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Business Cycles in Small Developed Economies: The Role of Terms of Trade and Foreign Interest Rate Shocks

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Abstract

Empirical evidence for small developed economies finds that consumption is procyclical and as volatile as output, and real net exports are countercyclical. Earlier studies have not been able to reproduce these regularities in a DSGE small open economy model when productivity shocks drive the business cycles and households have a normal intertemporal elasticity of substitution. Instead, these studies have reduced this elasticity to make consumption more procyclical and volatile and real net exports countercyclical. This paper shows that a standard model can reproduce these regularities, without lowering the intertemporal substitution, if the terms of trade and foreign interest rate are added as source of business cycle fluctuations. These shocks, compared to productivity shocks, make consumption and investment more volatile and procyclical relative to output, and make real net exports countercyclical.

JEL Classification Numbers: E21, E32, F32, F41 and N12
Keywords: Small Open Economy Model, Terms of Trade, Foreign Interest Rate, Consumption, Net Exports, and Intertemporal Elasticity of Substitution

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I. INTRODUCTION

Since Backus and others (1992), several articles have studied the business cycles regularities in small developed economies (SDEs) in the postwar period. They find that output volatility is the same as in the large developed economies; private consumption is procyclical and as volatile as output; investment is procyclical and about three times as volatile as output; and real net exports are countercyclical. These regularities contrast with the results from a dynamic stochastic general equilibrium (DSGE) small open economy model, when productivity shocks drive the business cycles and households have a normal intertemporal elasticity of substitution (IES). In these models consumption is less volatile than output and real net exports are procyclical.

Previous studies, Mendoza (1991, 1995), Correia and others (1995) and Raffo (2006), use a low IES or GHH preferences (Greenwood and others, 1988), in which the intertemporal substitution of leisure is zero. With GHH preferences, labor supply depends only on wages and not on consumption. Thus, productivity shocks create more volatile and procyclical hours of work and consumption, and countercyclical real next exports. This paper shows that a DSGE small open economy model, with a normal IES, can replicate the regularities mentioned above if the terms of trade and the foreign interest rate shocks are added as source of business cycle fluctuations. Compared to produtivity shocks, these two shocks increase the volatility of consumption and investment relative to output, and produce countercyclical real net exports. Furthermore, they reinforce each other as their innovations are negatively cross-correlated in the data.

The terms of trade shocks produce smaller changes in output than similar productivity shocks, but larger procyclical fluctuations in consumption and investment, and countercyclical, instead of procyclical, changes in real net exports. The foreign interest rate shocks also produce small changes in output, but affect the intertemporal price of consumption and investment, making both more volatile and procyclical, and making real net exports countercyclical.

This study uses a two sector model, the export one and the nontradable one. Domestic firms produce both goods using labor and capital inputs. Households have standard preferences, consume the nontradable good, buy the importable good for consumption and investment, and supply labor and capital to the firms. There are four shocks: Productivity in the export and nontradable sectors, the terms of trade and the foreign interest rate. The model is calibrated for Canada, which is also the case study in Mendoza (1991) and Raffo (2006).

The simulations show that when all four shocks are considered, the model is able to replicate the regularities of Canada's business cycles for values of the IES between ½ and ¼, in the normal range defined by Mehra and Prescott (1985). It captures the volatilities and correlations with output of consumption, investment, real net exports, and hours of work. But when business cycles are driven only by productivity shocks, the model predicts an excessive consumption smoothing and procyclical real net exports for the same preferences and IES.

The paper is organized as follows: Section 2 documents the SDEs' business cycle regularities. Section 3 discusses the related literature. Section 4 presents the model. Section 5 presents the calibration and shocks' processes. Section 6 shows the impulse responses and simulations comparing the moments from the model with those of the data. Section 6 concludes.

II. Empirical Regularities

The first study of the SDEs' business cycles regularities in the postwar period is Backus and others (1992). For annual data between 1950 and 1985, they find that output is as volatile as in the large developed economies; private consumption is procyclical and as volatile as output; fixed investment is procyclical and between two and four times as volatile as output; and real net exports are countercyclical. The exception is public consumption, which is countercyclical almost as often as procyclical. Afterwards, other studies have found similar regularities for different samples of countries and data frequency.

Table 1 reproduces the exercise in Backus and others (1992) for 15 SDEs and the G-7 excluding Canada, for annual data between 1980 and 2003. It shows the same regularities identified in the original article: SDEs' output is as volatile as in the big developed countries; consumption and investment are procyclical, the former as volatile as output, and the latter about 3 times as volatile as output. Real net exports are countercyclical in both groups, except for Austria and Switzerland, for which they are procyclical and acyclical, respectively. Finally, public consumption does not have a common volatility or cyclical pattern across countries.

Table 2 presents the regularities documented by Aguiar and Gopinath (2007) for a sample of 13 SDEs for quarterly data between 1980 and 2003. They find that the main regularities in Backus and others (1992) are also valid at quarterly frequency. Aggregate consumption is procyclical and as volatile as output, investment is procyclical and about 3.5 times as volatile as output, and real net exports are countercyclical, although less than for annual data.

III. Literature Review

Earlier studies have tried to replicate these regularities using a small open economy model or a two country model. Mendoza (1991) used a small open economy model to study the Canada's business cycles regularities. Although, the model reproduced them for a moderate adjustment cost of capital and a low persistence in productivity shocks, it relied on using GHH preferences. While this study did not present simulations for standard preferences, Correia and others (1995), using a similar setup to study Portugal's business cycles, considered two different specifications for the momentary utility function: A Cobb-Douglas one and the GHH one. They find that, for business cycles driven by productivity shocks, the setup with Cobb-Douglas preferences yielded a consumption less volatile and procyclical than in data, and procyclical real net exports. Only with GHH preferences they could reproduce the regularities in the data.

Aguiar and Gopinath (2007) used a small open economy model with two types of productivity shocks, a transitory shock around a trend and a permanent shock to the trend growth rate, to replicate Canada's empirical regularities. Their model with standard preferences replicated the procyclical and volatile path of consumption, but not the countercyclical net exports. Still, their results relied largely on the specification of shocks to the trend growth of productivity, which by their persistence create larger fluctuations in consumption and investment relative to the ones produced by the standard shocks to productivity around a trend.

Among the studies using a two country model, little attention has been paid to the implications for a small open economy. The pioneer work by Backus and others (1992) tried to replicate the regularities of two big open economies, the US and Europe. They find that with complete asset markets and moderate foreign transaction costs, the model replicated the volatility of investment and net exports, and the procyclicality of investment, but not the volatile and procyclical path of consumption nor the countercyclical path of net exports. Stockman and Tesar (1995) added non tradable goods to the model, finding that it could replicate the procyclical and volatile path of consumption, and the countercyclicality of net exports, although it under predicted its volatility. They also find a high correlation of consumption of tradable goods across countries, which they solved by introducing shocks to preferences, which makes the trade balance acyclical.

Baxter and Crucini (1995) added incomplete asset markets to the model, finding it not important when productivity shocks are trend stationary with spillovers. Restrictions on asset trade are important when shocks are persistent and the international spillovers of shocks are smaller. Only very persistent shocks, combined with incomplete asset markets, were able to replicate the cyclical co-movement and volatility of the main macroeconomic aggregates in the data.

