Journal of International Economics 75 (2008) 14 – 29

Journal of INTERNATIONAL ECONOMICS

www.elsevier.com/locate/econbase

Net exports, consumption volatility and international business cycle models ☆

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Received 22 February 2007; received in revised form 1 October 2007; accepted 3 October 2007

Abstract

Conventional two-country RBC models interpret countercyclical net exports as reflecting primarily the dynamics of capital. I show that, quantitatively, theoretical economies rely on counterfactual terms of trade effects: trade fluctuations, on the contrary, are driven by consumption smoothing, thus generating procyclical net trade in goods. I then consider a class of preferences that embeds home production in a reduced form: consumption volatility increases so that countercyclical net exports reflect primarily a strong relation between consumption and imports, as in the data. The major discrepancy between theory and data concerns the variability of international prices.
Published by Elsevier B.V.

Keywords: Net exports; International business cycles; Home production; Consumption volatility

JEL Classification: E32; F32; F41

1. Introduction

Countercyclical net exports represent a central feature of international data. This property indicates that countries borrow from international capital markets during booms and repay in recessions, which is at odds with the predictions of consumption smoothing theory.

In several articles, Backus-Kehoe-Kydland (1994, 1995) (BKK henceforth) show that two-country RBC models are consistent with various properties of international fluctuations, including countercyclical net exports. In their interpretation, countercyclical net exports largely reflect the dynamics of capital formation: expansions are associated with investment booms financed by borrowing from international capital markets.

☆ I would like to thank my advisor Andy Atkeson for encouragement and advice provided at all stages of this research. I am also grateful to Ariel Burstein, Hal Cole, Luca Dedola, Eduardo Ganapolsky, Lee Ohanian, Fabrizio Perri, Paolo Pesenti, Randall Wright, two anonymous referees and seminar participants at Arizona State University, Boston College, European Central Bank, Kansas City FRB, Midwest Macroeconomic Conference, 2005 EEA Meetings, Rice University, 2005 SCIEA Meetings, 2006 SED Meetings, UCLA and University of Maryland for helpful comments. Part of this project was conducted while visiting the Research Department at the Atlanta FRB and I thank them for hospitality and useful suggestions. Financial support form UCLA's Dissertation Year Fellowship is gratefully acknowledged.

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[1] The views expressed herein are solely those of the author and do not necessarily reflect the views of the Federal reserve bank of Kansas City or the Federal Reserve System.

0022-1996/$ - see front matter. Published by Elsevier B.V.
doi:10.1016/j.jinteco.2007.10.001

This paper argues that the mechanism by which the BKK model generates countercyclical net exports is counterfactual. After decomposing the cyclical movements of net exports into price and quantity fluctuations, I show that large terms of trade effects generate countercyclical net exports in the BKK model. In the data, however, countercyclical net exports are associated with fluctuations in the (net) quantity of goods traded across countries, while international prices play a minor role.

Countercyclical net exports have a counterpart in terms of volatilities: the volatility of domestic spending is larger than the volatility of output. I document that domestic spending in the BKK model, instead, is *systematically less volatile* than output. Throughout the analysis, I include adjustment costs to investment to avoid the volatility of domestic spending from being artificially increased. After reproducing the volatility of investment observed in the data, my findings suggest that the BKK model delivers too little volatility in consumption. In other words, consumption smoothing governs the dynamics of international trade in the model.

Next, I consider a class of preferences, proposed by Greenwood, Hercowitz and Huffman (1988) (GHH preferences), that include home production in a reduced form. Introducing home production in the BKK framework generates sufficient volatility in consumption so that domestic spending is more volatile than output, as in the data. Countercyclical net exports, it follows, do not reflect the dynamics of capital, but a strong relationship between consumption and imports.

An extensive literature documents that the interaction between home and market activities has important quantitative implications for business cycle predictions of DSGE models.[2] These studies incorporate the idea that households substitute between home and market activities depending on the wage rate. High wages during economic expansions are associated with an increase of hours worked in the market and a corresponding reduction in home production. As a consequence, households increase their consumption of market goods.

My results confirm that the home production structure implicit in the GHH preferences is a promising way to deal with the lack of variability in consumption implied by standard isoelastic preferences. Sensitivity analysis shows that these findings are robust to a wide range of parameter values. I study the effects of varying the trade elasticity, a critical parameter in the BKK model. Intuitively, high complementarity between traded goods implies that country-specific productivity shocks produce strong terms of trade effects by altering the relative scarcity of goods in international markets. In the original BKK formulation, this change in the relative price of traded goods translates into countercyclical net exports. With GHH preferences, however, the model relies on a mechanism that involves a larger response of market consumption to shocks and the value of this elasticity does not affect the cyclical properties of net exports.

I also analyze the effects of varying the Frisch elasticity of labor supply. These experiments confirm that to generate significant volatility in consumption the model requires large substitution between home and market activities, which is supported by the empirical evidence. GHH preferences incorporate this requirements through the Frisch elasticity of labor supply.

The structure of the paper is as follows. Section II presents the main international business cycle features, focusing on the cyclical behavior of net exports, terms of trade and domestic absorption. Section III presents the BKK model and Section IV provides a discussion about its counterfactual implications for the dynamics of international trade in goods. Section V introduces GHH preferences in the BKK model and presents the main findings. Section VI concludes.

2. Data

The data are from OECD's *Quarterly National Accounts* database. All statistics refer to the residual component obtained after applying HP-filter with a smoothing parameter equal to 1600 to the natural logarithm of each series. For net exports no logarithm transformation is implemented. The terms of trade are constructed as the ratio of the import price index (import at current prices over import at constant prices) and the export price index (export at current prices over export at constant prices).

The first column of Table 1 presents the contemporaneous correlation between net exports to GDP ratio and output for most OECD countries, where both variables are measured at current prices. The second column of the table reports the same correlation for emerging economies as documented in Aguiar and Gopinath (2004).

The trade balance is negatively correlated with output in all cases except Israel, with the median correlation value being −0.39. Countercyclical net exports represent a central feature of international data, as noted by Backus and Kehoe (1992) among others, and it implies that countries borrow from international capital markets during high income periods. This observation seems at contrast with the implications of consumption smoothing.

[2] See, for example, Benhabib et al. (1991), and McGrattan et al. (1997).

Table 1
Correlation between net exports and output

Developed economies		Emerging economies	
Australia	−0.36	Argentina	−0.89
Belgium	−0.18	Brazil	−0.03
Canada	−0.17	Ecuador	−0.79
Finland	−0.27	Israel	0.12
France	−0.41	Korea	−0.86
Germany	−0.07	Malaysia	−0.74
Greece	−0.39	Mexico	−0.87
Italy	−0.27	Peru	−0.24
Japan	−0.40	Philippines	−0.40
Netherlands	−0.15	Slovak Republic	−0.44
Norway	−0.01	South Africa	−0.54
Spain	−0.38	Thailand	−0.83
Sweden	−0.04	Turkey	−0.69
Switzerland	−0.21		
US	−0.49		
UK	−0.52		
EU-15	−0.54		
Average		−0.40	
Median		−0.39	

Note. Developed economies: data from OECD–QNA (1980:1–2004:2). Emerging economies: see Aguiar and Gopinath (2004). Series were filtered using HP filter with smoothing parameter of 1600.

