EUROPEAN CENTRAL BANK
EUROSYSTEM

Working Paper Series

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Real exchange rates and international co-movement: news-shocks and non-tradable goods with complete markets

No 1946 / August 2016

Abstract

We propose a fully flexible, complete-market model of the international business cycle that is consistent with two major empirical facts: positive cross-country co-movement of economic aggregates and a negative correlation between the real exchange rate and relative consumption (the Backus-Smith puzzle). The novelty of our paper is twofold. First, we allow for imperfect substitutability of capital which significantly reinforces Harrold-Balassa-Samuelson effects, producing more empirically relevant movements in real exchange rates. Second, we introduce changes in expectations (news-shocks) as an explanation to the Backus-Smith puzzle through movements in relative hours across countries, while being consistent with expectations-driven economic expansions.

Keywords: Backus-Smith Puzzle, Real-Exchange Rates, News-Driven Cycles
JEL Classification: F41, F44

Non-technical summary

International cyclical fluctuations exhibit two distinctive features. First, macroeconomic aggregates like output, consumption, investment and hours worked are positively correlated across countries. Second, the correlation between the real exchange rate and relative consumption is low or negative. Inherent efficiency in a frictionless model with complete markets as in Backus, Kehoe and Kydland (1992, 1994 henceforth BKK) is at odds with these facts. A productivity shock in the home country implies higher imports of capital goods, thereby investment moves in opposite directions across countries. Similarly, higher productivity increases wages and hours worked at home but generates a wealth effect in the rest of the world; increasing leisure and decreasing hours. Further, under complete and perfect international financial markets economic agents would sign contracts such that consumption is higher where it is cheaper; implying a strong positive correlation between bilateral real exchange rates and relative consumption bundles. This is known in the literature as the Backus-Smith puzzle (Backus and Smith 1993).

An immediate solution seems to be to move away from efficiency in financial markets. Nevertheless, market-incompleteness alone is not sufficient to break the tight link between consumption and real exchange rates (Chari, Kehoe and McGrattan 2002). This is largely because the optimal allocation under full international financial integration need not be very different from the allocation of an economy with a single, unconditional bond (Heathcote and Perri 2002) or even financial autarky (Cole and Obstfeld 1991), provided that shocks are not permanent (Baxter and Crucini 1995). On the other hand, shocks that change directly the marginal utility of consumption (Stockman and Tesar 1995) or that generate strong wealth effects (Corsetti et al 2008) could imply a disproportionate increase in relative demand for the home good and hence its relative price.

In this work, we suggest an alternative explanation to the Backus-Smith puzzle in an economy with complete markets. The mechanism in our model operates through two distinct but complementary channels. First, we allow for an imperfect substitutability of capital across sectors of tradable and non-tradable goods production. This generates a strong reaction in the price of the non-tradable good (Balassa-Samuelson effect); thereby breaking the tight link between relative consumption and real exchange rates. Although achieving a strong decrease in the consumption-real exchange rate correlation; the latter is still positive and high. Second, we allow for sectoral productivity innovations to be perfectly anticipated one-period in advance;

what is called a news-shock. News-shocks have the allure of changing agents' expectations about future income without changing current fundamentals. The response of hours to expected Total Factor Productivity (TFP) innovations becomes an important driver or real exchange fluctuations and breaks the tight positive relation between relative consumption and its relative price. The correlation between the real exchange rate and relative consumption turns negative and the model's fit to the data is significantly improved compared to the case of traditional, unexpected disturbances.

Nevertheless, any model driven by expected disturbances should also be consistent with an economic upturn following good news, and a recession following bad news. As is well known, it is surprisingly difficult for standard business cycle models to generate economic expansions following improved prospects about new technologies (Beaudry and Portier 2007, Jaimovich and Rebelo 2009). The novelty of our work is to lay down the theoretical underpinnings that allow the model to generate a worldwide economic boom conditional on anticipated innovations to productivity, while simultaneously generating empirically relevant movements in relative prices. Further, the model produces positive unconditional correlations of output, consumption, hours and investment across countries that are not far from their empirical counterparts.

1 Introduction

International cyclical fluctuations exhibit two distinctive features. First, macroeconomic aggregates like output, consumption, investment and hours worked are positively correlated across countries. Second, the correlation between the real exchange rate and relative consumption is low or negative. Standard macroeconomic theory has difficulty reconciling these facts. The frictionless, complete markets model of Backus, Kehoe and Kydland (1992, 1994, henceforth BKK) suggests that following a productivity shock resources move to the country that is the most productive, implying a negative correlation of investment across countries. Moreover, wealth effects among the residents of the country whose productivity did not improve should increase leisure, hence hours worked should also move in opposite directions. Further, perfect risk sharing in the BKK world instructs that the international transmission of productivity shocks is positive, working via a depreciation in the real exchange rate at home and an improvement in the terms of trade abroad. Efficiency and home-bias imply an increase in relative consumption resulting in a strong positive correlation which is missing in the data (Backus and Smith 1993). In the literature, this is referred to as the Backus-Smith puzzle[1] or the consumption-real exchange rate anomaly (Chari, Kehoe and McGrattan 2002).