Backus and others (1994) endogeneize the terms of trade by allowing each country to produce a single differentiated good. Consumption, investment and government purchases are composites of foreign and domestic goods, and business cycles are driven by shocks to productivity and government purchases. This setup predicts a procyclical consumption and countercyclical net exports, but as noted by Raffo (2007), the latter is due to changes in relative prices (terms of trade) instead of quantities, while the opposite is observed in the data.

Raffo (2007) uses a two country model to reproduce the regularities of the US and Canada. He finds that the model's ability to create countercyclical net exports relies on the terms of trade fluctuations, as it delivers procyclical real net exports. This is worse for a small open economy, in which even nominal net exports are procyclical due to the lack of terms of trade effects. He solves the problem by using GHH preferences, finding that this is enough to reproduce the regularities in the data not only for a small open economy, but also for large economies.

None of the small open economy models discussed above used the terms of trade or foreign interest rate shocks as source of business cycles, and the two country models could not generate the terms of trade volatility observed in the data (Backus and others, 1994). The next sections show that adding these shocks as sources of business cycles allows a small open economy model, with standard preferences, to reproduce the regularities in the data.

IV. The Model

Consider a small open economy perfectly integrated to the world in goods, but faces the following aggregate upward sloping supply of external funds:

$$R_t = R_t^* + \eta\left(\bar{b} - b_t\right) \tag{1}$$

where R_t is the domestic rate of return, R_t^* is the foreign rate of return, b_t is the net external assets position, $\bar{b}$ is the level of net external assets at which the risk premium is zero, and η is the elasticity of such premium to the level of net foreign assets. R_t^* is stochastic according to:

$$R_t^* = \exp\left(\varepsilon_t^R\right) R^* \tag{2}$$

where R^* is its unconditional mean and ε_t^R its first-order auto regressive shock:

$$\varepsilon_{t+1}^R = \rho^R \varepsilon_t^R + v_{t+1}^R \tag{3}$$

with $E\left(v_{t+1}^R\right) = 0$ and $V\left(v_{t+1}^R\right) = \sigma_R^2$. This model is not a frictionless setup, in which $R_t = R_t^*$, because when a frictionless model is log-linearized around the steady state, it yields a unit root for net foreign assets (see Correia and others, 1995). A unique steady state requires to anchor external debt in equilibrium. This can be done by setting an upward-sloping supply of external funds, a cost function of adjusting the external asset portfolio, or an endogenous discount factor. Schmitt-Grohe and Uribe (2003) show that all of these three forms yield the same first and second moments. I chose the first, and I kept η small to make the model a good approximation of the frictionless setup.

There are three goods in the economy, an exportable good (X), an importable good (M) and a nontradable good (N). The two production factors are labor (h) and capital (k). Firms produce the *X* and *N* goods, using *h* and *k* inputs. Capital is sector specific and labor is freely mobile across sectors. The law of one price holds for both tradable goods. The external price of *M* is normalized to one, and the external price of the exportable is stochastic, according to:

$$P_t^X = \exp\left(\varepsilon_t^{P^X}\right) P^{X*} \tag{4}$$

where P^{X*} is its unconditional mean and $\varepsilon_t^{P^X}$ its first-order autoregressive shock:

$$\varepsilon_{t+1}^{P^X} = \rho^{P^X} \varepsilon_t^{P^X} + v_{t+1}^{P^X} \tag{5}$$

with $E\left(v_{t+1}^{P^X}\right)=0$ and $V\left(v_{t+1}^{P^X}\right)=\sigma_{P^X}^2$. There are two types of domestic agents: households and firms. Households own the firms, consume the *M* and *N* goods, supply *h* and *k* to the firms, and have access to the foreign capital market. There are two firms, the nontradable and the export ones; both use *h* and *k* to produce their output. The economy follows a balanced growth path at the rate $(\gamma-1)$, and population is constant. In the following, the model is set in stationary form.

A. Households

Households maximize their lifetime utility given by equation 6:

$$U=E_0\left[\sum_{t=0}^{\infty}\beta^{*t}\frac{\left\{c_t^{\alpha}\left(1-h_t\right)^{1-\alpha}\right\}^{1-\sigma}}{1-\sigma}\right] \tag{6}$$

where $\beta^*=\beta\gamma^{\alpha(1-\sigma)}$, β is the discount factor, h_t is the normalized hours of work and c_t is a CES aggregation of consumption of importable $\left(c_t^M\right)$ and nontradable $\left(c_t^N\right)$ goods:

$$c_t=\left(\varpi c_t^{M\rho}+\left(1-\varpi\right)c_t^{N\rho}\right)^{\frac{1}{\rho}} \tag{7}$$

The intertemporal elasticity of substitution is $1/\sigma$. The households flow budget constraint is:

$$w_t h_t+q_t^X k_t^X+q_t^N k_t^N+R_t b_t=c_t^M+P_t^N c_t^N+i_t^X+i_t^N+\gamma b_{t+1} \tag{8}$$

where w_t is the wage rate, P_t^N the relative price of *N* to *M*, and k_t^j, i_t^j and q_t^j are capital, investment, and the rental rate of capital in sector *j*, respectively. Investment covers the capital adjustment costs, replaces depreciated capital, and accumulates new capital, according to:

$$\gamma k_{t+1}^j=\left(1-\delta\right)k_t^j+i_t^j-\frac{\theta}{2}\left(i_t^j\right)^2 \tag{9}$$

For *j* = *X*, *N*, where δ is the depreciation rate and θ a coefficient in the quadratic adjustment cost. Households choose the sequence $\left\{c_t^M,c_t^N,h_t,i_t^X,i_t^N,k_{t+1}^X,k_{t+1}^N,b_{t+1}\right\}_{t=0}^{\infty}$ to maximize equation 6, subject to equations 8 and 9. Their first-order conditions are as follows:

$$\alpha\varpi\left(\varpi c_t^{M\rho}+\left(1-\varpi\right)c_t^{N\rho}\right)^{\frac{\alpha}{\rho}(1-\sigma)-1}\left(1-h_t\right)^{(1-\alpha)(1-\sigma)}c_t^{M(\rho-1)}=\lambda_t \tag{10}$$

$$\alpha\left(1-\varpi\right)\left(\varpi c_t^{M\rho}+\left(1-\varpi\right)c_t^{N\rho}\right)^{\frac{\alpha}{\rho}(1-\sigma)-1}\left(1-h_t\right)^{(1-\alpha)(1-\sigma)}c_t^{N(\rho-1)}=P_t^N\lambda_t \tag{11}$$

$$\left(1-\alpha\right)\left(\varpi c_t^{M\rho}+\left(1-\varpi\right)c_t^{N\rho}\right)^{\frac{\alpha}{\rho}(1-\sigma)}\left(1-h_t\right)^{\alpha(\sigma-1)-\sigma}=\lambda_t w_t \tag{12}$$

$$\phi_t^X=\lambda_t+\phi_t^X\theta i_t^X \tag{13}$$

$$\phi_t^N=\lambda_t+\phi_t^N\theta i_t^N \tag{14}$$

$$\gamma\phi_t^X=\beta E_t\left[\lambda_{t+1}q_{t+1}^X+\phi_{t+1}^X\left(1-\delta\right)\right] \tag{15}$$

$$\gamma\phi_t^N=\beta E_t\left[\lambda_{t+1}q_{t+1}^N+\phi_{t+1}^N\left(1-\delta\right)\right] \tag{16}$$

$$\gamma\lambda_t=\beta E_t\left[\lambda_{t+1}R_{t+1}\right] \tag{17}$$

$$E_t\left[\lim_{t\to\infty}\beta^t\lambda_t\left(k_{t+1}^X+k_{t+1}^N+b_{t+1}\right)\right]=0 \tag{18}$$

where λ_t, ϕ_t^X and ϕ_t^N are the Lagrange multipliers on equations 8 and 9, respectively.