Table 2 reports, for most OECD countries, international business cycle statistics of interest for the analysis. The first four columns present the standard deviation of consumption (C), government expenditure (G), investment (I) and domestic absorption (DA) relative to the standard deviation of output. The remaining three columns show the correlation of net exports over GDP (NX), the terms of trade (TOT) and real net exports over GDP (NXQTY) with output. This last variable is constructed using exports, imports and output measured at constant prices and can be interpreted as a proxy for the real net trade of goods and services between countries.

Table 2
Business cycles statistics

Country	Std Dev relative to output				Correlation with output		
	C	G	I	DA	NX	TOT	NXQTY
Australia	0.67	1.04	3.44	1.35	−0.36	−0.18	−0.40
Belgium	0.75	0.94	3.46	1.16	−0.18	−0.18	−0.05
Canada	0.77	0.62	2.62	1.12	−0.17	−0.22	−0.19
Finland	0.93	0.63	3.16	1.48	−0.27	−0.28	−0.46
France	0.82	0.78	2.85	1.07	−0.41	0.30	−0.18
Germany	0.85	0.90	2.08	1.05	−0.07	0.41	0.23
Italy	1.27	0.93	3.29	1.45	−0.27	−0.02	−0.29
Japan	0.67	0.84	2.53	1.05	−0.40	0.43	−0.14
Netherlands	0.99	0.79	2.87	1.11	−0.15	0.11	−0.14
Spain	1.03	1.21	3.48	1.69	−0.38	−0.06	−0.59
Sweden	1.08	0.87	3.68	1.03	−0.04	−0.28	−0.26
Switzerland	0.58	1.16	2.65	1.22	−0.19	−0.19	0.05
UK	1.16	0.79	3.31	1.22	−0.52	0.35	−0.32
US	0.74	0.68	2.74	1.05	−0.49	0.08	−0.44
EU-15	0.89	0.53	2.79	1.19	−0.54	0.16	−0.38
Average	0.88	0.85	3.00	1.21	−0.30	0.08	−0.24
Median	0.85	0.84	2.87	1.12	−0.27	0.11	−0.26

Note. DA = Domestic Absorption, C = Consumption, I = Investment, TOT = Terms of Trade, NX = Net Exports over GDP, NXQTY = Real Net Exports over Real GDP. All series were logged (except NX) and HP filtered using smoothing parameter of 1600.

Some interesting empirical regularities emerge. First, since net exports equal the difference between output and domestic absorption by definition, it follows that countercyclical net exports have a counterpart in terms of volatilities: domestic absorption has to be more volatile than output[3]. The data confirms that this is the case for all countries.

The other statistics in terms of volatilities document the usual business cycle facts reported elsewhere in the literature, such as in Backus and Kehoe (1992). Investment is more or less three times more volatile than output, with the median value being 2.87, while consumption is 0.85 times as volatile as output. Considering that the investment share of output is about 20%, these statistics altogether indicate that a large part of the volatility in domestic absorption originates from consumption. This observation shows that theoretical economies need to generate a substantial degree of variability in consumption at business cycle frequencies.

The right section of the table reports the cyclical properties of the trade variables of interest, namely the terms of trade and net exports. The correlation between the terms of trade and output is slightly positive with the median correlation being 0.11 and values ranging from −0.28 to 0.43. This observation suggests that the terms of trade do not display any significant pattern over the cycle. On the other hand, both net exports (NX) and real net exports (NXQTY) are countercyclical, indicating that real imports of goods and services exceed exports during expansions.

In summary, three important features characterize international business cycles. First, net exports are countercyclical, suggesting that countries borrow from international capital markets during expansions. Second, domestic absorption is more volatile than output and a large fraction of this volatility originates from consumption volatility. Third, the real net trade in goods across countries is countercyclical while the terms of trade do not display any strong cyclical pattern.

3. The model

3.1. Preferences and technology

Time in this model is discrete. Let s_t denote an event drawn each period from a set S_t, s^t denote the history of events up to date t and $\pi(s^t)$ the probability at time 0 of a particular history s^t. There are two countries (i=1, 2) populated by identical infinitively lived agents. Countries might differ in terms of their relative size where π_i indicates the measure of each country. There are two intermediate goods (j=A, B) and two final goods (C_i). Each country specializes in the production of one intermediate good and factors of production are immobile across countries.

Households' preferences are of the standard isoelastic form

$$U(C_i(s^t), 1 - N_i(s^t)) = \frac{\left[C_i^{\mu}(s^t)(1 - N_i(s^t))^{1-\mu}\right]^{1-\gamma}}{1-\gamma} \tag{1}$$

where C_i is consumption, N_is is labor and the time endowment is normalized to one. Households supply labor and rent capital to firms producing intermediate goods in a perfectly competitive market. Intermediate good producers solve a standard profit maximization problem

$$\begin{aligned} &Max\Pi_i(K_i(s^t), N_i(s^t)) = q_i^j(s^t)e^{z_i(s^t)}F(K_i(s^t), N_i(s^t)) - W_i(s^t)N_i(s^t) - R_i(s^t)K_i(s^t) \\ &s.t.\quad F(K_i(s^t), N_i(s^t)) = K_i^{\theta}(s^t)N_i^{1-\theta}(s^t) \end{aligned} \tag{2}$$

where $q_i^j(s^t)$ is the price of the intermediate good j in country i relative to the final good of country i, $W_i(s^t)$ and $R_i(s^t)$ are wages and rental rates in final good units, $K_i(s^t)$ is capital and $z_i(s^t)$ is an exogenous technology shock.

After intermediates are produced, households trade goods in the international market without frictions (hence the law of one price holds) and sell all their holdings of intermediate goods to firms that produce domestic final goods. The final good can be either consumed or invested. Capital is subject to a convex adjustment cost and evolves according to the law of motion

$$K_i(s^{t+1}) = (1-\delta)K_i(s^t) + X_i(s^t) + \Psi\left(\frac{X_i(s^t)}{K_i(s^t)}\right)K_i(s^t) \tag{3}$$

[3] Using the definition DA = Y−NX, we can calculate Var(Da) = Var(Y) + Var(NX)−2cov(Y,NX). Hence, Cov(Y,NX) < 0 implies Var(DA) > Var(Y).

where $X_i(s^t)$ is investment and δ is the depreciation rate. $\Psi(.)$ is such that $\Psi'(.)>0$, $\Psi''(.)<0$. Final good producers are competitive and solve the problem

$$\begin{aligned} &\text{Max} \quad \Pi_i(A_i(s^t), B_i(s^t)) = G_i(A_i(s^t), B_i(s^t)) - q_i^A(s^t)A_i(s^t) - q_i^B B_i(s^t) \\ &s.t. \quad G_i(A_i(s^t), B_i(s^t)) = \begin{cases} \left[\varpi_i A_i^{1-\alpha}(s^t) + (1-\varpi_i)B_i^{1-\alpha}(s^t)\right]^{\frac{1}{1-\alpha}} & i=1 \\ \left[(1-\varpi_i)A_i^{1-\alpha}(s^t) + \varpi_i B_i^{1-\alpha}(s^t)\right]^{\frac{1}{1-\alpha}} & i=2 \end{cases} \end{aligned} \tag{4}$$

where $\varpi_i>0.5$ determines home bias in the composition of final goods. The parameter $\sigma=\frac{1}{\alpha}$ denotes the elasticity of substitution between intermediate goods A and B.