The latter might suggest that markets are incomplete and that world residents do not optimally share the risks of country-specific shocks (Kollman 1995). Nevertheless, market-incompleteness alone is not sufficient to break the tight link between consumption and real exchange rates (Chari, Kehoe and McGrattan 2002). This is largely because the optimal allocation under full international financial integration need not be very different from the allocation of an economy with a single, unconditional bond (Heathcote and Perri 2002) or even financial autarky (Cole and Obstfeld 1991), provided that shocks are not permanent (Baxter and Crucini 1995). Cole and Obstfeld (1991) call for an important role of the terms of trade in propagating the benefits of country-specific shocks via price changes, and suggest that the degree of substitutability of goods that are traded across countries can be important for the extent of risk-sharing that this mechanism can provide. Another possible explanation could be that cycles are driven by demand-type shocks, as in Stockman and Tesar (1995), since these disturbances can simultaneously increase both prices and quantities[2].

[1] For the remaining of the paper we abbreviate the latter to B-S.

[2] Corsetti et al (2006) and Enders and Müller (2009) show empirically that the US real exchange rate and terms of trade fall following a permanent increase in manufacturing and aggregate TFP.

We develop a two-country, complete-market model with non-tradables that is able to reconcile these facts in a theoretical economy driven by sectoral productivity shocks. The main contribution of our work is to propose an alternative explanation to the Backus-Smith puzzle based on two main channels: strong Harrold-Balassa-Samuelson (HBS) effects and news-shocks. In a world with complete Arrow-Debreu international markets, a negative correlation between the real exchange rate and relative consumption can arise only through a relatively strong appreciation of the home non-tradable good. We achieve this by allowing for an imperfect substitutability of capital services across tradable-goods and non-tradable-goods sectors - as in Mendoza and Uribe (2000) and Arellano et al (2002). This amplifies HBS effects contributing to a substantially lower correlation between consumption and real exchange rates. Nevertheless, this correlation is still positive unless shocks to TFP are anticipated. News-shocks have the allure of changing agents' expectations about future income without changing current fundamentals. The response of hours to expected Total Factor Productivity (TFP) innovations becomes an important driver or real exchange fluctuations and breaks the tight positive relation between relative consumption and its relative price. The correlation between the real exchange rate and relative consumption turns negative and the model's fit to the data is significantly improved compared to the case of traditional, unexpected disturbances. Our result does not depend on market inefficiency or very low levels of trade elasticity (see Corsetti et al 2008). Instead, it is the efficient allocation in an economy where preferences exhibit low wealth effects on labour supply, the price of non-tradables plays an important role in real exchange rate movements - in accordance to the Harrod-Balassa-Samuelson framework - and innovations to (sectoral) TFP are known one period in advance. Nevertheless, any model driven by expected disturbances should also be consistent with an economic upturn following good news, and a recession following bad news. As is well known, it is surprisingly difficult for standard business cycle models to generate economic expansions following improved prospects about new technologies (Beaudry and Portier 2007, Jaimovich and Rebelo 2009). The novelty of our work is to lay down the theoretical underpinnings that allow the model to generate a world-wide economic boom conditional on anticipated innovations to productivity, while simultaneously generating empirically relevant movements in relative prices. Further, the model produces positive unconditional correlations of output, consumption, hours and investment across countries that are not far from their empirical counterparts.

Therefore, models that rely on productivity to drive business cycles (RBC paradigm) also need to be consistent with a low B-S correlation.

The model possesses several distinctive features that contribute to our results. First, we assume preferences as in Jaimovich and Rebelo (2009, henceforth JR-preferences), but parametrised to exhibit very low intertemporal substitution in labour effort, thus being very close to Greenwood, Hercowitz and Huffman (1988, henceforth GHH). JR-preferences introduce strong non-separabilities between consumption and leisure, thereby reducing the consumption-real exchange rate correlation. Moreover, almost eliminating the wealth effect in labour supply ensures a positive response of hours in both countries given expected shocks to tradables' TFP. Second, as discussed, we allow for an imperfect substitution of capital across sectors which triggers sizable movements in the price of the non-tradable good. Indeed, the exchange rate between the home and foreign non-tradable good appreciates in response to a technology shock in the benchmark model whereas it depreciates in economies where capital is homogeneous. The resulting unconditional B-S correlation in such economies is positive and high - in line with the typical Backus-Smith model - and any changes implied by news-shocks do not adequately decrease it. Third, we allow for variable capacity utilisation which ensures an increase in the supply of labour and output in response to improved expectations about the future state of productivity, following the intuition in Jaimovich and Rebelo (2009). At the same time, variable capacity utilisation amplifies the exogenous propagation mechanisms of the model (Jaimovich and Rebelo 2009, Burnside and Eichenbaum 1996, Baxter and Farr 2005), further intensifying the Balassa-Samuelson effect and allowing for humped-shaped responses. In the context of our theoretical economy, variable capacity utilisation is an essential element to explain news-driven cycles and real exchange rate fluctuations.