B. Firms

Both firms have Cobb-Douglas constant-return-to-scale technologies and choose $\left\{h_t^{fj},k_t^{fj}\right\}_{t=0}^{\infty}$ to maximize profits, with $j = X, N$. The first-order conditions for the nontradable firm are:

$$w_t=\left(1-\alpha_N\right)P_t^N\exp\left(\varepsilon_t^N\right)\left(k_t^{fN}\right)^{\alpha_N}\left(h_t^{fN}\right)^{-\alpha_N} \tag{19}$$

$$q_t^N=\alpha_N P_t^N\exp\left(\varepsilon_t^N\right)\left(h_t^{fN}\right)^{(1-\alpha_N)}\left(k_t^{fN}\right)^{(\alpha_N-1)} \tag{20}$$

while the first-order conditions for the export firm are

$$w_t=\left(1-\alpha_X\right)P_t^X\exp\left(\varepsilon_t^X\right)\left(k_t^{fX}\right)^{\alpha_X}\left(h_t^{fX}\right)^{-\alpha_X} \tag{21}$$

$$q_t^X=\alpha_X P_t^X\exp\left(\varepsilon_t^X\right)\left(h_t^{fX}\right)^{(1-\alpha_X)}\left(k_t^{fX}\right)^{(\alpha_X-1)} \tag{22}$$

Where ε_t^j is the productivity shock in each sector $j = X, N$, respectively. These shocks follow a first-order autoregressive process:

$$\varepsilon_{t+1}^j=\rho^j\varepsilon_t^j+v_{t+1}^j \tag{23}$$

with $E\left(v_{t+1}^j\right)=0$ and $V\left(v_{t+1}^j\right)=\sigma_j^2$.

C. Definition of a Competitive Equilibrium

Given b_0, k_0^X and k_0^N, and shocks' processes $\left(\varepsilon_t^R, \varepsilon_t^{P^X}, \varepsilon_t^X, \varepsilon_t^N\right)_{t=0}^{\infty}$, a competitive equilibrium corresponds to sequences of households' allocations $\left\{c_t^M, c_t^N, h_t, i_t^X, i_t^N, k_{t+1}^X, k_{t+1}^N, b_{t+1}\right\}_{t=0}^{\infty}$, firms' allocations $\left\{h_t^{fX}, h_t^{fN}, k_t^{fX}, k_t^{fN}\right\}_{t=0}^{\infty}$, and prices $\left\{P_t^X, P_t^N, q_t^X, q_t^N, w_t, R_t\right\}_{t=0}^{\infty}$, such that:

- Given prices, b_0, k_0^X, k_0^N, and shocks' processes, $\left\{c_t^M, c_t^N, h_t, i_t^X, i_t^N, k_{t+1}^X, k_{t+1}^N, b_{t+1}\right\}_{t=0}^{\infty}$ solve the households' problem.
- Given prices and shocks' processes, $\left\{h_t^{fX}, k_t^{fX}\right\}_{t=0}^{\infty}$ solve firm X's problem.
- Given prices and shocks processes, $\left\{h_t^{fN}, k_t^{fN}\right\}_{t=0}^{\infty}$ solve firm N's problem.
- Markets clear: $c_t^N = y_t^N$, $k_t^X = k_t^{fX}$, $k_t^N = k_t^{fN}$, and $h_t = h_t^{fX} + h_t^{fN}$
- The resource constraint is satisfied: $R_t b_t + P_t^X y_t^X = c_t^M + i_t^X + i_t^N + \gamma b_{t+1}$

V. Steady State and Calibration

The parameters are calibrated to match Canada's average macroeconomic ratios between 1979 and 2004. Table 3 presents the results and the macroeconomic ratios in the data and in the model's steady state. The risk premium elasticity, η, is 0.001 as in Schmitt-Grohe and Uribe (2003), net foreign debt is 10 percent of GDP as in Aguiar and Gopinath (2007), and $\bar{b}$ is 6.6 percent of GDP , to yield a spread $R_t - R_t^*$ of 25 basis points in steady state. The value of γ is 1.007, or one plus the average quarterly growth rate of GDP.

Sectoral output is built by allocating GDP from national accounts as export or nontradable as in Stockman and Tesar (1995). The export sector consists of agriculture, manufacturing and mining, equal to 24 percent of GDP, and the nontradable sector consists of construction, services and utilities, equal to 76 percent of GDP. The same aggregation is used for hours of work, obtaining a 22 and 78 percent in the export and nontradable sectors, respectively.

With the sectoral allocations of work hours and output in steady state, and as labor is freely mobile across sectors, the capital shares are obtained by equating the marginal productivity of labor across sectors, making the average share equal to 0.36 as in Raffo (2006). The respective capital shares in the export and nontradable sectors are 0.41 and 0.34. The capital stock is build using equation (9), with δ equal to 0.025 as in Raffo (2006), while the initial capital and θ are set to equate the average growth rate of capital to the one of GDP, and to match the volatility of investment in the benchmark simulations. The steady state allocations of capital are 27.4 and 72.6 percent in the export and nontradable sectors, respectively.

On preferences, β is 0.98 to satisfy equation (17), and ρ is -0.34 as in Mendoza (1995). σ is set at 2.6 to replicate the correlation of net exports to GDP in the data, with an intertemporal elasticity of substitution of 0.38, in the normal range of Mehra and Prescott (1985), and only slightly lower than in Backus and others (1994), Baxter and Crucini (1995), Stockman and Tesar (1995), and Aguiar and Gopinath (2007). Nontradable consumption is equal to nontradable output, and importable consumption is equal to the rest of total consumption. The values of ϖ , λ , ϕ^X , and ϕ^N were set to satisfy the households' first order conditions.

Note that the current account balance is equal to zero in steady state, whereas it is in surplus in the data, so I increased the ratios to GDP of importable consumption and investment to calibrate a consistent steady state. Table 3 shows that the calibration is consistent with the macroeconomic ratios in the data, except for the adjustments made to achieve a zero current account balance in steady state.

