shocks as the drivers the fluctuations in the two

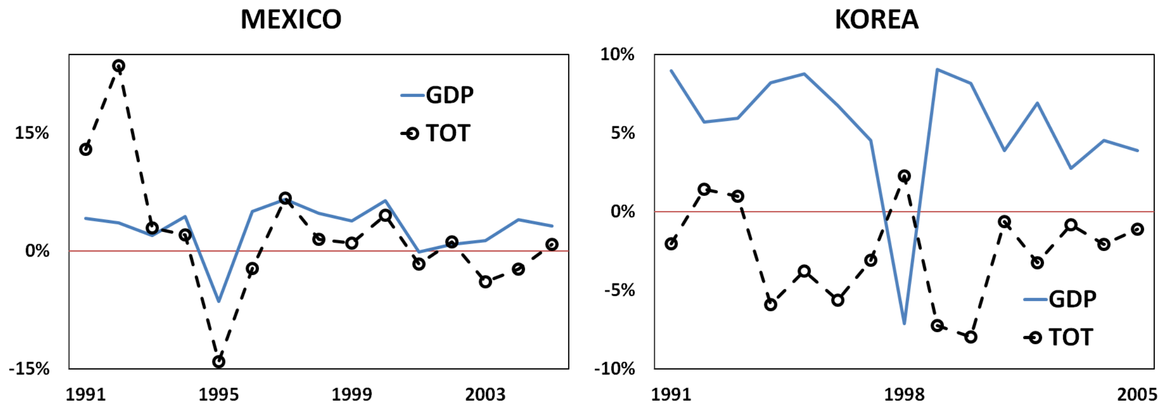

Figure 8: Cyclicality of manufacturing terms of trade. Left panel - Mexico. Right panel - Korea
Source: WDI.

emerging economies. One of the important moments used in the analysis will be the correlation of terms of trade with output.

Table 5: Business cycle statistics - Korea vs. Mexico

	Std. deviations		Corr. with GDP	
	GDP	Consumption	TOT	NX
Korea	2.49	4.29	**-0.31**	-0.84
	(0.19)	(0.32)	(0.10)	(0.03)
Mexico	2.46	3.17	**0.47**	-0.79
	(0.18)	(0.24)	(0.08)	(0.04)

6 Quantitative Analysis

6.1 Estimation of the foreign shock processes

Because shocks in country 1 have no impact on the large country we can first estimate the parameters governing the shock processes in the latter one. Those parameters will then be taken as given.

In the data, I identify country 2 with the United States and the parameters are calibrated to match the moments in the US data.

The major moment identifying the standard deviation of the productivity shock is the volatility of GDP. The major moment identifying the value of the investment adjustment cost parameter is relative volatility of investment. The moment that identifies standard deviation of the preferences shocks is the relative volatility of consumption. Because each of the three parameters (keeping other fixed) will affect all three moments generated by the model, the three parameters must be calibrated jointly. Table 6 summarizes the values of parameters calibrated together with the moments that were used as targets. All three moments were matched exactly.

Table 6: Calibration of country 2 parameters

Parameter	**Value**	**Moment targeted**	**Value**
σ_{z^2}	0.86%	$\sigma(GDP)$	1.36%
ρ_{z^2}	0.62	$\rho(GDP, GDP_{t-1})$	0.87
ϕ	0.84	$\frac{\sigma(INV)}{\sigma(GDP)}$	2.72

NOTES: Quarterly U.S. data 1980-2007. All series in logs and filtered with Hodrick-Prescott filter with $\lambda = 1600$. All three moments were calibrated jointly. The values targeted were matched exactly.

6.2 Method of moments estimation

In this section I will evaluate the quantitative contribution of various shocks to fluctuations in the model emerging economy. The analysis in this section proceeds as follows. First, I use simulated method moments to estimate the standard deviations of all the shocks in the encompassing model using the correlation of the terms of trade with output as one of the identifying moments. Then, using those estimates I decompose the variance of major macro aggregates in the model, following Hamilton (1994), page 323.

6.2.1 Method of moments estimation

The standard deviations of the four shocks are estimated with simulated method of moments. The moment conditions used in this section are: (1) standard deviation of output in country 1, (2) relative volatility of consumption in country 1, (3) correlation of trade balance with output in country 1 and (4) correlation of terms of trade with output in country 1. Overall there are four moments conditions and three parameters to be estimated. The results from the 2-stage estimation are presented in Table 7.