Our paper is found in the intersection of three different strands of the literature. First is the literature that tries to reconcile empirical business cycle facts with expected innovations to TFP (Beaudry and Portier (2004, 2006, 2007, 2014), Jaimovich and Rebelo (2008, 2009) and Schmitt-Grohé and Uribe (2012)) and in particular to contributions that look at news-driven international business cycles (Beaudry et al 2011). We add to this list an attempt to simultaneously account for movements in quantities *and* relative prices, in a frictionless open-economy model. Opazo (2006) and Nam and Wang (2010)[a] also investigate news-shocks as a potential source of the consumption-real exchange rate correlation in models where markets are incomplete. We show that a low B-S statistic can be the efficient allocation in an economy where expected improvements in productivity trigger an economic expansion. Second, our work lies in the class of multi-sector, international business cycle models trying to explain the Backus-Smith puzzle. Corsetti et al (2008) show that an incomplete-market model where the trade elasticity is low is consistent with a low degree of international risk sharing. Unlike Cole and Obstfeld (1991), their results suggest that movements in the terms of trade aggravate the risk-sharing problem, instead of mitigating it, in line with some empirical evidence (Corsetti et al 2006, Enders and Müller 2009). Benigno and Thoenissen (2008) construct a model where movements in non-tradables' prices are the main reason behind a negative B-S statistic in a world where a single bond is traded. Stockman and Tesar (1995) suggest that accounting for taste-shocks can be important to explain several facts of international cyclical fluctuations. Raffo (2010) proposes a mechanism via investment-specific technology shocks to account for the consumption-real exchange rate anomaly, as this type of disturbances cause sizable shifts in domestic absorption and acts like a demand shock. As in our case, this mechanism can also work in complete-market environments but can be inconsistent with co-movements of investment across countries[3]. Karabarbounis (2010) shows that accounting for a home-sector can potentially explain the observed limited degree of international risk sharing. Lastly, our work is closely related to the open-economy literature that analyses implications of imperfect capital substitutability (Mendoza and Uribe 2000 and Arellano et al 2009) which, nonetheless, have not been extensively investigated[4]. It's importance for our results suggests that it merits further scrutiny.

The following section outlines the model. Our main results are given in section three while section four inspects the mechanism that drives them, providing the model's underlying intuition. Section five reports some sensitivity analyses to selected parameter values and section six concludes.

2 The model

The model follows closely the workhorse international business cycle model of Backus, Kehoe and Kydland (1992, 1994) extended with a non-tradables sector. Additional features include JR preferences, imperfect substitutability of capital services and variable capacity utilisation. There are two ex-ante symmetric countries, $i = 1, 2$. All exchanges take place in a common currency. Markets are perfect and complete. Time is discrete and infinite, $t = 0, 1, 2, ...$

[3] Moreover, it has been shown to be less relevant once the exogenous process is estimated in the data (Mandelman et al 2011)

[4] The literature seems to favour more the imperfect substitution of labour, instead of capital, across sectors; see for example ECB's EAGLE model (Gomes et al (2010).

2.1 Production

There is full-specialisation in production of intermediate goods; country one produces intermediate good a and country two intermediate good b. Neither capital nor labour are mobile across countries but intermediate goods can be freely exchanged around the world. Output of intermediate goods is produced using a standard Cobb-Douglas production function:

$$\begin{aligned} Y_{at} &= Z_{1Tt}(S_{1Tt})^{\alpha_T}(N_{1Tt})^{1-\alpha_T} \\ Y_{bt} &= Z_{2Tt}(S_{2Tt})^{\alpha_T}(N_{2Tt})^{1-\alpha_T} \end{aligned} \tag{1}$$

where S_{ijt}, N_{ijt}, Z_{ijt} denote capital services (see below), labour and technology in country $i = 1, 2$ and the tradables sector - $j = T$.

Final-good producers are competitive. They purchase domestic and foreign intermediate goods at prices q_a^i and q_b^i, which are transformed into final goods via a constant-elasticity of substitution (CES) production function. Final goods are used locally for consumption (C_{iT}) and investment (Ii):

$$\begin{aligned} C_{1Tt} + I_{1t} &= \{\omega a_{1t}^{\frac{\theta-1}{\theta}} + (1-\omega)b_{1t}^{\frac{\theta-1}{\theta}}\}^{\frac{\theta}{\theta-1}} \\ C_{2Tt} + I_{2t} &= \{(1-\omega)a_{2t}^{\frac{\theta-1}{\theta}} + \omega b_{2t}^{\frac{\theta-1}{\theta}}\}^{\frac{\theta}{\theta-1}} \end{aligned} \tag{2}$$

where a_{it} and b_{it} denote the use of good a and b in country i. We introduce home-bias in each country by allowing $\omega > 0.5$ and $\theta > 0$ is the elasticity of substitution between the two intermediate goods. For values of θ close to zero intermediate goods are complements, $\theta = 1$ corresponds to the Cobb-Douglas case and for $\theta \to \infty$ goods are perfect substitutes. The world's resource constraints for intermediate goods imply:

$$\begin{aligned} Y_{at} &= a_{1t} + a_{2t} \\ Y_{bt} &= b_{1t} + b_{2t} \end{aligned} \tag{3}$$

Moreover, each country produces a final non-tradable good using a Cobb-Douglas production function. We assume that these goods are used only for consumption, as in Corsetti et al (2008), Benigno and Thoenissen (2008) and Karabarbounis (2010).

$$\begin{aligned} C_{1Nt} &= Z_{1Nt}(S_{1Nt})^{\alpha_N}(N_{1Nt})^{1-\alpha_N} \\ C_{2Nt} &= Z_{2Nt}(S_{2Nt})^{\alpha_N}(N_{2Nt})^{1-\alpha_N} \end{aligned} \tag{4}$$

where the subscript N stands for the non-tradables sector. Following the literature, we maintain the assumption of homogeneous labour, and introduce sector-specific capital (Mendoza and Uribe 2000, Arellano et al 2009). In particular, we assume that the capital-services-transformation curve is a CES aggregator of sector specific-services:

$$\begin{aligned} u_{it}K_{it} &= g(S_T, S_N) = (S_{iTt}^{\frac{\varepsilon-1}{\varepsilon}} + S_{iNt}^{\frac{\varepsilon-1}{\varepsilon}})^{\frac{\varepsilon}{\varepsilon-1}} \\ N_{it} &= N_{iTt} + N_{iNt} \quad i = 1, 2 \end{aligned} \tag{5}$$

where u_{it} the rate of capacity utilisation and K_{it} is aggregate capital in country i. The parameter $\varepsilon > 1$ captures the elasticity of substitution of capital services across sectors. Perfect homogeneous capital services correspond to the case where $\varepsilon \to \infty$. The production possibility frontier is concave, owing to differences in factor intensities across the two sectors as well as to the curvature of aggregate services as given by $g(.)$. We view this function as a simple way of capturing imperfect substitutability of capital services across sectors, from the households' point of view. That is households, in lending their capital, have some preferences as to which sector their flows end to. For example during the internet bubble, households may have had some exogenous preference to invest in information technology. This would create a real friction in the financial markets with households requiring a different premium for lending capital to different sectors. As in Arellano et al (2009) and Mendoza and Uribe (2000), we remain agnostic about the exact functional form of the above in the real world, we rather see it as a simple way to add a real friction into the model. As we shall see, depending on the degree of substitutability, the price of non-tradables adjusts accordingly with important implications for the real exchange rate in the spirit of the Harrod-Balassa-Samuelson (HBS) framework. Finally, this approach has the practical appeal of being relatively simple, and we can easily check the implications of our model to different degrees of this elasticity, including homogeneous capital.

Aggregate consumption is a CES composite of tradable (C_{iT}) and non-tradable goods (C_{iN}):

$$C_{it} = \{\omega_T C_{iTt}^{\frac{\rho-1}{\rho}} + (1-\omega_T) C_{iNt}^{\frac{\rho-1}{\rho}}\}^{\frac{\rho}{\rho-1}} \quad i = 1, 2 \tag{6}$$

where ω_T captures the preference for the tradable good and $\rho > 0$ is the elasticity of substitution between the two consumption goods.

2.2 Capital Accumulation

Capital stocks evolve according to:

$$K_{it+1} = (1 - \delta(u_{it}))K_{it} + I_{it}\left(1 - S(\frac{I_{it}}{I_{it-1}})\right) \tag{7}$$

The depreciation rate is an increasing and convex function of capital utilisation such that $\delta'(u_{it}) > 0$, $\delta''(u_{it}) \geq 0$. Function S(.) represents investment adjustment costs, assumed to be zero at the steady-state, and is such that: $S(1) = 0$, $S'(1) = 0$ and $S''(1) > 0$. When we abstract from adjustment costs in the flow of investment we set $S(.) = 0$.

2.3 Households

Households are symmetric and their preferences are characterised by a utility function as in Jaimovich and Rebelo (2009):

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{(C_{it} - \psi N_{it}^{\nu} X_{it})^{\gamma}}{\gamma} \quad \imath = 1, 2 \tag{8}$$

where

$$X_{it} = C_{it}^{\phi} X_{it-1}^{1-\phi} \tag{9}$$

and where C_{it} and N_{it} are consumption and hours worked in country i. We assume that $0 < \beta < 1$, $\nu > 1$ and $\psi > 0$. The presence of X_{it} makes preferences non-time-separable in consumption and hours worked. As explained in Jaimovich and Rebelo (2009), these preferences nest as special cases two well-known classes of utility functions. When $\phi = 1$, we obtain preferences of the class discussed in King, Plosser, and Rebelo (KPR, 1988). When $\phi = 0$ we obtain the preferences proposed by Greenwood, Hercowitz, and Huffman (GHH, 1988). The closest we are to GHH preferences, the lower the wealth effect on labour supply.

2.4 Prices and equilibrium

As the production function in (2) is homogeneous of degree one, we have in equilibrium:

$$\begin{aligned} C_{1Tt} + I_{1t} &= q^1_{at} a_{1t} + q^1_{bt} b_{1t} \\ P_{2Tt}(C_{2Tt} + I_{2t}) &= q^2_{at} a_{2t} + q^2_{bt} b_{2t} \end{aligned} \tag{10}$$

where q^i_{at} and q^i_{bt} are the prices of the two intermediate goods in each country and P_{2Tt} is the price of the country-two good; all expressed in units of the country-one final tradable good (the numeraire). Obviously, with free movement of intermediate goods the law of one price holds: $q^1_{at} = q^2_{at} = q_{at}$ and $q^1_{bt} = q^2_{bt} = q_{bt}\ \forall\ t$. We thus define the terms of trade as the marginal rate of transformation between the two intermediate goods in country one evaluated at equilibrium quantities; which (in equilibrium) equals their relative price[5]:

$$p_t = \frac{q_{bt}}{q_{at}} = \frac{\frac{dY_{1Tt}}{db_{1t}}}{\frac{dY_{1Tt}}{da_{1t}}} = \left(\frac{1-\omega}{\omega}\right)\left(a_{1t}/b_{1t}\right)^{\frac{1}{\theta}} \tag{11}$$