A. Shock Processes

The terms of trade is the ratio of prices of exports to imports of goods and services, and the foreign real interest rate is the US Fed Funds rate minus inflation. Total factor productivity in the export and nontradable sectors is the Solow residual. The sectoral series of work hours and capital are built by equating the marginal productivity of labor and capital across sectors. This is an equilibrium condition for the freely mobile labor, but not for the sector specifc capital. Households, however, can freely allocate investment to either sector, thus equating the marginal productivity of capital across sectors is a first best allocation, but is constrained as investment can not be negative. Sectoral investment was obtained for this allocation using equations (20) and (22), finding that investment in both sectors is always positive.

Table 3 presents the autocorrelations and standard deviations of all shocks, and their innovations’ cross-correlations. All shocks are highly autocorrelated, with coefficients between 0.6 and 0.9. The terms of trade are the most volatile, between four and five as volatile as the other shocks. The innovations to the foreign interest rate shocks are negatively cross-correlated with the ones of all other shocks, while the innovations to both productivity shocks are highly cross-correlated between them, but barely correlated to the terms of trade.

VI. Simulations and Impulse Responses

The model is log-linearized around the steady state, so the simulations and impulse-response functions are percentage deviations of the variables from their steady state values. Two scenarios are simulated: The benchmark one, when business cycles are driven by all four shocks, and the standard one, when business cycles are driven by shocks to productivity. In the benchmark case, three parameters are set to make the model replicate some specific features of the data. The standard deviations of all four shocks are scaled by the same factor to match the volatility of GDP, while θ and σ are set to replicate the volatility of investment and correlation between real net exports and GDP, respectively[2]. In the standard case, only the shocks' standard deviations and θ are modified for the simulations to match the volatility of GDP and investment, respectively. The IES is kept as in the benchmark case.

A. Impulse - Responses

Figure 1 presents four different impulse-response functions derived from the benchmark scenario. Each line represents the endogenous reaction of the respective variable to a positive shock of 1 percent to productivity or terms of trade, or to a fall of 50 basis points in the foreign real interest rate. These impulse-response functions reflect the shocks' autocorrelations and cross-correlations presented in table 4.

Figure 1 shows that a positive productivity shock to any sector produces large increases in output of exportable and nontradable, as they are highly cross-correlated. Consumption and investment also increase, but less than output, which added to the increase in exports, create procyclical real and nominal net exports. Total work hours also increase less than output, raising in the export sector and falling in the nontradable one.

A positive terms of trade shock, however, produces a lower increase in output than a similar productivity shock, but generates larger changes in consumption and investment than the one of output, and reduces exportable output. This results in lower real and nominal net exports, as the fall in the real net exports more than offsets the increase in the terms of trade. Also, aggregate hours of work increase more than with a similar productivity shock, raising in the nontradable sector and falling in the export one.

A reduction in the foreign real interest rate produces a small increase in output, but a larger increase in consumption and investment than the one of output. It also reduces output of exportables and worsen real and nominal net exports, as the terms of trade do not change significantly. Aggregate work hours decrease, resulting in lower hours of work in the exportable sector and in higher hours in the non tradable one.

The intuition is as follows: A positive productivity shock increases output in both sectors directly through the production function, while a positive terms of trade shock only increases the foreign value of the export good. Both shocks, however, increase the households' wealth and demand for importable and nontradable goods, and reduce their supply of work hours. The importable good is brought from abroad, but raising consumption of nontradable requires increasing its domestic production. For productivity shocks, nontradable output increases without extra work hours or investment, but for terms of trade shocks, work hours

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[2] As discussed above, the resulting IES is inside the range considered normal by Mehra and Prescott (1985).

and investment have to increase, generating a reallocation of work hours from the export sector to the nontradable one. Finally, aggregate consumption increases less, and total work hours increase more, with terms of trade shocks than with productivity shocks.

Figure 1 shows that when productivity increases by one percent, investment increases by half as much and hours of work by a 1/3 as much, as for a similar terms of trade shock. However, output raises more due to the gains in productivity. Thus, terms of trade shocks produce smaller increases in exportable output than similar productivity shocks, but larger increases in consumption of importable and investment, generating lower real and nominal net exports.

A fall in the foreign real interest rate lowers the cost of investment and the price of future consumption relative to present consumption. Consumption and investment increase, and work hours fall. As nontradable goods are produced domestically, labor is shifted to this sector from the export one. Nontradable output increases and export output falls, and as a result real and nominal net exports decrease as the terms of trade remain relatively constant.

Thus, productivity shocks generate a low volatility of consumption and investment relative to output, and procyclical net exports, while the terms of trade and foreign real interest rate produce more procyclical and volatile consumption and investment, and countercyclical net exports. Thus, adding these last two shocks to a standard DSGE small open economy model can make it able to generate the regularities observed in the data.

B. Simulations

This section studies the model's ability to replicate selected first and second moments of Canada's business cycles for the two scenarios previously defined. Table 5 presents the standard deviations, first order autocorrelations and correlations with current and lagged output, of the main series in the data and in the simulations for both scenarios.

Standard scenario: Only productivity shocks

The standard deviations of both productivity shocks are scaled up by 50 percent with respect to Table 4, and θ is reduced from 0.05 to 0.01, to make the model match the volatility of GDP and investment in the data, respectively. The shocks' autocorrelations and cross-correlations are kept as in Table 4, while the IES remains as in Table 3.

Table 5 shows that when business cycles are driven only by productivity shocks, the model produces contradicting results with the data. First, although consumption is procyclical, its volatility is small, specially for importable goods. Second, real net exports are procyclical and too volatile. Third, investment is too procyclical, specially in non tradable capital. Last, although total hours of work are procyclical, the model under predicts their volatility. Intuitively, productivity shocks increase nontradable output without extra work hours or investment in this sector, and households use the external capital market, at a roughly constant interest rate, to smooth importable consumption over time. As a result, domestic demand is less volatile than output, and real net exports are procyclical and volatile.

Benchmark scenario: All four shocks

The standard deviations of all four shocks are increased by 15 percent relative to Table 4 to make the model match the volatility of GDP in the data, while their autocorrelations and cross correlations remain as in Table 4. Also, θ and the IES are set to replicate the observed volatility of investment and correlation between real net exports and GDP, respectively.

Table 5 shows that the terms of trade and foreign interest rate shocks improve the model's ability to replicate the moments of consumption, investment and real net exports relative to the previous case. Consumption is as volatile as in the data, although more procyclical, and investment is less procyclical, although still more than in the data. Adding these shocks also brings the volatility of work hours closer to the data, making them more procyclical and volatile in the nontradable sector, and less procyclical but more volatile, in the export one.

In summary, domestic demand is more procyclical and volatile than output, and real net exports are countercyclical and less volatile than in the standard scenario. However, nominal net exports are still procyclical, while they are weakly countercyclical in the data. This raises the question of whether the Fed Funds rate is a good measure of the foreign interest rate shock, and whether a lower IES could improve the ability of the model to replicate the regularities in the data. The next two subsections explore these questions in more detail.

Different Foreign Interest Rates

Table 6 presents the simulations for three alternative measures of the foreign interest rate: the 3 months and 10 years US treasury bill rates, and the 3 months LIBOR rate in US dollars. In each case the standard deviations of all four shocks are scaled by the same factor to match the volatility of GDP, θ is chosen to match the volatility of investment, and the IES is set to make the model replicate the observed correlation between real net exports and GDP.