In the benchmark case, asset markets are complete. Let $D_i(s^t,s_{t+1})$ be the quantity of bonds purchased by consumer in country i after history s^t that entitles the buyer to one unit of country 2 consumption if event s_{t+1} happens in period $t+1$. Let $Q(s^t,s_{t+1})$ be the price of the asset. Then the budget constraint for the representative citizen of country i is

$$\begin{aligned} &C_i(s^t) + X_i(s^t) + rx(s^t)\sum_{s_{t+1}} Q(s^t, s_{t+1})D_i(s^t, s_{t+1}) = \\ &= W_i(s^t)N_i(s^t) + R_i(s^t)K_i(s^t) + rx(s^t)D_i\left(s^{t-1}\right) \end{aligned} \tag{5}$$

where $rx(s^t)$ denotes the real exchange rate[4]. The household in each country maximizes utility subject to this budget constraint and the law of motion for capital.

In addition, the case in which agents can trade only a riskless bond is considered. Denote by $D_i(s^t)$ the quantity of bonds purchased by the consumer in country i after history s^t that entitles the buyer to one unit of (country 2) consumption in period $t+1$ with certainty. Let $Q(s^t)$ be the price of such an asset. The budget constraint for the representative citizen of country i can be expressed as follows

$$\begin{aligned} &C_i(s^t) + X_i(s^t) + rx(s^t)Q(s^t)D_i(s^t) + \Phi(D_i(s^t)) = \\ &= W_i(s^t)N_i(s^t) + R_i(s^t)K_i(s^t) + rx(s^t)D_i(s^{t-1}) \end{aligned} \tag{6}$$

where $\Phi(D_i(s^t))$ is a convex portfolio adjustment cost.

3.2. Equilibrium

An equilibrium is an allocation and a set of prices for all s^t and for all $t\geq 0$ such that, given prices, all agents optimize, both types of firms optimize and markets clear. Market clearing for final goods requires

$$C_i(s^t) + X_i(s^t) = G_i(A_i, B_i) \quad i=1,2\,. \tag{7}$$

In the complete markets case, bond market clearing requires

$$\Pi_1 D_1(s^t, s_{t+1}) + \Pi_2 D_2(s^t, s_{t+1}) = 0 \quad \forall s_{t+1} \in S\,. \tag{8}$$

If only a risk-free bond is traded, the market clearing condition for bonds is:

$$\Pi_1 D_1(s^t) + \Pi_2 D_2(s^t) = 0. \tag{9}$$

Intermediate goods market clearing requires

$$\Pi_1 A_1(s^t) + \Pi_2 A_2(s^t) = F(K_1(s^t), N_1(s^t)) \tag{10}$$

$$\Pi_2 B_2(s^t) + \Pi_1 B_1(s^t) = F(K_2(s^t), N_2(s^t)). \tag{11}$$

In order to solve the model, I first compute the non-stochastic steady state by setting the innovations in productivity equal to their unconditional mean values. I then impose that aggregate variables are consistent with long-run ratios

[4] Given that bonds are issued in country 2 units of consumption, the real exchange rate does not appear in the budget constraint of country 2.

Table 3
Benchmark parameters

Preferences	$\beta=0.99$	$\mu=0.34$	$\gamma=2.0$
Technology	$\theta=0.36$	$\delta=0.025$	$\sigma=1.5$
Trade shares	im=0.15		
Productivity			
Transition Matrix		$\begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix}$	
Std Dev innovations		$\sigma_1=0.00852$	
		$\sigma_2=0.00852$	
Corr innovations		$\sigma_{1,2}=0.2580$	

observed in the data (namely, consumption-output ratio equal to 0.8, investment-output ratio equal to 0.2 and import share equal to 0.15). Finally, I log–linearize the system of equations characterizing the solution of the model around the deterministic steady state and solve the resulting system of stochastic difference equations using the method of undetermined coefficients as described in Uhlig (1999). Table 3 reports the benchmark parameters, which are taken from the original BKK.

3.3. Additional variables of interest

The following variables will be the focus of the analysis in comparing the quantitative predictions of theoretical economies with the data. The terms of trade are defined as the price of imports relative to exports

$$\mathrm{TOT}(s^t) = \frac{q_1^B(s^t)}{q_1^A(s^t)}. \tag{12}$$

Net exports over GDP (expressed in terms of final good units) are defined as

$$\mathrm{NX} = \frac{\Pi_2 q_1^A(s^t) A_2(s^t) - \Pi_1 q_1^B(s^t) B_1(s^t)}{\Pi_1 q_1^A F(K_1(s^t), N_1(s^t))}. \tag{13}$$

Changes in net exports are determined by changes in quantities (exports and imports of goods) and prices (terms of trade). The variable NXQTY represents the difference between exports and imports when both terms are evaluated at steady state prices:

$$\mathrm{NXQTY} = \frac{\Pi_2 \overline{q}_1^A A_2(s^t) - \Pi_1 \overline{q}_1^B B_1(s^t)}{\Pi_1 \overline{q}_1^A F(K_1(s^t), N_1(s^t))}. \tag{14}$$

4. Net exports and terms of trade in BKK

This section shows that two-country international business cycle models generate countercyclical net exports through large terms of trade effects, which is counterfactual. This failure is related to the inability of the model to deliver sufficient volatility in domestic spending relative to output. Throughout the analysis, I include adjustment cost to capital so that the volatility of domestic spending is not artificially increased by the excessive responsiveness of investment to productivity shocks. In particular, the elasticity of the investment-capital ratio with respect to Tobin's q is calibrated to reproduce the same investment volatility (relative to output) as in the data.

4.1. Impulse responses

Fig. 1 presents the impulse responses in country 1 after a 1% increase in its own productivity. An increase in productivity has the usual effects of increasing production, consumption and investment. For our purposes, I focus on the trade variables.