Table 7: Domestic shocks' standard deviations - SMM estimates

	Mexico		**Korea**	
	Moments used		Moments used	
	w/o TOT	*w/ TOT*	*w/o TOT*	*w/ TOT*
σ_z	0.42	0.15	0.21	0.22
	(0.01)	(0.04)	(0.02)	(0.03)
σ_g	2.05	2.96	1.72	1.77
	(1.11)	(1.32)	(0.52)	(0.77)
σ_{CS}	1.99	4.34	4.01	1.22
	(0.87)	(1.70)	(1.04)	(0.34)

NOTES: Moments used include: $\sigma(GDP)$, $\sigma(C)/\sigma(GDP)$, $\rho(NX, GD)$. Results in second and fourth column include also $\rho(TOT, GDP)$

6.2.2 Variance decomposition

Table 8 presents variance decomposition of output and consumption in Mexico and in Korea. For comparison, I present variance decomposition based on two estimations of the model: one with and one without cyclicality of the terms of trade used as an identifying moment. Adding that information has a substantial impact on the conclusions about the importance of interest rate movements for fluctuations in aggregate quantities. In Mexico, during the 1990s, terms of trade

Table 8: Variance decomposition for the estimated model

		Mexico		**Korea**	
		Moments used		Moments used	
		w/o TOT	*w/ TOT*	*w/o TOT*	*w/ TOT*
Real GDP					
	Productivity	0.95	0.89	0.87	0.97
	Interest rate	0.05	0.11	0.13	0.03
Consumption					
	Productivity	0.56	0.36	0.33	0.76
	Interest rate	0.44	0.64	0.67	0.24

NOTES: The number in each cell is the share of the variance of one-step ahead forecast accounted for by each exogenous shock. See also notes at Table 7. Productivity shocks include both transitory and trend shocks.

were strongly pro-cyclical. In Korea, during the same time period, they were counter-cyclical. In case of Mexico, if we add cyclicality of terms of trade as one of the identifying moments, the movements in interest rates account for more than 11% of output movements and for over 64% of consumption movements (comparing to 5% and 44% if we ignore that information). In Korea, the effect is the opposite. If we omit the information about terms of trade movements, interest rate shocks account for 13% of output and 67% of consumption movements. If we include information about the terms of trade, interest rate fluctuations account for 3% of output fluctuations and 24% of consumption movements (all of the above numbers refer to deviations from the balanced growth path).

6.3 On the role of interest rates

In this section, I did not use standard deviation of interest rates as one of the identifying moments. Instead, I inferred the magnitude of shocks to the country spread using other business cycle moments. These estimates, however, have implications for the volatility of real interest rate in a model emerging economy. Table 9 below, presents implied business cycle statistics about the real interest rates in Mexico and in Korea. It also displays empirical statistics for three different interest rates in the two countries. The empirical counter-part that is conceptually the closest to the interest rate in the model is the one faced by the households. That interest rate is among the least volatile in Korea during the period 1996-2010. Empirical standard deviation is 1.5%. The volatility implied by the model is also quite low - 1.02%. The volatility of interest rates implied by the model for Mexico is quite high - 3.14%. Unfortunately, to the best of my knowledge, the relevant empirical statistics that would cover the period during the Tequila crisis is not available (data in Bhang (2011) goes back to 1996 which misses the key time period for Mexico).

The analysis in this paper does not imply interest rate shocks to did not play important role in Korea during the Asian crisis. In fact, the statistics in Table 9 are quite consistent with the behavior of Korean terms of trade and models exploiting the role of financial frictions. The most volatile are the interest rates on commercial papers. Those interest rates affect the terms on which

Table 9: Business cycle moments of interest rates: model implied estimates vs. data

	Mexico		**Korea**	
	$\sigma(R)$	$\rho(R, GDP)$	$\sigma(R)$	$\rho(R, GDP)$
Model	3.14	-0.32	1.02	-0.07
Data				
Commercial paper	.	.	4.18	-0.08
Corporate bonds	2.64	-0.87	2.42	-0.22
HH deposits	.	.	1.49	-0.57

Sources: Korea - Bhang (2011). Mexico - Neumeyer and Perri (2005).

firms can borrow to finance their operations. Fluctuations in those rates will affect firms' costs and hence, will manifest themselves as supply shocks in a frictionless model. In that sense, the behavior of terms of trade informs us about the channel through which interest rates may affect the economy. Counter-cyclical terms of trade indicate the supply channel might be the dominant one.

7 Conclusions

I showed fluctuations in manufacturing terms of trade may be an important source of information that can help us identify which classes of models are most helpful in understanding output movements in open economies. Terms of trade are pro-cyclical if the major source of fluctuations are exogenous movements in the world interest rate and counter-cyclical, if the major of source of fluctuations are internal shocks to productivity. This is also true for permanent productivity shocks.