This exercise shows that all three measures of the foreign interest rate yield about the same moments of consumption, investment, work hours and net exports. Nominal net exports are as procyclical as in the benchmark case, showing that this avenue is not adequate to replicate the moments of nominal net exports while keeping the other moments close to the data.

Different intertemporal elasticities of substitution

Table 7 shows simulations for three values of σ: $\sigma = 2$, $\sigma = 3$ and $\sigma = 4$, and in each case the standard deviations of all shocks are scaled by the same factor, and θ is set, to match the volatility of GDP and investment in the data, respectively. The shocks' autocorrelations and cross-correlations are kept as in Table 4. Note that these simulations are not bound to replicate the observed correlation between real net exports and GDP.

The simulations are sensitive to the choice of the IES. Raising it to 0.5 makes consumption and aggregate work hours less procyclical and volatile than in the data, makes investment acyclical and exportable output more procyclical and volatile, resulting in more procyclical and volatile real and nominal net exports than in the data. Reducing the IES to 0.25 makes consumption, investment and work hours are more procyclical and volatile than in the data, and makes nominal net exports acyclical by making real net exports more countercyclical than in the data. Thus, reducing the IES does not seem adequate to reduce the procyclicality of nominal exports either, as it worsens other moments.

VII. CONCLUSIONS

A DSGE small open economy model with standard preferences and a normal intertemporal elasticity of substitution, can replicate the SDEs business cycles regularities if the terms of trade and foreign interest rate shocks are added to the productivity shocks as source of business cycles fluctuations. Productivity shocks produce large procyclical fluctuations in exportable output, and a lower volatility of consumption and investment than the one of output. Thus, when business cycles driven only by productivity shocks, the model generates excessive consumption smoothing, and procyclical and volatile real and nominal net exports.

The terms of trade, however, produce smaller changes in output than productivity shocks, but generate more procyclical and volatile variations in consumption and investment relative to output, and countercyclical fluctuations in real and nominal net exports, as changes in quantities more than offset changes in prices. The foreign interest rate shocks also produce small variations in output, but large procyclical fluctuations in consumption and investment relative to output, and countercyclical changes in real and nominal net exports. Furthermore, both shocks reinforce each other as their innovations are negatively correlated in the data.

The failure in previous studies using DSGE small open economy models has been to exclude the terms of trade and foreign interest rate shocks as source of business cycles, while the two country models have failed replicating the volatility of these shocks in the data. However, although the model in this paper replicates the moments of most variables, it over estimates the correlation between nominal net exports and GDP. Changing the measure of the foreign interest rate or the intertemporal elasticity of substitution does not solve the issue, as they reduce the ability of the model to replicate other moments.

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Table 1. Business Cycles Indicators for Developed Economies, Annual Data, 1980 – 2003

A. *Cross-Correlations with Output:*

	$\rho(Y_t, Y_{t-1})$	ρ(Cpriv,Y)	ρ(Cpub,Y)	ρ(C,Y)	ρ(I,Y)	ρ(NX/Y,Y)
G 7 exc. Canada	**0.70**	**0.91**	**0.14**	**0.85**	**0.91**	**-0.54**
Australia	0.51	0.50	0.42	0.58	0.86	-0.35
Austria	0.63	0.87	0.18	0.80	0.70	0.18
Belgium	0.67	0.87	-0.02	0.80	0.91	-0.57
Canada	0.64	0.91	-0.02	0.78	0.83	-0.28
Denmark	0.70	0.78	-0.26	0.69	0.91	-0.78
Finland	0.78	0.94	0.62	0.92	0.96	-0.63
Greece	0.53	0.58	0.03	0.62	0.71	-0.04
Iceland	0.67	0.87	0.49	0.87	0.79	-0.53
Ireland	0.66	0.68	0.18	0.72	0.87	-0.56
Netherlands	0.69	0.87	0.15	0.88	0.87	-0.43
New Zealand	0.58	0.86	0.43	0.81	0.82	-0.48
Norway	0.72	0.83	-0.28	0.80	0.70	-0.49
Portugal	0.77	0.93	0.83	0.93	0.85	-0.75
Spain	0.83	0.94	0.68	0.91	0.96	-0.92
Sweden	0.72	0.80	-0.28	0.71	0.94	-0.53
Switzerland	0.63	0.86	0.35	0.85	0.77	0.00
Mean Small Economies	**0.67**	**0.82**	**0.22**	**0.79**	**0.84**	**-0.45**

B. *Standard Deviations Relative to Output:*

	σ(Y)	σ(Cpriv)/σ(Y)	σ(Cpub)/σ(Y)	σ(C)/σ(Y)	σ(I)/σ(Y)	σ(NX/Y)
G 7 exc. Canada	**2.11**	**1.11**	**0.92**	**0.92**	**2.82**	**0.91**
Australia	1.66	0.70	0.93	0.62	3.51	1.10
Austria	1.44	0.90	1.30	0.79	2.96	0.76
Belgium	1.63	0.92	0.60	0.69	4.54	1.13
Canada	2.38	0.95	0.97	0.76	2.73	1.27
Denmark	1.89	1.12	1.19	1.85	5.04	1.42
Finland	3.90	1.00	0.58	0.83	3.12	1.53
Greece	1.99	1.01	1.14	0.78	2.70	1.03
Iceland	3.37	1.59	0.54	1.27	3.38	3.14
Ireland	2.65	1.17	1.18	0.92	3.50	1.09
Netherlands	1.89	1.16	0.94	0.83	2.59	0.74
New Zealand	2.31	0.92	1.86	0.98	3.53	1.16
Norway	2.15	1.24	0.85	0.79	3.90	1.56
Portugal	3.23	1.16	0.92	1.09	2.84	1.82
Spain	2.33	1.24	1.11	1.18	3.51	1.75
Sweden	2.26	1.39	0.66	0.90	4.03	1.20
Switzerland	1.85	0.64	1.08	0.61	2.46	0.88
Mean Small Economies	**2.31**	**1.07**	**0.99**	**0.93**	**3.40**	**1.35**

Source: World Economic Outlook, IMF.

Note: GDP (Y), private consumption (Cpriv), public consumption (Cpub), total consumption (C) and investment (I) are Hodrick-Prescott filtered logarithms; net exports (NX) is the Hodrick-Prescott filtered ratio to output. For the first and last variables, the reported statistic in part B is the standard deviation of the variable multiplied by 100, while for the others is the ratio of standard deviation of the variable to the one of GDP.