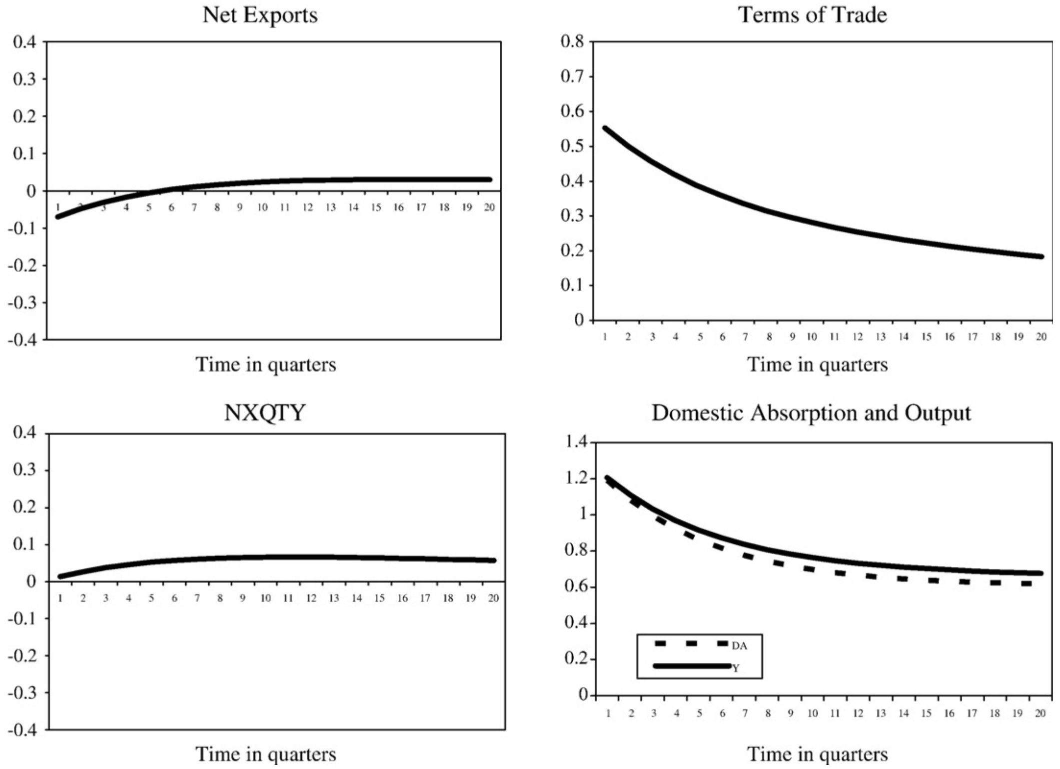

Fig. 1. BKK: Impulse response for 1% productivity shock in country 1. Trade variables.

Fig. 1 decomposes the dynamics of net exports into changes in quantities (NXQTY) and terms of trade effect (TOT). The linearized version of the trade balance provides the mechanics of this decomposition[5]:

$$\widehat{\mathrm{nx}} = \mathrm{im}\left[\hat{a} - \hat{b} - \widehat{\mathrm{tot}}\right] \tag{15}$$

where $\widehat{\mathrm{tot}}$ represents changes in the terms of trade and the first component $(\hat{a}-\hat{b})$ is obtained from the linearization of net exports evaluated at steady state prices, that is

$$\widehat{\mathrm{nxqty}} = \mathrm{im}\left[\hat{a} - \hat{b}\right]. \tag{16}$$

As shown in the figure, the model does indeed generate countercyclical trade balance (NX starts from below zero), as originally argued in Backus et al. (1994). However, this result is entirely due to the strong reaction of the terms of trade. The impulse response of the actual net trade in goods (NXQTY), instead, starts from around zero and stays in the positive region. The intuition for this result is straightforward: positive productivity shocks increase domestic output relative to foreign output, but agents consume a bundle of the two intermediates. When countries trade intermediates in the international market, the relative scarcity of country 2 good is reflected by an increase of the terms of trade. Consequently, net exports become negative during booms because the value of imports increases relative to the value exports. As for quantities, country 1 is exporting more than importing, which is in contrast with the evidence reported in Table 2.

An alternative interpretation on this failure can be obtained from the response of domestic absorption relative to output to productivity shocks (bottom right panel in Fig. 1). In the data, countercyclical net exports are associated with domestic absorption being more volatile than output. The impulse response of domestic absorption, however, is below the impulse response of output, which suggests that the model cannot reproduce this property of the data.

[5] See Appendix A for a full derivation of Eqs. (15) and (16). The term *im* refers to the import share.

Table 4
Properties of theoretical economies

BKK	Std Dev relative to output			Correlation with output		
	DA	C	I	NX	TOT	NXQTY
Data	1.12	0.81	2.76	−0.51	0.12	−0.41
Benchmark	0.98	0.58	2.76	−0.50	0.64	0.39
Large elasticity	0.95	0.56	2.76	0.26	0.64	0.50
Two shocks	0.96	0.71	2.76	−0.35	0.67	0.49
Bond economy	0.98	0.60	2.76	−0.53	0.63	0.32
Bond economy BC	0.99	0.62	2.76	−0.51	0.66	0.15
Bond economy CDL	1.02	0.65	2.76	−0.59	0.57	−0.19

Note. DA = Domestic Absorption, C = Consumption, I = Investment, TOT = Terms of Trade, NX = Net Exports over GDP, NXQTY = Real Net Exports over Real GDP. Statistics for the model refer to averages of 100 simulations of length 100 quarters after applying HP filter (smoothing parameter equal to 1600). In all simulations, capital adjustment costs are included to reproduce the volatility of investment relative to output.

4.2. Model simulations

Table 4 reports the statistics for the variables of interest generated by simulating theoretical economies under a wide range of parameters[6].

The first row presents the data. Given the symmetry assumed in the parametrization and in the estimation of the productivity process, empirical moments are averages of the U.S. and the E.U. statistics. Net exports are counter-cyclical with a correlation with output of −0.51, which is associated with domestic absorption being more volatile than output (1.12). The correlation with output of the terms of trade is close to zero (0.12). The volatility of consumption relative to the volatility of output is 0.81, which denotes a substantial degree of cyclical variability. Investment is somewhat less than three times as volatile as output (2.76).

The second row reports the findings for the standard BKK model with complete asset markets. Net exports are indeed negatively correlated with output (−0.50), but the driving force behind this result is the strong terms of trade effect generated by the change in the relative scarcity of goods across countries. Positive productivity shocks at home increase the production of home goods thus reducing its international value. The subsequent worsening of the terms of trade makes foreign goods more expensive than home goods, generating a negative trade balance mainly because of price effect. However, the net flow of goods between countries is procyclical (the correlation between NXQTY and output is 0.39). This mechanism is at stark contrast with the data, where expansions are associated with imports exceeding exports.

Our previous discussion provides directions to understand why the model is not consistent with the data: the volatility of domestic spending generated by the model is lower than the volatility of output[7]. This finding is also counterfactual. Provided that we are replicating the volatility of investment observed in the data, these results altogether indicate that the model suffers from excessive smoothness in consumption.

The response of the terms of trade to productivity shocks depends critically on the elasticity of substitution between intermediates. The row "Large Elasticity" shows the results for the case in which this elasticity takes value of 2.5 (instead of 1.5 as in the benchmark case). Higher substitution between intermediates translates into lower response of the terms of trade. At this value, net exports are already procyclical. In the limiting case of perfect substitute intermediates, this economy resembles a one-good economy and net exports are systematically procyclical (results are not reported for convenience). Notice that the latter finding is essentially a restatement of one of the findings presented in Backus et al. (1995). In their one-good version of the international business cycle model, Backus et al. (1995) obtain acyclical net exports despite investment being ten times more volatile than output. In my simulations of the one-good environment, I reproduce the volatility of investment observed in the data and obtain procyclical net exports.