Similarly, equilibrium in local markets requires that:

$$\begin{aligned} P_{1t}C_{1t} &= C_{1Tt} + P_{1Nt}C_{1Nt} \\ P_{2t}C_{2t} &= P_{2Tt}C_{2Tt} + P_{2Nt}C_{2Nt} \end{aligned} \tag{12}$$

where P_{it}, P_{iNt} are respectively the price of aggregate consumption and the price of non-tradables in country i. The price of the non-tradable good is defined as the marginal rate of transformation of the CES aggregator of final consumption (equation (6)):

$$\begin{aligned} P_{1Nt} &= \left(\frac{1-\omega_T}{\omega_T}\right)\left(C_{1Tt}/C_{1Nt}\right)^{\frac{1}{\rho}} \\ \frac{P_{2Nt}}{P_{2Tt}} &= \left(\frac{1-\omega_T}{\omega_T}\right)\left(C_{2Tt}/C_{2Nt}\right)^{\frac{1}{\rho}} \end{aligned} \tag{13}$$

The real exchange rate is defined as the relative price of aggregate consumption across countries:

$$Q_t = \frac{P_{2t}}{P_{1t}} \tag{14}$$

[5] Notice that this is not the standard definition of terms of trade, as it represents the relative price of imports (the foreign good) in terms of exports (the local good). However, this is consistent with the standard definition of the real exchange rate in macroeconomic models.

2.5 Shocks

Finally, we close the model by specifying the technology process which constitutes the exogenous variable in our system and the sole driving force of fluctuations:

$$\begin{pmatrix} Z_{1Tt} \\ Z_{2Tt} \\ Z_{1Nt} \\ Z_{2Nt} \end{pmatrix} = \begin{pmatrix} 0.9616 & -0.0402 & -0.2303 & 0.1748 \\ -0.0402 & 0.9616 & 0.1748 & -0.2303 \\ 0.0396 & -0.0083 & 0.5595 & 0.0730 \\ -0.0083 & 0.0396 & 0.0730 & 0.5595 \end{pmatrix} \begin{pmatrix} Z_{1Tt-1} \\ Z_{2Tt-1} \\ Z_{1Nt-1} \\ Z_{2Nt-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1Tt-q} \\ \varepsilon_{2Tt-q} \\ \varepsilon_{1Nt-q} \\ \varepsilon_{2Nt-q} \end{pmatrix}, q \geq 0 \tag{15}$$

with the following variance-covariance matrix:

$$V = \begin{pmatrix} 0.0059 & 0.0005 & 0.0015 & 0.0001 \\ 0.0005 & 0.0059 & 0.0001 & 0.0015 \\ 0.0015 & 0.0001 & 0.0018 & 0.0004 \\ 0.0001 & 0.0015 & 0.0004 & 0.0018 \end{pmatrix} \times \frac{1}{100} \tag{16}$$

We estimate Solow residuals using the EU-KLEMS database for the period 1978-2004[6]. Country one is the US and country two is a “Rest of the World aggregate” comprised by EU-15, Canada and Japan. Shocks are pure surprises when $q = 0$, whereas assuming $q > 0$ allows the technology shock to be forecastable with certainty in advance (news-shock). Note that under this specification, shocks are either expected or not, irrespective of the country or sector of origin. It is worth emphasising that $q > 0$ does not change the exogenous sources of persistence and volatility of the system since neither the matrix of autoregressive coefficients nor the volatility of the shocks have changed[7]. The mere change is in the timing of the shock. In other words, the two processes are observationally equivalent. That is, an econometrician trying to estimate equation (15) cannot know whether shocks are expected or unexpected; for as long as she uses only the data in vector Z_t to estimate the shock.

2.6 Calibration, Steady-State and Solution Method

We calibrate all parameters of our model to annual data while following closely previous studies. We choose a rate of time preferences β equal to 0.9615 that corresponds to an annual real interest rate of 4%. Following Jaimovich and Rebelo (2009), we

[6]See O′Mahony, M. and Marcel, P. T. (2009).

[7]Any change would be endogenous, resulting from changes in the behaviour of rational agents in light of new information.

set $\phi = 0.001$, such that preferences are close to the GHH form, and $\nu = 1.4$ corresponding to an elasticity of labour supply equal to 2.5. Parameter ψ is adjusted so that at the steady-state agents spend 33% of their time on market activities. The elasticity of substitution of tradable intermediate goods seems to be one of the most controversial parameters in the open-economy literature. This is not only due to the uncertainty surrounding the empirical studies that attempt to estimate its value, but mostly for its important implications about the transmission mechanism of TFP shocks (see Cole and Obstfeld 1991, Corsetti et al 2008). According to Backus, Kehoe and Kydland (1994) the most reliable empirical studies estimate it between one and two, thus they calibrate it at 1.5, whereas Corsetti et al (2008) claim that the range of variation is wider, from 0.1 to 2 (see Hooper et al 2000). On the other hand, the trade industrialisation literature tends to assign higher values (see for example R. Jaef 2011). For our benchmark parametrisation we set trade elasticity to two, which is a bit higher compared to BKK but well within the range of estimates mentioned above. This value is also used by Benigno and Thoenissen (2008) and Karabarbounis (2010) estimates it to 1.907. As part of our sensitivity analysis we test the performance of our model to different values.

We assume that the two final goods are complements in consumption ($\rho = 0.74 < 1$). This value is estimated by Mendoza (1991) and used by Corsetti et al (2008). Stockman and Tesar (1995) set this parameter lower to 0.44 but their sample includes developing countries as well. The degree of home-bias is calibrated assuming an import share equal to 5% while the bias towards the tradable consumption good is set assuming that its share in aggregate consumption is 47%, following Corsetti et al (2008). As for the production function, we assume that the labour share is 61% in tradables production and 56% in non-tradables production. We assume a level of investment adjustment costs equal to 0.05. This value is lower than in other studies where it is often chosen to match the relative variance of investment. In our model investment is not too volatile so we set κ to the minimum value consistent with expectations-driven cycles following a news-shock to the tradables sector in country one under the benchmark parametrisation (see more below). We choose to focus on the tradables sector since it is the main driver of aggregate fluctuations.