Table 2. Business Cycles Indicators for Developed Economies, Quarterly Data, 1980 – 2003

A. *Cross-Correlations with Output:*

	$\rho(Y_t, Y_{t-1})$		$\rho(C,Y)$		$\rho(I,Y)$		$\rho(NX/Y,Y)$	
Australia	0.84	(0.04)	0.48	(0.13)	0.80	(0.14)	-0.43	(0.16)
Austria	0.90	(0.08)	0.74	(0.20)	0.75	(0.11)	0.10	(0.13)
Belgium	0.79	(0.05)	0.67	(0.14)	0.62	(0.14)	-0.04	(0.10)
Canada	0.91	(0.04)	0.88	(0.08)	0.77	(0.13)	-0.20	(0.21)
Denmark	0.49	(0.14)	0.36	(0.20)	0.51	(0.11)	-0.08	(0.18)
Finland	0.85	(0.09)	0.84	(0.09)	0.88	(0.10)	-0.45	(0.17)
Netherlands	0.77	(0.07)	0.72	(0.11)	0.70	(0.11)	-0.19	(0.09)
New Zealand	0.77	(0.10)	0.76	(0.11)	0.82	(0.13)	-0.26	(0.15)
Norway	0.48	(0.11)	0.63	(0.12)	0.00	(0.11)	0.11	(0.11)
Portugal	0.72	(0.11)	0.75	(0.12)	0.70	(0.14)	-0.11	(0.15)
Spain	0.82	(0.03)	0.83	(0.09)	0.83	(0.12)	-0.60	(0.12)
Sweden	0.53	(0.21)	0.35	(0.17)	0.68	(0.13)	0.01	(0.12)
Switzerland	0.92	(0.05)	0.58	(0.14)	0.69	(0.17)	-0.03	(0.17)
Mean	**0.75**		**0.66**		**0.67**		**-0.17**	

B. *Standard Deviations Relative to Output:*

	$\sigma(Y)$		$\sigma(C)/\sigma(Y)$		$\sigma(I)/\sigma(Y)$		$\sigma(NX/Y)$	
Australia	1.39	(0.21)	0.69	(0.00)	3.69	(0.03)	1.08	(0.12)
Austria	0.89	(0.09)	0.87	(0.14)	2.75	(0.04)	0.65	(0.04)
Belgium	1.02	(0.09)	0.81	(0.13)	3.72	(0.04)	0.91	(0.07)
Canada	1.64	(0.21)	0.77	(0.09)	2.63	(0.03)	0.91	(0.08)
Denmark	1.02	(0.16)	1.19	(0.10)	3.90	(0.02)	0.88	(0.14)
Finland	2.18	(0.39)	0.94	(0.07)	3.26	(0.02)	1.11	(0.10)
Netherlands	1.20	(0.13)	1.07	(0.09)	2.92	(0.03)	0.71	(0.09)
New Zealand	1.56	(0.20)	0.90	(0.10)	4.38	(0.02)	1.37	(0.18)
Norway	1.40	(0.10)	1.32	(0.12)	4.33	(0.03)	1.73	(0.19)
Portugal	1.34	(0.14)	1.02	(0.11)	2.88	(0.05)	1.16	(0.12)
Spain	1.11	(0.12)	1.11	(0.07)	3.70	(0.03)	0.86	(0.07)
Sweden	1.52	(0.20)	0.97	(0.14)	3.66	(0.04)	0.94	(0.09)
Switzerland	1.11	(0.13)	0.51	(0.31)	2.56	(0.05)	0.96	(0.09)
Mean	**1.34**		**0.94**		**3.41**		**1.02**	

Source: Aguiar, M. and G. Gopinath, "Emerging Market Business Cycles: The Cycle is the Trend". Federal Reserve Bank of Boston.

Table 3. Calibrated Parameters and Macroeconomic Ratios

		Macroeconomic Ratios		
Parameter	Value	Variable	Data	Model
Preferences		Aggregate Demand		
β	0.98	c/y	0.844	0.850
ρ	-0.340	c^N/y	76.0	76.0
?	0.051	c^M/y	8.4	8.6
σ	2.58	i/y	13.7	15.3
α	0.669	tb/y	0.021	0.00
		b/y	n.a.	-0.10
Technology				
		Production		
α_X	0.413			
α_N	0.343	y^N/y	76.0	76.0
θ	0.053	y^X/y	24.0	24.0
δ	0.025			
		Inputs		
Supply of External Funds				
		k/y	n.a.	3.50
$\bar{b}$	-6.63	k^N/k	n.a.	0.73
η	0.001	k^X/k	n.a.	0.27
		h	0.27	0.27
Long Term Growth		h^N/h	0.77	0.78
		h^X/h	0.23	0.22
γ	1.007			

Source: CANSIM - Canadian Economic Indicators.

Table 4. Shocks Processes

Shocks	Statistic	ρ	Standard Deviation	Cross correlation of innovations with P^X	r^*	z^X	z^N
Terms of Trade	P^X	0.883	3.70	1.000	-0.201	0.055	0.049
Foreign Interest Rate	r^*	0.783	0.68	-0.201	1.000	-0.100	-0.101
Productivity Exportable	z^X	0.721	0.91	0.055	-0.100	1.000	0.995
Productivity Non Tradable	z^N	0.646	0.84	0.049	-0.101	0.995	1.000

Table 5. Data Moments, Standard and Benchmark Model Simulations

		Data				Only productivity shocks				Adding TOT and R*			
Variable	x	$\rho(x_t, y_t)$	$\rho(x_t, y_{t-1})$	$\sigma(y)$	$\sigma(x)/\sigma(y)$	$\rho(x_t, y_t)$	$\rho(x_t, y_{t-1})$	$\sigma(y)$	$\sigma(x)/\sigma(y)$	$\rho(x_t, y_t)$	$\rho(x_t, y_{t-1})$	$\sigma(y)$	$\sigma(x)/\sigma(y)$
Aggregate output	y	1.00	0.90	1.57	1.00	1.00	0.52	1.57	1.00	1.00	0.60	1.57	1.00
Output exportables	y^x	0.91	0.79	3.26	2.07	0.99	0.55	3.06	1.95	0.70	0.42	3.06	1.95
Output non tradables	y^n	0.93	0.87	1.23	0.78	0.99	0.49	1.12	0.71	0.90	0.53	1.55	0.99
Aggregate consumption	c	0.81	0.70	1.55	0.98	0.99	0.48	0.93	0.59	0.87	0.53	1.66	1.06
Consumption importables	c^m	-0.05	-0.15	4.47	2.84	0.04	-0.19	0.22	0.14	0.64	0.43	3.12	1.99
Consumption non tradables	c^n	0.93	0.87	1.23	0.78	0.99	0.49	1.12	0.71	0.90	0.53	1.55	0.99
Investment	i	0.49	0.55	5.57	3.54	0.89	0.47	5.57	3.55	0.66	0.46	5.57	3.55
Investment exportable	i^x	--	--	--	--	-0.22	-0.18	4.64	2.96	0.61	0.44	14.62	9.31
Investment non tradable	i^n	--	--	--	--	0.97	0.52	7.47	4.76	0.70	0.46	3.09	1.97
Real net exports	nx	-0.17	-0.17	--	0.88	0.80	0.48	--	3.28	-0.17	-0.15	--	1.30
Nominal net exports	nnx	-0.05	-0.01	--	0.97	0.80	0.48	--	3.29	0.54	0.36	--	1.15
Hours of work	h	0.88	0.88	1.65	1.05	0.97	0.55	0.22	0.14	0.71	0.49	1.52	0.97
Hours of work exportable	h^x	0.89	0.81	3.23	2.06	0.96	0.57	2.61	1.66	0.44	0.31	4.39	2.80
Hours of work non tradable	h^n	0.75	0.80	1.42	0.90	-0.93	-0.56	0.47	0.30	0.46	0.32	1.81	1.15
Capital exportable	k^x	0.72	0.62	1.71	1.08	-0.65	-0.52	0.17	0.11	0.31	0.11	1.28	0.82
Capital non tradable	k^n	-0.60	-0.45	0.97	0.62	0.25	-0.10	0.46	0.29	0.13	-0.07	0.18	0.11