[6] Moments for the model are calculated as averages of 100 simulations of series of length 100 periods. HP filter with smoothing parameter of 1600 is applied before computing each statistics.

[7] Notice that despite $Cov(Y, NX)<0$, we obtain that $Var(DA)<Var(Y)$, which seems to contradict the logic presented throughput the paper. This discrepancy is due to the fact that moments for aggregate series are calculated at constant prices, hence they do not take into account changes in the price of consumption relative to output. This price effect is the domestic counterpart of the terms of trade effect read in the dynamics of net exports.

In the "Two Shocks" row, I consider shocks to both productivity and government purchases. Following Backus et al. (1994), government purchases are highly persistent and do not have significant spillover effects. The bivariate process governing these shocks has an autoregressive matrix $B=\mathrm{diag}(0.95,0.95)$, uncorrelated innovations across countries and standard deviations of 0.004. In most dimensions, the properties of the model with two shocks are similar to those in the benchmark economy. The variability of private consumption does increase, but total consumption variability does not: domestic absorption remains less volatile than output.

The "Bond Economy" experiment refers to the case in which only a riskless bond is traded internationally[8]. The business cycle statistics of the model under incomplete markets are very similar to the benchmark case. Several authors find that in this class of models one internationally traded bond allows to achieve allocation similar to the complete market case. Cole and Obstfeld (1991) show that in a two-goods environment with unit elasticity of substitution, positive income shocks in one country translate into movements in the opposite direction of the terms of trade, so that relative wealth is not affected by the presence of incomplete asset markets. Heathcote and Perri (2002) extend these findings to the BKK model and illustrate that for a wide range of parametrization of the productivity process and the trade elasticity, allocations under incomplete markets remain close to the complete markets case.

Baxter and Crucini (1995) study a one-good economy and show that shocks need to have unit root persistence with no spillover effects for the asset structure to matter for business cycle properties. The experiment "Bond Economy BC" presents the results for an economy where asset markets are incomplete and productivity shocks are highly persistent ($\rho_{11}=\rho_{22}=0.98$) with no spillover effect ($\rho_{12}=\rho_{21}=0$). Under this specification, the effect of productivity shocks on relative wealth is stronger, which creates the possibility of large response of consumption to shocks. Simulations show that, despite the fairly high degree of persistence in shocks, there is no significant difference between bond economy and complete markets. This result applies to the cyclical properties of net exports as well: only under near unit root processes for productivity ($\rho_{11}=\rho_{22}=0.995$), no spillover and large trade elasticity, I find that real net exports become countercyclical, confirming the results of Baxter and Crucini (1995).

In a recent contribution, Corsetti-Dedola-Leduc (2007) show that when agents trade only uncontingent bonds and the trade elasticity is low, international business cycle models can generate significant wealth effects to account for the negative correlation between the real exchange rate and relative consumption (so called "Backus-Smith puzzle"). More specifically, productivity shocks are associated with an appreciation of the terms of trade, thus generating large departures from full insurance. In this spirit, the row "Bond Economy CDL" presents simulations for a bond economy with trade elasticity equal to 0.5 and productivity process as in the benchmark case. For this calibration, the terms of trade do not display a negative transmission mechanism[9], yet the net trade in goods is indeed countercyclical. However, this result is driven primarily by the high complementary between goods in the final consumption bundle. The volatility of consumption relative to output does increase, but it remains well below what we observe in the data (0.65 in the model *vs* 0.81 for US–EU average, OECD mean and median are around 0.85). In addition, for this value of the trade elasticity, the volatility of the terms of trade is larger than the volatility of output, with two important implications. First, countercyclical net exports at current prices still reflect strong terms of trade effects and weakly countercyclical real net exports. Second, high volatility in the terms of trade is associated with low volatility in trade flows: the volatility of real net exports is one fourth of its empirical counterpart. Once again, this discussion emphasizes that in order to generate significant inflows of goods during booms, the model needs to replicate the large volatility in consumption observed in the data. The experiments presented in this section indicate that incomplete asset markets per se' do not generate sufficient volatility in aggregate consumption.

In conclusion, these experiments provide two main insights. First, investment incentives to "make hay while the sun shines" are not quantitatively strong enough to generate countercyclical trade balance. In other words, the dynamics of consumption (and not capital, as proposed in BKK) is the main determinant of the cyclical properties of the trade balance. Second, the inability to generate countercyclical net exports can be interpreted as yet another manifestation of the low variability in consumption delivered by standard real business cycle models. This problem is even more severe in their two-country version because of the additional insurance possibilities offered by international trade.

[8] Limiting asset trade to a riskless bond introduces non-stationarity in bond holdings. I follow Schmitt-Grohé and Uribe (2003) and include convex portfolio adjustment costs to induce stationarity.

[9] In their model, the trade elasticity turns out to be smaller than the elasticity of substitution because of the presence of distribution services. The calibration presented here abstracts from this channel, thus yielding procyclical terms of trade.

5. BKK with GHH preferences

In this section, I show that introducing home production in the two-country framework enables the model to reproduce countercyclical net exports. I model home production by use of GHH preferences, as proposed by Greenwood, Hercowitz and Huffman (1988). I present my results using GHH preferences, as opposed to a fully articulated home production model, because they offer a simple yet easy to implement way to deal with the lack of variability in consumption generated by the BKK model. Nonetheless, I report the results for the fully structural BKK model with home production in an appendix[10]. These experiments suggest that for high elasticity of substitution between home and market activities, which is the case supported by empirical estimates, the business cycle properties of the BKK model with home production are quantitatively very similar to the properties generated by the BKK model with GHH preferences.

Two types of considerations motivate the importance of home production in business cycle fluctuations. From the inputs perspective, there is large evidence on the importance of the allocation of time between market and non-market activities. From the output perspective, we observe a high degree of cyclicality in market consumption of goods and services that are substitutes for home production (such as eating at restaurants, child-care, housecleaning...). Altogether, this evidence suggests that there is a large reallocation of resources across market and non-market sectors at business cycle frequency.

GHH preferences, or more generally home production models, capture this trade-off as driven primarily by changes in market technology relative to home technology. Suppose, for example, that the economy experiences a positive productivity shock in the market technology. The increase in market wages induces households to supply more labor in the market, substituting away from home production. The reduction in production of home goods is replaced by an increase in consumption of market goods. Therefore, booms are associated with a larger response in market consumption than in the standard one sector model.

5.1. Simulation results with GHH preferences

Under GHH preferences, the momentary utility takes functional form of the type

$$U(C,N) = \frac{[C - \Psi N^{\nu}]^{1-\gamma}}{1-\gamma} \tag{17}$$

where $\nu > 1$, $\Psi > 0$. Benhabib et al. (1991) show that this utility function can be obtained analytically as a reduced form case from a model that includes home activities[11]. Greenwood et al. (1988), in their original contribution, explore the quantitative implications of such preferences in an environment in which shocks to the marginal efficiency of investment are important sources of business cycle fluctuations.