We now move on to the choice of the elasticity of substitution of capital services, for which to our knowledge there are no empirical estimates[8]. Given the uncertainty

[8] Mendoza and Uribe (2000) calibrate it to -0.11 for Mexican data because this value ensures that the response of the non-tradables' price to a "devaluation-risk shock" matches the empirical one estimated in a Vector Autoregression (VAR). Arellano et al (2009) use this value for Ivory Coast, simply following these authors. However, simply adopting this value would not be appropriate since

Table 1: Parametrisation

Preferences		
$\beta = 0.9615$	Discount factor	Annual interest rate of 4%
$\frac{1}{\nu - 1}$	Elasticity of labour supply at 2.5	Jaimovich and Rebelo (2009)
$\gamma = -1$	Risk Aversion equal to two	Backus, Kehoe and Kydland (1994)
$\phi = 0.001$	Balance between KPR and GHH utility function	Jaimovich and Rebelo (2009)
ψ	Steady-state labour supply: 33%	
Elasticity of substitution		
$\theta = 2$	Home and foreign intermediate good	Benigno and Thoenissen (2008)
$\rho = 0.74$	Tradable and Non-tradable good	Mendoza (1991)
$\varepsilon = 1.67$	Capital Services	Estimated
Bias		
$\omega = 0.772$	Home bias	Import share: 5%
$\omega_T = 0.445$	Bias in tradables consumption	Consumption share of tradables: 47%
Technology		
$\alpha_T = 0.39$	Capital share in tradables production	Corsetti et al (2008)
$\alpha_N = 0.44$	Capital share in non-tradables production	Corsetti et al (2008)
$\delta = 0.10$	Annual depreciation rate	
Investment		
$\kappa = 0.05$	Level of adjustment costs	Positive responses to expected shock
Utilisation		
$\frac{\delta''(\bar{u})}{\delta'(\bar{u})}\bar{u} = 0.15$	Elasticity of marginal depreciation	Jaimovich and Rebelo (2009)

and lack of empirical evidence surrounding the value of this parameter, we estimate it as to minimise the distance between some theoretical moments - in economies driven by surprise TFP shocks - and their empirical counterparts. The chosen moments are the correlations of the real exchange rate with respect to relative output, terms of trade, and the net exports to GDP ratio[9]. Strong HBS effects are likely to drive the first two moments in opposite directions, so including them in the estimation ensures a fair balance between the two. The last moment helps to resemble the co-movements in relative prices and international trade flows as in the data. We perform the exercise also using only the last two moments, i.e. the correlation of the real exchange rate with the terms of trade and with the ratio of net exports over GDP. As mentioned, investment adjustment costs are necessary in our model to ensure positive response of hours, investment and output following an announced increase in tradables TFP. We would like to choose the lowest value consistent with the latter. Therefore, we proceed our exercise as follows: first, we run our method of moments estimation for ε in economies driven by unexpected shocks to TFP, using a relatively high value of the investment adjustment cost parameter (0.055). Such a value ensures that the model produces expectations-driven booms, once shocks are allowed to be anticipated, for any degree of capital substitutability. This exercise gives an optimum value of ε equal to 1.492 if we take into account all the three moments and 1.856 if we include only the last two; on average 1.67[10]. At this value, the calibrated choice for the investment-adjustment cost parameter is 0.05. Note that the minimum distance estimator of ε when $\kappa = 0.05$ is still very close to 1.67, validating our choice.

Finally, we discuss issues concerning capacity utilisation. The depreciation function is assumed to be quadratic of the form:

$$\delta(u_t) = \delta_0 + \delta_1(u_{it} - \overline{u}_i) + \frac{\delta_2}{2}(u_{it} - \overline{u}_i)^2 \tag{17}$$

Setting $\delta_0 = 0.1$ we ensure that the depreciation rate is 10% per annum at the steady-state. Moreover, we assume a constant steady-state utilisation rate (equal to unity) and we calibrate the elasticity of marginal depreciation to $\frac{\delta''(\overline{u})}{\delta'(\overline{u})}\overline{u} = \frac{\delta_2}{\delta_1}\overline{u} = 0.15$, following Jaimovich and Rebelo (2009). As these authors explain, a low elasticity

we focus on developed economies.

[9]Specifically, we estimate the sum of quadratic deviations of model-estimated (asymptotic) moments vis - à - vis the data. We select the value of ε that minimises the quadratic loss function. Moments are equally weighted, which ensures that the general method of moments estimator is unbiased and consistent.

[10]Figure 13 in the Appendix plots these loss functions. They are both well defined and a global minimum is attained.

of $\delta'(u)$ implies that utilisation is more responsive to shocks, resulting to a powerful amplification mechanism.

Given the parameters, we solve the problem of the social planner who weights both countries equally. We log-linearise the model around the symmetric, non-stochastic steady-state and we solve it using standard numerical methods.

3 Results

3.1 Unconditional Correlations

In this section we describe our benchmark results, which are presented in Table 2. Both empirical and model-generated data are HP-filtered with a smoothing parameter equal to 100[11]. Theoretical moments are asymptotic.