Table 6. Model Simulations, Different Measures of R*

		Tresury Bill 3 Months				Libor 3 Months				Tresury Bill 10 Years			
Variable	x	$\rho(x_t, y_t)$	$\rho(x_t, y_{t-1})$	$\sigma(y)$	$\sigma(x)/\sigma(y)$	$\rho(x_t, y_t)$	$\rho(x_t, y_{t-1})$	$\sigma(y)$	$\sigma(x)/\sigma(y)$	$\rho(x_t, y_t)$	$\rho(x_t, y_{t-1})$	$\sigma(y)$	$\sigma(x)/\sigma(y)$
Aggregate output	y	1.00	0.59	1.57	1.00	1.00	0.60	1.57	1.00	1.00	0.59	1.57	1.00
Output exportables	y^x	0.80	0.49	2.82	1.80	0.68	0.40	3.10	1.97	0.69	0.41	3.04	1.94
Output non tradables	y^n	0.93	0.54	1.45	0.92	0.89	0.53	1.58	1.01	0.90	0.54	1.56	0.99
Aggregate consumption	c	0.91	0.54	1.56	0.99	0.87	0.53	1.69	1.08	0.87	0.53	1.68	1.07
Consumption importables	c^m	0.65	0.43	3.07	1.96	0.64	0.43	3.17	2.02	0.63	0.43	3.26	2.08
Consumption non tradables	c^n	0.93	0.54	1.45	0.92	0.89	0.53	1.58	1.01	0.90	0.54	1.56	0.99
Investment	i	0.68	0.46	5.57	3.55	0.65	0.46	5.57	3.55	0.65	0.45	5.57	3.55
Investment exportable	i^x	0.63	0.46	13.94	8.88	0.61	0.44	14.84	9.45	0.60	0.44	14.98	9.54
Investment non tradable	i^n	0.71	0.46	3.26	2.08	0.70	0.46	3.04	1.94	0.69	0.46	3.01	1.92
Real net exports	nx	-0.17	-0.15	--	1.15	-0.17	-0.16	--	1.34	-0.17	-0.16	--	1.33
Nominal net exports	nnx	0.64	0.43	--	1.00	0.52	0.34	--	1.17	0.55	0.36	--	1.13
Hours of work	h	0.70	0.49	1.50	0.96	0.71	0.49	1.52	0.97	0.70	0.49	1.50	0.96
Hours of work exportable	h^x	0.56	0.40	3.81	2.43	0.41	0.29	4.49	2.86	0.42	0.29	4.31	2.75
Hours of work non tradable	h^n	0.45	0.31	1.63	1.04	0.46	0.32	1.86	1.18	0.45	0.32	1.83	1.17
Capital exportable	k^x	0.30	0.10	1.24	0.79	0.31	0.11	1.29	0.82	0.31	0.11	1.30	0.83
Capital non tradable	k^n	0.12	-0.09	0.20	0.13	0.13	-0.07	0.18	0.11	0.13	-0.07	0.17	0.11

Table 7. Model Simulations, Different Intertemporal Elasticities of Substitution

		$\sigma = 2$				$\sigma = 3$				$\sigma = 4$			
Variable	x	$\rho(x_t, y_t)$	$\rho(x_t, y_{t-1})$	$\sigma(y)$	$\sigma(x)/\sigma(y)$	$\rho(x_t, y_t)$	$\rho(x_t, y_{t-1})$	$\sigma(y)$	$\sigma(x)/\sigma(y)$	$\rho(x_t, y_t)$	$\rho(x_t, y_{t-1})$	$\sigma(y)$	$\sigma(x)/\sigma(y)$
Aggregate output	y	1.00	0.51	1.57	1.00	1.00	0.64	1.57	1.00	1.00	0.67	1.57	1.00
Output exportables	y^x	0.88	0.47	4.04	2.57	0.59	0.37	2.47	1.57	0.43	0.29	1.78	1.13
Output non tradables	y^n	0.84	0.41	1.11	0.71	0.93	0.60	1.72	1.10	0.96	0.65	1.90	1.21
Aggregate consumption	c	0.77	0.36	1.18	0.75	0.92	0.60	1.71	1.09	0.96	0.65	1.69	1.08
Consumption importables	c^m	0.12	0.01	5.29	3.37	0.74	0.53	1.87	1.19	0.09	0.16	0.42	0.27
Consumption non tradables	c^n	0.84	0.41	1.11	0.71	0.93	0.60	1.72	1.10	0.96	0.65	1.90	1.21
Investment	i	0.08	0.02	5.57	3.55	0.80	0.57	5.57	3.55	0.90	0.66	5.57	3.55
Investment exportable	i^x	0.04	0.01	15.42	9.82	0.75	0.56	13.50	8.60	0.85	0.64	12.16	7.75
Investment non tradable	i^n	0.14	0.03	3.01	1.92	0.84	0.58	3.32	2.11	0.93	0.66	3.61	2.30
Real net exports	nx	0.46	0.27	--	1.60	-0.39	-0.31	--	1.10	-0.61	-0.46	--	0.86
Nominal net exports	nnx	0.63	0.34	--	1.60	0.38	0.27	--	0.90	0.08	0.07	--	0.61
Hours of work	h	0.33	0.22	1.01	0.64	0.83	0.59	1.81	1.15	0.92	0.66	2.07	1.32
Hours of work exportable	h^x	0.62	0.36	5.79	3.69	0.35	0.27	3.54	2.25	0.19	0.18	2.56	1.63
Hours of work non tradable	h^n	-0.99	-0.52	0.60	0.38	0.70	0.49	2.25	1.43	0.87	0.61	2.66	1.69
Capital exportable	k^x	-0.06	-0.07	1.33	0.85	0.43	0.19	1.18	0.75	0.54	0.27	1.07	0.68
Capital non tradable	k^n	-0.09	-0.14	0.15	0.10	0.21	-0.03	0.22	0.14	0.30	0.04	0.27	0.17