The solution of the model requires two additional parameters to be calibrated, namely Ψ and ν. The parameter ν governs the Frisch elasticity of labor supply and is calibrated so that this elasticity is the same as in the Cobb–Douglas case. In particular, under Cobb–Douglas preferences the elasticity of labor supply (with marginal utility held constant) is equal to

$$\varepsilon_{CD} = \frac{(1-N)[1-\mu(1-\gamma)]}{\gamma N} \tag{18}$$

while the value for this elasticity implied by GHH preferences is

$$\varepsilon_{\mathrm{GHH}} = \frac{1}{\nu - 1}. \tag{19}$$

Once ν is calculated, Ψ can be computed from the static first order condition so that in steady state the household allocates one third of her time endowment to market activities.

[10] Please see “Appendix: Net Exports, Consumption Volatility and International Business Cycle Models” available at http://www.kc.frb.org/econres/staff/axr.htm.

[11] The relevant assumption is that home and market consumption are close substitutes. Benhabib et al. (1991), and McGrattan et al. (1997) provide evidence in favor of this assumption.

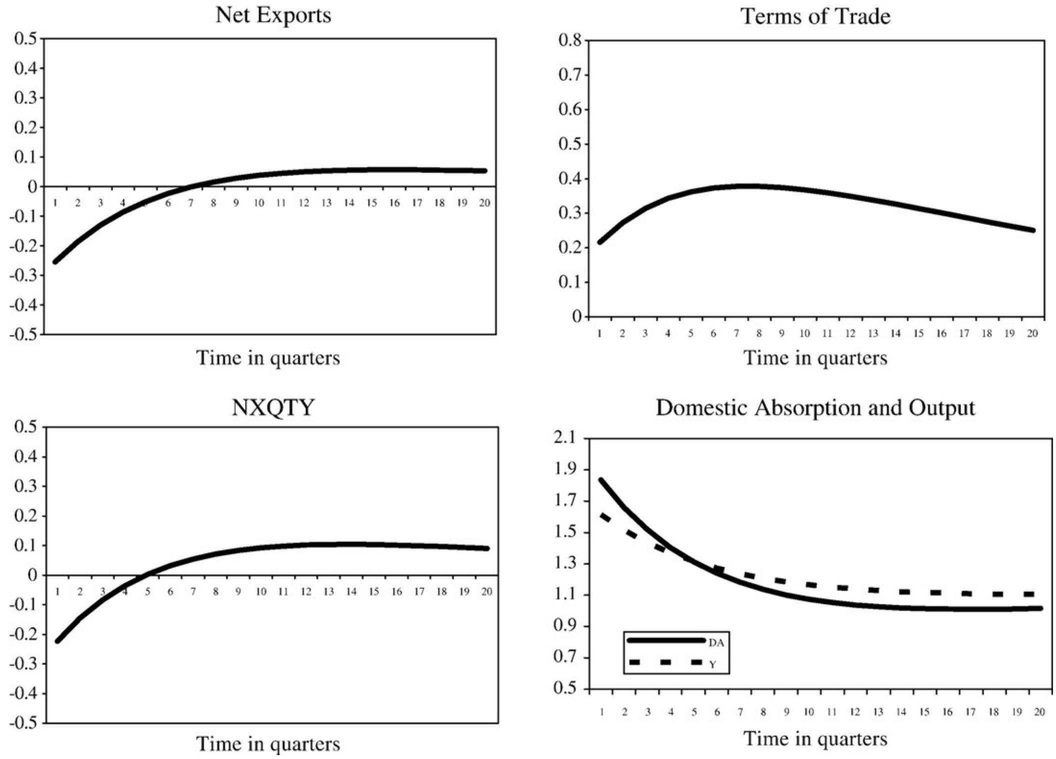

Fig. 2. BKK with GHH preferences: Impulse response for 1% productivity shock in country 1.

Fig. 2 reports the impulse responses for the trade variables in country 1 after a positive productivity shock. The top panels illustrates that net exports are countercyclical and the terms of trade procyclical. However, with GHH preferences net exports are countercyclical because of changes in the net trade of goods (NXQTY). Contrary to the case with isoelastic preferences, domestic absorption (bottom right panel) responds much more than output to productivity shocks: the ratio between the impact coefficients of domestic absorption and output is around 1.11 under GHH preferences, while 0.97 with isoelastic preferences. Given that the response of investment is kept constant across experiments (though in a unconditional sense), the larger response of domestic absorption to productivity shocks must originate from consumption.

Simulations confirm this intuition. Table 5 compares the performance of the BKK model under isoelastic and GHH preferences. The first striking difference is the increase in the volatility of domestic absorption relative to the benchmark case. Under GHH preferences, the volatility of domestic spending is indeed greater than output volatility, as in the data. This effect is due to the increase in consumption volatility relative to output volatility.

Net exports are countercyclical, but with GHH preferences the net flow of goods across countries (NXQTY) is also countercyclical, as in the data. This result confirms that countercyclical net exports reflect a quantitatively strong association between consumption and imports.

Table 5
Symmetric BKK with GHH preferences

	Std Dev relative to output			Correlation with output		
	DA	C	I	NX	TOT	NXQTY
Data	1.12	0.81	2.76	−0.51	0.12	−0.41
BKK	0.98	0.58	2.76	−0.50	0.64	0.39
GHH	1.09	0.79	2.76	−0.51	0.43	−0.44

Note. See note Table 4.

Under GHH preferences, the correlation between the terms of trade and output remains largely positive (0.43). This finding raises concerns about the contribution of the terms of trade in generating countercyclical net exports at current prices. In addition, this result is clearly at odds with the empirical evidence presented in Table 2, which reported acyclical terms of trade or even countercyclical for several countries. I will briefly address these concerns here, while Section 5.3 will present a more extensive discussion on the economic forces behind the results.

With respect to the first issue, notice that the volatility of the terms of trade under GHH preferences is extremely low (0.31 for the benchmark parametrization). This result has two implications. First, the contribution of the terms of trade to generate countercyclical net exports in the model is minimal. In fact, when the trade elasticity is very large the model reduces to a one-good economy and net exports are still countercyclical. Second, highly volatile and countercyclical terms of trade would make generating countercyclical net exports at current prices even harder, requiring strongly countercyclical trade flows.

Regarding the cyclical correlation of the terms of trade, I find that for some combination of trade parameters (namely higher trade elasticity and lower trade share) the model does generate countercyclical terms of trade. However, I decided to present the results under the benchmark calibration because it makes the comparison with the standard BKK model more straightforward. Also, the failure to reproduce significant volatility in the terms of trade indicates that the theory is missing some important elements to account for the overall dynamics of international prices[12].