First, we note that in this benchmark parametrization, the model is able to generate positive correlations of economic aggregates across countries for any type of shock. For shocks that are pure surprises the model produces higher cross-country correlations for consumption and hours than observed in the data and lower correlations of output and investment. Cross-country correlations are slightly lower in news-driven economies. Finally, the model produces a higher correlation in consumption than output when we observe the contrary in the data.

The most novel results of the paper come from the statistics on relative prices across countries. The correlation between bilateral relative consumption and the real exchange rate is positive and relatively strong (0.51) in a world where shocks are unexpected, but drops by almost sixty basis points and becomes negative (-0.10) in news-driven cycles. Morover, the correlation between the real exchange rate and relative output which is positive when shocks are pure surprises becomes negative when shocks are anticipated, as in the data. The correlation of the real exchange rate with the terms of trade and net exports maintains the correct sign despite some changes in magnitude. Importantly, these significant improvements observed when allowing productivity shocks to be anticipated come at no cost in terms of international co-movement. All international correlations remain largely unchanged and positive. At the same time, a worldwide economic expansion pursues good news about the future state of productivity (see below).

Other successful features include counter-cyclical net exports and strong pro-

[11]Our results are largely unchanged when we use a smoothing coefficient of 6.25 as advised in Ravn and Uhlig (2002). These results are reported in Table 7.

Table 2: Baseline Model

	Data	Unexpected Shocks	News Shocks
St. Deviation relative to GDP			
Consumption	0.81	0.58	0.55
Investment	3.50	2.02	2.11
Hours	0.78	0.66	0.65
Real Exchange Rate	2.91	0.12	0.21
Terms of Trade	2.04	0.45	0.39
Correlation between real GDP and			
Real Net Exports	-0.56	-0.20	-0.38
International co-movements			
Output	0.35	0.21	0.16
Consumption	0.25	0.32	0.28
Hours	0.12	0.26	0.23
Investment	0.21	0.13	0.08
Correlation between RER and			
Rel. Consumption	-0.51	**0.51**	**-0.10**
Rel. Output	-0.46	0.45	-0.22
Terms of Trade	0.72	0.72	0.34
Real NX over GDP	0.35	0.56	0.83

Actual data are from UPENN World Tables, 1970-2011 at annual frequency. Both empirical and model-generated data are HP-filtered with a smoothing parameter equal to 100. Theoretical moments are asymptotic.

cyclical movements in employment, investment and consumption within countries (not shown). On the other hand, the model generates too little volatility, especially for relative prices - a common problem of open-economy models (BKK, Heathcote and Perri 2002). Nevertheless, the real exchange rate is almost twice as volatile in the news-driven economy.

3.2 International Co-movements

The main insight of our model is that news-driven international cycles as discussed in Beaudry, Dupaigne and Portier (2011) and Jaimovich and Rebelo (2009) can also be consistent with a negative correlation between the real exchange rate and relative consumption.

Consider an anticipated shock to the tradables TFP in country one. Impulse responses are given in figure 1. Investment adjustment costs provide an incentive for investment smoothing so that the response is positive on impact. An increase in investment today lowers the value of installed capital since adjustment costs mean that higher investment today lowers the cost of augmenting the capital stock in the future. As capital is less valuable, it becomes efficient to increase its rate of utilisation. The

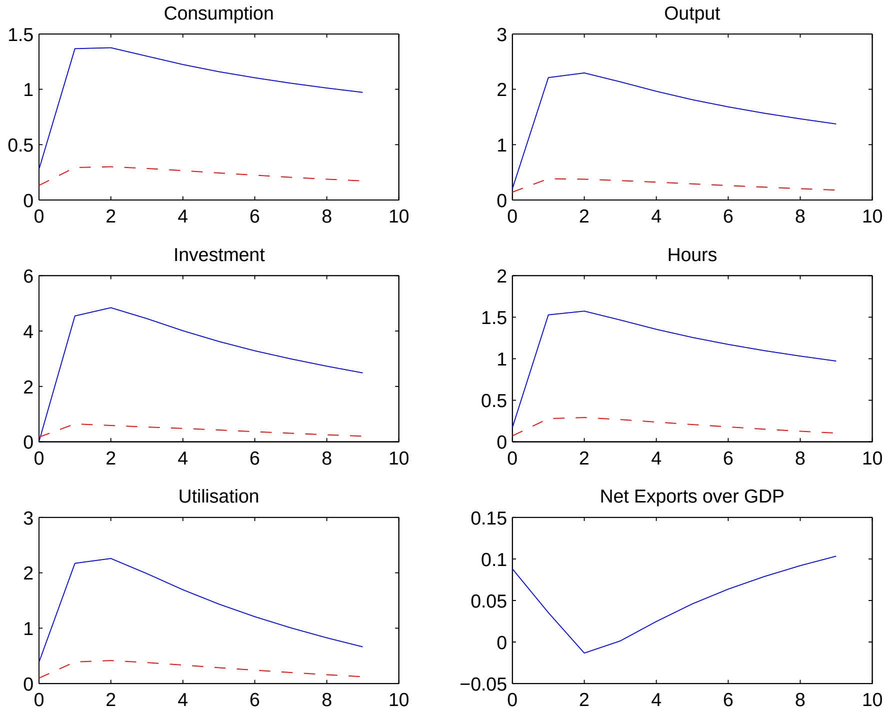

Figure 1: World expansion generated by an expected shock to the tradables sector TFP of country one. Solid lines: country one. Dashed lines: country two. Percentage deviations from steady-state, except for net exports.

latter increases the marginal productivity of labour hence, given almost zero wealth effects on labour supply, workers postpone leisure raising hours and output. In the foreign country agents also anticipate a future increase in their income, coming from positive cross-country productivity spillovers, since we assume that news is a common, public announcement. Therefore, the response is similar to that of country one but weaker.