The result is of particular interest for emerging markets, as it shows that the cyclical movements of manufacturing terms of trade can distinguish between two major theories of fluctuations in emerging economies: the *stochastic trend* model of Aguiar and Gopinath (2007) and the *interest* *rate shocks* model of Neumeyer and Perri (2005). Empirical results presented in this paper suggest that foreign interest rate shocks were more important in driving the fluctuations in Mexico in the last 20 years then were the permanent shocks to total factor productivity. However, given substantial cross-country differences in the cyclicality of terms of trade, the *stochastic trend* model appears to be a promising starting point of analysis for a number of emerging economies.

The result presented in this paper is important for practical purposes. As pointed out by Garcia-Cicco et al. (2010) as well as Aguiar and Gopinath (2007), in order to identify the permanent component of the TFP process one needs in practice a very long time series. Needless to say, such series are not easily available, especially in developing countries. An alternative is to look at the data through the lenses of a structural model and use additional moments to identify permanent shocks. In a seminal paper, Cochrane (1994) showed that different (in magnitude) response of consumption can be one such moment. Aguiar and Gopinath (2007) exploited this intuition in their study of fluctuations in Mexico. However, the response of consumption turns out to be very similar in models with permanent productivity shocks and in models with country risk shocks, making it hard to distinguish between the two. In this paper I showed that the responses of the terms of trade (in addition to consumption) can be used as an identifying moment which allows to distinguish between country risk and permanent productivity shocks.

The results also suggest that terms of trade movements may inform us about the channel through which interest rate movements affect GDP. Strong pro-cyclicality of terms of trade in Mexico indicates that the main channel is likely to be the demand channel. In Korea, on the other hand, terms of trade were counter-cyclical. Reconciliation of that fact with relatively large movements in interest rates suggests that the main channel in that country was the supply channel (as e.g. in Uribe and Yue (2006) or Neumeyer and Perri (2005)). Further research in this area should focus on a careful analysis of interest rates faced by households and those faced by domestic firms.

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A Appendix - Data

This section describes the data used in calculations presented in Tables **??** and **??**.

National accounts

National Accounts data used in Section 2 is from the World Bank World Development Indicators database. This database has been chosen to keep the statistics as comparable across countries as possible.

- Real GDP (Y) = Gross Domestic Product in constant prices

- Consumption (C) = private consumption expenditure in constant prices
- Investment (I) = Gross Fixed Capital Formation in constant prices
- Trade balance to GDP = (Exports - Imports)/GDP, all in current prices

Terms of trade

I construct the series on manufacturing terms of trade using the procedure in Backus and Crucini (2000). Following their notation, let P_t^m be the price index of imports at time t, and let $P_t^{m,mf}$, $P^{m,nmf}$, $Q^{m,mf}$, $Q^{m,nmf}$ be the prices and quantities of manufacturing and non-manufacturing imports. The current price of imports, relative to a base period price can be written as:

$$\frac{P_t^m}{P_0^m} = \frac{P_t^{m,mf} Q_t^{m,mf} + P_t^{m,nmf} Q_t^{m,nmf}}{P_0^{m,mf} Q_t^{m,mf} + P_0^{m,nmf} Q_t^{m,nmf}} = \frac{P_t^{m,mf}}{P_0^{m,mf}} \cdot \frac{1}{S^{m,mf}} \cdot \frac{P_0^{m,mf} Q_t^{m,mf}}{P_0^{m,mf} Q_t^{m,mf} + P_0^{m,nmf} Q_t^{m,nmf}}$$

where $S^{m,mf}$ is the share of manufacturing imports. The above expression can be written succinctly as:

$$\frac{P_t^m}{P_0^m} = \frac{P_t^{m,mf}}{P_0^{m,mf}} \cdot \frac{1}{S^{m,mf}} \cdot Q_t^m$$

where Q_t^m is the ratio of the quantity of manufacturing imports to total quantity of imports, evaluated at base year prices. Following the same procedure for exports, we will arrive at the following expression for the manufacturing terms of trade:

$$P_t^{mf} = \frac{P_t^{x,mf}}{P_t^{m,mf}} = \frac{P_t^x}{P_t^m} \cdot \frac{S_t^{x,mf}}{S_t^{m,mf}} \cdot \frac{Q_t^x}{Q_t^m} \tag{A.1}$$

Due to data limitations (and similarly to Backus and Crucini (2000)), I must set $Q_t^i = Q^i$, $i = x, m$, i.e. the ratio of physical quantities of manufacturing to non-manufacturing imports and exports is assumed fixed.

Data from Section 5

The data used to calculate business cycle statistics for Mexico and Korea in Section 5 is from OECD Main Development Indicators with the following definition of the variables:

- Real GDP (Y) = Gross Domestic Product in constant prices
- Consumption (C) = private consumption expenditure in constant prices
- Investment (I) = Gross Fixed Capital Formation in constant prices
- Trade balance to GDP = (Exports - Imports)/GDP, all in current prices