The main mechanism introduced by GHH preferences works through the static first order condition, which in equilibrium equates the marginal rate of substitution between consumption and leisure to the real wage. Under standard isoelastic preferences we obtain the familiar expression

$$\frac{1-\mu}{\mu}\frac{C_i(s^t)}{1-N_i(s^t)} = W_i(s^t). \tag{20}$$

Under GHH preferences, this condition becomes

$$\Psi v N_i(s^t)^{v-1} = W_i(s^t). \tag{21}$$

Eq. (21) implies that, under GHH preferences, there is no income effect on labor supply (the marginal utility is close to linear in consumption), so that it generates a stronger response of hours of work to productivity shocks. As in the isoelastic case, however, in order for agents to smooth (the marginal utility of) consumption over time, changes in consumption should be roughly proportional to changes in labor[13]. It follows that these preferences generate a stronger response of consumption to output.

The absence of an income effect on labor supply might raise some concerns about GHH preferences, in that the empirical evidence finds very low estimates for the labor supply elasticity at the individual level. Yet, there are a few considerations to keep in mind when working with GHH preferences. A growing literature finds that, despite low elasticity at the individual level, we can obtain models through the aggregation process with large labor supply elasticity at the aggregate level. Seminal works by Hansen (1985) and Rogerson (1988) show that in an environment characterized by non-convexities (agents either work or not), the aggregate labor supply schedule is very elastic. In this environment, aggregate preferences are actually linear in leisure. More recently, Chang and Kim (2006), and Gourio and Noual (2007), estimate structural models by first specifying explicitly the aggregation mechanism and obtain the same dichotomy between micro and macro elasticities. The range of estimates they obtain for the Frisch elasticity of labor supply is between 0.4 and 0.5 at the individual level, between 1 and 1.5 at the aggregate level.

In addition, the home production interpretation stressed in this paper provides a rationale for working with a large labor supply elasticity. In this interpretation, a positive productivity shock increases the market wage so that households reallocate labor from the home sector into the market sector. The reduction in total hours of work in the home sector and, as a consequence, in consumption of home goods induces agents to increase their consumption of goods produced in the market. This mechanism of substitution between work activities ultimately generates the increase in volatility of consumption necessary to produce countercyclical net exports.

[12] For example, Corsetti et al. (in press) show that a combination of low trade elasticity and incomplete markets can account for the properties of the terms of trade observed in the data.

[13] A necessary condition for this result is $\gamma > 1$.

Table 6
BKK with GHH preferences: sensitivity analysis

	Std Dev relative to output			Correlation with output		
Elasticity:	DA	C	I	NX	TOT	NXQTY
(A) Elasticity of substitution between intermediate goods						
1.5	1.09	0.79	2.76	−0.51	0.43	−0.44
5	1.07	0.75	2.76	−0.38	0.42	−0.34
25	1.07	0.75	2.76	−0.32	0.39	−0.30
100	1.05	0.74	2.76	−0.28	0.37	−0.27
(B) Labor supply elasticity (Frisch elasticity)						
1.36	1.12	0.79	2.76	−0.51	0.43	−0.44
1.00	1.06	0.75	2.76	−0.51	0.48	−0.40
0.75	1.05	0.73	2.76	−0.51	0.52	−0.37
0.50	1.02	0.67	2.76	−0.49	0.53	−0.25

Note. See note Table 4.

A final remark before concluding this section. The economics behind home production is closely related to the introduction of a non-tradeable sector into the original BKK formulation. Hence, one might conclude, understanding countercyclical net exports requires simply to introduce non-tradeable goods into the analysis. Two arguments instead make the choice of home production *vis-à-vis* a standard non-tradeable sector preferable. First, GHH preferences introduce a non-tradeable good that is close substitute for tradable consumption. While the empirical evidence suggests that there is a high degree of substitution between home and market consumption, this is not the case for nontraded goods. Many studies estimate the elasticity of substitution between tradeables and non-tradeable to be less than one[14]. This element is important because the model requires a large value for the elasticity of substitution between goods to generate sufficient variability in consumption, that is, the main outcome that we are after[15].

A second reason to prefer the home production interpretation stems from the two-sector implications of the model. In a two-sector environment (with large elasticity of substitution), changes to the relative efficiency of production induce substantial reallocation of inputs across sectors. This is the mechanism at work with home production. In the case of a non-tradeable sector, however, this mechanism would generate negative inputs comovements across sectors belonging to the same economy, whereas business cycles data display high positive comovement across sectors. The negative comovement between home and market activities generated by the model is, on the other hand, a desirable property which is consistent with the empirical evidence.

In summary, this analysis shows that GHH preferences, and the home production structure implicit in them, generate sufficient variability in consumption so that net exports are countercyclical. Moreover, it suggests that not the dynamics of capital, but the response of consumption to income shocks represents a fundamental determinant of trade balance dynamics.

5.2. Sensitivity analysis

This section provides additional evidence in favor of the introduction of GHH preferences into the BKK model by performing sensitivity analysis with respect to two key parameters, namely the elasticity of substitution between traded goods and the Frisch elasticity of labor supply.

The top panel in Table 6 reports sensitivity analysis to different values for the elasticity of substitution between intermediate goods. This parameter is critical because it affects the volatility of the terms of trade: the lower the value for this elasticity, the higher the response of the terms of trade to productivity shocks. Hence, standard BKK formulations require a low value for this elasticity to generate countercyclical net exports. Table 6 illustrates that under

[14] Stockman and Tesar (1995), for example, estimate an elasticity of substitution between traded and nontraded goods equal to 0.44. Their sample includes both developing and developed countries. Mendoza (1991) reports an estimate of 0.74 for a group of industrialized countries.

[15] In the Appendix to the paper available online, I show that for values of the elasticity of substitution between tradeables and nontradeables (i.e., market and home goods) lower than unity, as commonly assumed in the literature, net exports are systematically procyclical. When this elasticity equals 2, net exports are acyclical. For values larger than 4, the correlation between net exports and output is by and large negative (−0.36).

Table 7
BKK with GHH: international prices and cross-country moments

	Std Dev relative to output				Cross-country correlation			
	TOT	RER	NX	NXQTY	Y_1, Y_2	C_1, C_2	I_1, I_2	L_1, L_2
Data	1.12	2.89	0.30	0.23	0.66	0.51	0.53	0.33
BKK	0.57	0.39	0.07	0.05	0.06	0.78	−0.66	−0.89
GHH	0.31	0.22	0.18	0.17	0.32	0.71	−0.89	0.35

Note. TOT = Terms of Trade, RER = Real Exchange Rate, NX = Net Exports over GDP, NXQTY = Real Net Exports over Real GDP, Y = GDP, C = Consumption, I = Investment, L = Labor. Statistics for the model refer to averages of 100 simulations of length 100 quarters after applying HP filter (smoothing parameter equal to 1600). Capital adjustment costs are calibrated to reproduce the volatility of investment relative to output.

GHH preferences, the behavior of net exports does not depend on the particular value of this parameter. In all cases, countercyclical net exports are associated with countercyclical net trade in goods and domestic absorption is more volatile than output. Moreover, even for very large values of the elasticity of substitution (i.e. for the limiting case of a one-good economy), net exports are systematically countercyclical. This last result is of particular interest because in the one-good economy, the standard BKK model cannot generate countercyclical net exports despite investment being ten times more volatile than output, thus confirming to quantitative role of consumption in explaining this empirical regularity.