Figure 1. Impulse - Response Functions

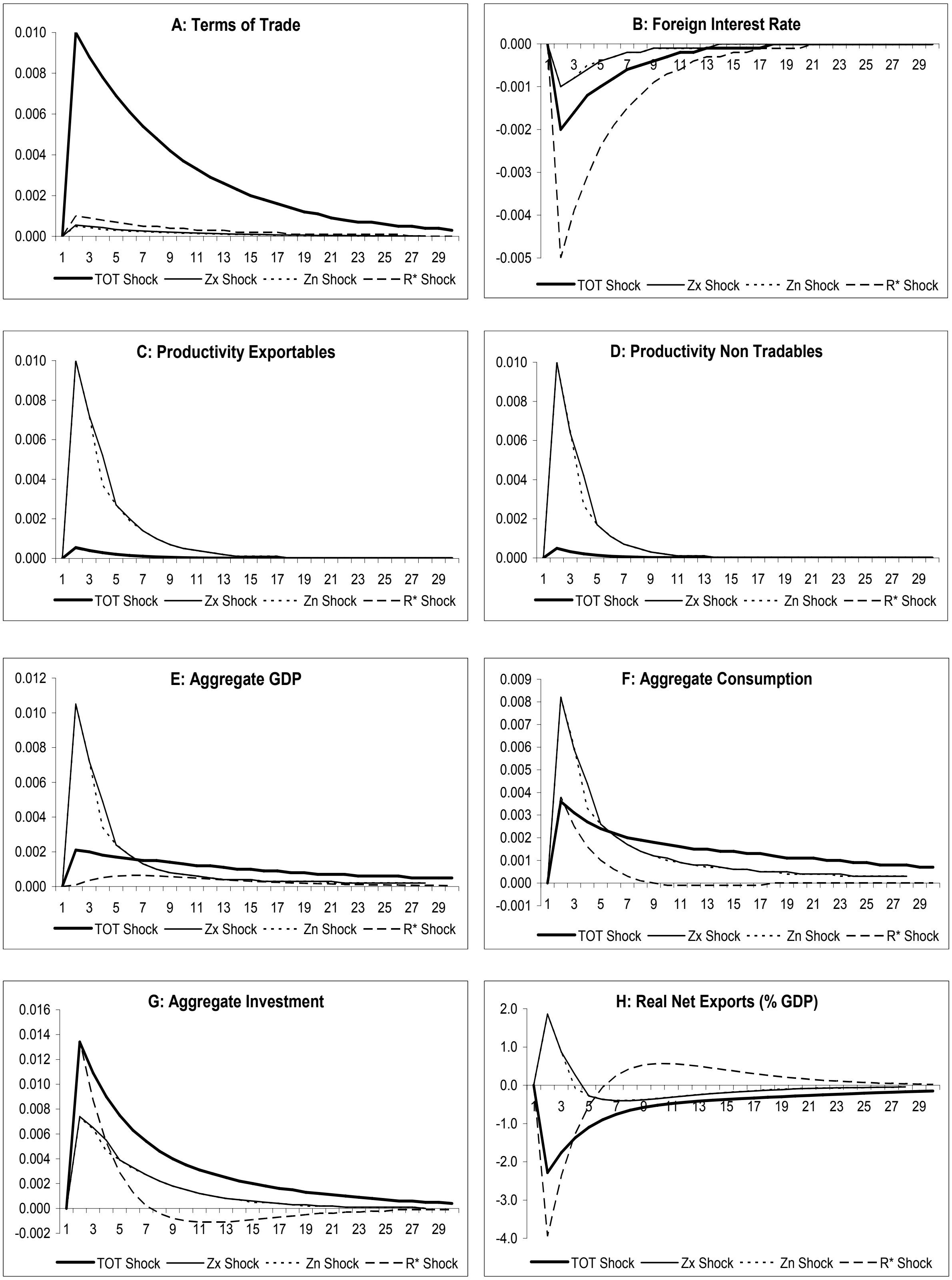

Figure 1. Impulse - Response Functions (Continued)

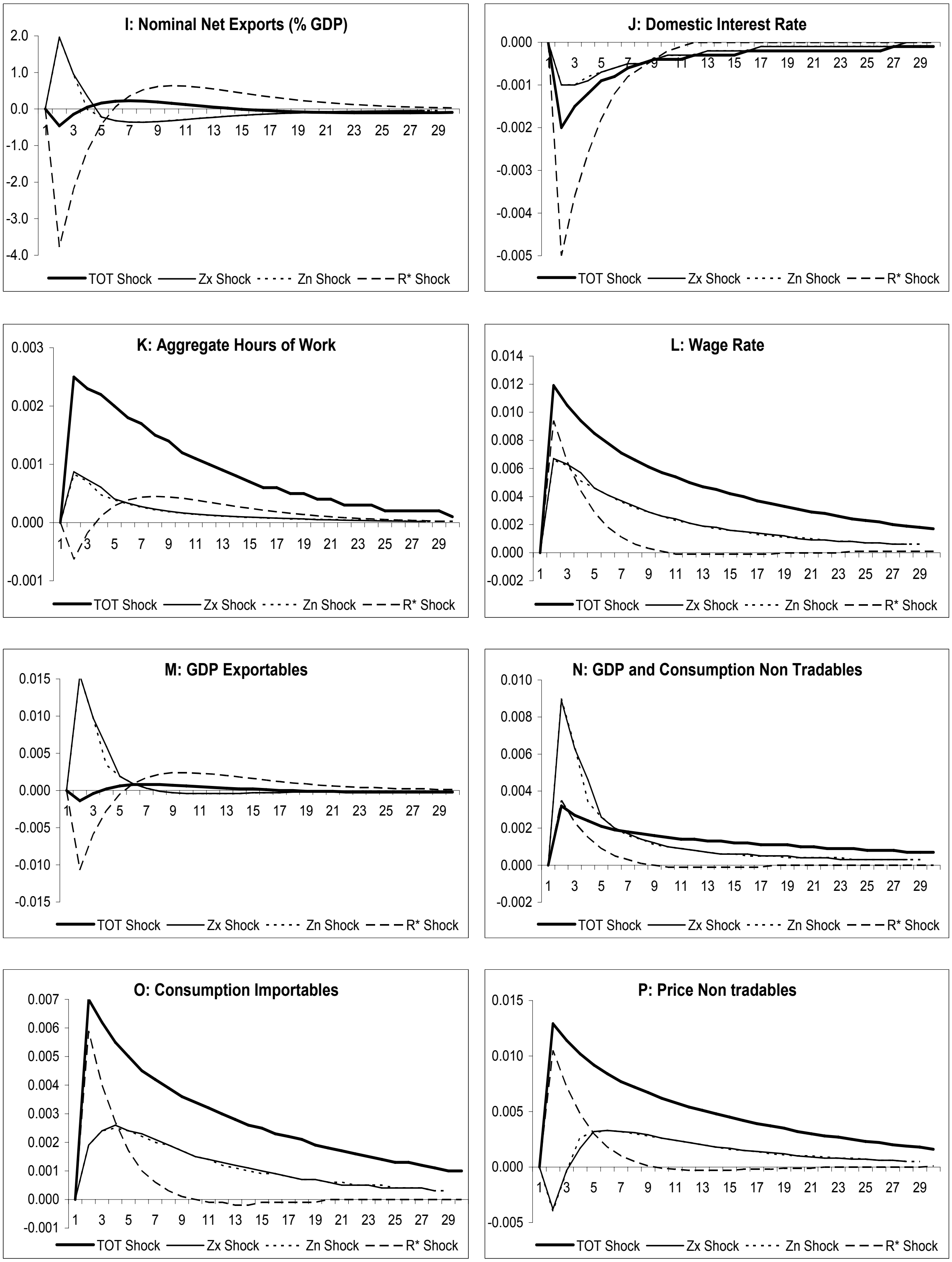

Figure 1. Impulse - Response Functions (Concluded)