The bottom panel of Table 6 presents sensitivity analysis to the Frisch elasticity of labor supply. After all, the main mechanism introduced by GHH preferences works through the static first order condition, hence we should expect this parameter to be important. The simulations show that for values of this elasticity close to unity, the overall performance of the model is not affected: net exports are countercyclical together with large consumption volatility. For low values of this elasticity, however, the model's ability to generate countercyclical real net exports deteriorates. This finding confirms the intuition that theoretical economies require sufficient reallocation of labor input between home and market activities: higher values for the elasticity of substitution between home and market activities induce larger response of market hours to productivity shocks. GHH preferences fulfill this requirement through the Frisch elasticity of labor supply.

5.3. Some final remarks

I finally discuss the implications of GHH preferences for other business cycle moments commonly reported in the literature. The left section of Table 7 compares the volatility of international prices under the original BKK formulation and under GHH preferences. The data, which for simplicity refer to the U.S. only, reveal two important features: the terms of trade (*TOT*) are more volatile than output and the real exchange rate[16](RER) is extremely volatile (more than the terms of trade).

Under the standard BKK formulation, the terms of trade are half as volatile as in the data. Under GHH preferences, the volatility of terms of trade is one fourth of the volatility observed in the data. Appendix A presents the derivation of the linearized expression of the terms of trade

$$\widehat{tot} = \eta\left[\phi\left(\widehat{y}_1 - \widehat{G}_1\right) + (\widehat{y}_1 - \widehat{y}_2)\right] \tag{22}$$

where both η and ϕ are positive coefficients. This equation implies that changes in the terms of trade are the result of two offsetting forces. The second term $(\widehat{y}_1 - \widehat{y}_2)$ is a supply effect and captures the idea that productivity shocks alter directly the relative scarcity of goods in the international markets. Hence, positive productivity shocks at home imply that foreign goods become more expensive. The first term $(\widehat{y}_1 - \widehat{G}_1)$ represents a shift in domestic aggregate demand. The cyclical properties of the terms of trade reflect the balancing of these two effects. In the original BKK formulation, the former effect strongly dominates the latter, so that the terms of trade display some variability. Under GHH preferences, domestic absorption responds more to productivity shocks, thus offsetting the relative scarcity effect embedded in the model. As a consequence, the terms of trade display very little variability. The counterpart of this effect is that the model generates more realistic dynamics in goods trade. Not only net exports are countercyclical in the model, but the volatility of net exports is also closer to the empirical volatility. This finding confirms the intuition that under GHH preferences large movements in consumption are associated with significant inflows of traded goods.

[16] The series for the U.S. real exchange rate is the trade-weighted measure reported by the Board of Governors.

In this class of models there is a linear relationship between the terms of trade and the real exchange rate such that the real exchange rate is always less volatile than the terms of trade. This relationship depends only on the production structure and is independent of preferences and asset markets assumptions. Not surprisingly, then, the model under GHH preferences preserves the ranking of volatilities implicit in the BKK model, thus making the real exchange rate implications of the model still at odds with the data.

The right section of Table 7 shows the performance of the model with respect to cross-country correlations. In the standard BKK formulation, the cross-country correlation of consumption exceeds the correlation of output. With GHH preferences the model reduces the gap between the two correlations, but does not invert the ranking.

The BKK model also delivers strong negative correlation in labor and investment across countries, which reflects the incentives to shift resources after changes in productivity. This result is at odds with the data since countries tend to comove positively over the business cycle. Under GHH preferences, the model produces positive comovement in labor input across countries which is closer to the data. The explanation for this result involves the stronger response of labor to productivity shocks together with the positive correlation of innovations across countries. In terms of investment comovement, instead, the model still predicts negative correlation across countries.

In summary, under GHH preferences the model generates international business cycles in line with the data with respect to the overall dynamics of quantities. The major discrepancy between theory and data concerns the variability of international prices.

6. Conclusions

This paper challenges the conventional wisdom that trade fluctuations reflect, to a large extent, the dynamics of capital formation typical of two-country models à la Backus et al. (1994, 1995). After replicating the volatility of investment, theoretical economies generate countercyclical net exports through large terms of trade effects, while the net flow of goods is indeed procyclical. In the data, however, the latter is countercyclical, indicating that there is a strong relationship between consumption and imports.

Countercyclical net exports have a counterpart in terms of volatilities: domestic absorption is more volatile than output. I use this observation to point out that the model delivers too little variability in consumption or, in other words, consumption smoothing is the main force governing the dynamics of trade. I then introduce home production through GHH preferences in the standard two-country framework. Productivity shocks, by altering the relative efficiency between home and market activities, are associated with stronger response in market consumption so that net exports are countercyclical because of imports exceeding exports, as in the data. These findings suggest that countercyclical net exports reflect primarily the dynamics of consumption.

In general, under GHH preferences, the model successfully reproduces the cyclical properties of quantities, including the correlation and volatility of trade variables with respect to output. The major discrepancy between theory and data concerns the low volatility of international prices implied by the model.

Appendix A. Linearization

Given that the Armington aggregator is homogenous of degree one, its log-linearized version is[17]

$$\widehat{G(.)} = \frac{\overline{G}_a\overline{a}}{\overline{G}}\,\widehat{a}_1 + \frac{\overline{G}_b\overline{b}}{\overline{G}}\,\widehat{b}_1 = (1-\mathrm{im}_1)\,\widehat{a}_1 + \mathrm{im}_1\,\widehat{b}_1 \tag{A.1}$$

where im is the import share. Net exports over GDP as defined in (13) have the linear representation

$$\widehat{\mathrm{nx}} = \mathrm{im}_1\left[\widehat{a}_2 - \widehat{b}_1 - \widehat{p}\right]. \tag{A.2}$$

Market clearing condition for good A, Eq. (10), yields

$$\widehat{y}_1 = (1-\mathrm{im}_1)\widehat{a}_1 + \mathrm{im}_1\widehat{a}_2. \tag{A.3}$$

[17] In what follows, a hat denotes percentage deviations from steady state and a bar denotes steady state values.

Combining (A.1) and (A.3) we obtain

$$\widehat{\text{nxqty}} = \hat{y}_1 - \hat{G}_1 = \text{im}_1\left[\hat{a}_2 - \hat{b}_1\right] \tag{A.4}$$

which is the difference between exports and imports evaluated at steady state prices.

Expression (22) can be derived from the linear approximation of the terms of trade

$$\hat{p} = \frac{1}{\sigma}\left[\hat{a}_1 - \hat{b}_1\right]. \tag{A.6}$$

Combining (A.3), (A.4), (A.6) and its analogous for country 2 we obtain

$$\hat{p} = \eta\left[\phi\left(\hat{y}_1 - \hat{G}_1\right) + (\hat{y}_1 - \hat{y}_2)\right] \tag{A.7}$$

where $\eta = \frac{1}{2\sigma(1-\text{im}_1)}$ and $\phi = \frac{1-2\text{im}_1}{\text{im}_1}$.

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