Jaimovich and Rebelo (2009) show that preferences with low wealth effects on labour supply, investment adjustment costs and variable capacity utilisation are consistent with a pro-cyclical response to news about a permanent change in TFP in a single-sector, closed-economy model[12]. A major contribution of our work is to extend their analysis to a two-country world consistent with news-driven economic expansions both within and across countries. These elements serve as a powerful source of international business cycle synchronization under expected shocks to the (tradables) TFP. On the other hand, Beaudry and Portier (2007) show that cost-complementarities can also deliver within country co-movements in a multi-sector

[12]In an earlier part of their work (Jaimovich and Rebelo 2008) they derive similar results in the context of a small open-economy model.

economy for as long as the elasticity of labour supply is not too low. Beaudry, Dupaigne and Portier (2011) develop a multi-sector model of national and international business cycles with complementarities between capital and labour in the production of the consumption good, as well as sector-specific factors of production. We show that complementarities are not necessary once we allow for the elements of our model.

To sum up, we have shown that our model is able to replicate two of the most well-known empirical facts of international macroeconomics: positive international co-movements of economic aggregates (both unconditionally and conditional to a news-shock) and a negative correlation between relative consumption and the real exchange rate. In what follows, we analyse in detail the mechanisms that drive our results, especially with respect to the B-S correlation.

4 Inspecting the mechanism

4.1 The Balassa - Samuelson effect

There is no consensus on the impact of sectoral productivity differentials and the relative price of non-tradables on real exchange rate movements. Kakkar (2003), Bergstrand (1991), De Gregorio and Wolf (2004) and Corsetti et al (2006) document empirical evidence in favour of Balassa-Samuelson effects, whereas Betts and Kehoe (2006) document an important role for the relative price of non-tradables to the US-Canada and US-Mexico real rate (see also Mendoza and Uribe 2000). On the other hand, Engel (1999), Engel and Rogers (1996) and Chari, Kehoe and McGrattan (2002) find that most of the real exchange rate variability is due to tradables and deviations from the law of one price.

Consider a temporary, but persistent, TFP shock to the home tradable-good sector alone[13]. The dynamics are governed by the well-known Harrold-Balassa-Samuelson framework: the terms of trade depreciate - reflecting efficiency in international financial markets - and the price of the non-tradable good increases reflecting sectoral productivity differentials and free labour mobility across sectors. The response of the real exchange rate will depend on the relative strength of the two effects: the terms of trade effect that pushes towards a depreciation and the Balassa-Samuelson effect that pushes towards an appreciation. Under our parametrization, the first effect wins

[13]We choose to analyse responses to shocks in the tradables sector TFP as these are the main drivers of cycles. Responses to shocks to the non-tradables sector productivity are provided in the appendix (figures 11 and 12).

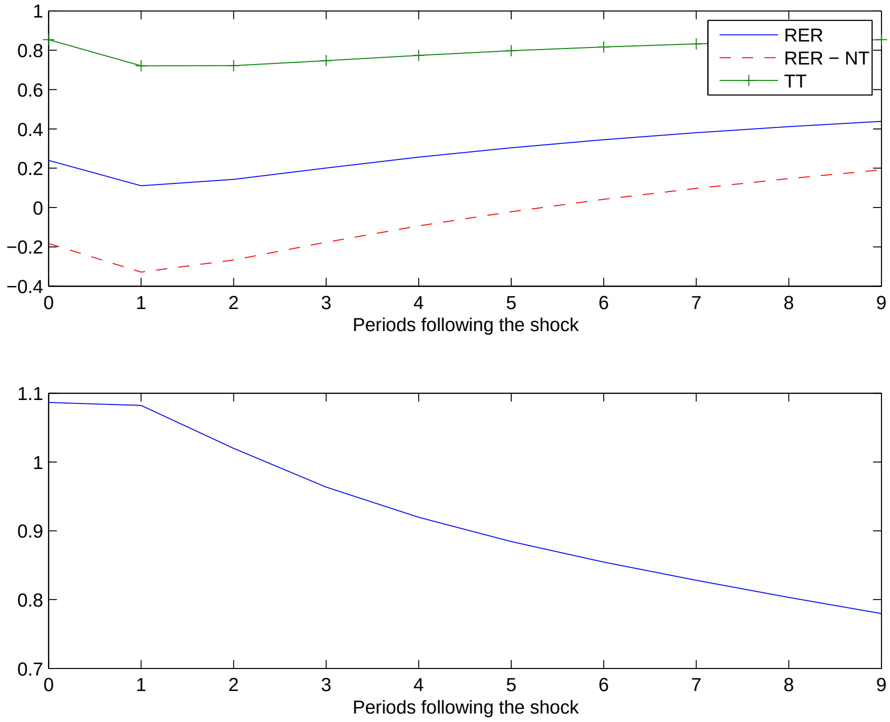

Figure 2: The HBS effect in the benchmark model. The response of relative prices (upper panel), i.e. the real exchange rate (RER), the terms of trade (TT) and the relative price of non-tradables (RER-NT), and relative consumption (lower panel) to one standard deviation unexpected shock to the tradable-goods sector. Percentage deviations from the steady state.

and the real exchange rate depreciates on impact (see Figure 2). However, the real exchange rate moves on a downward path for one period (appreciation) and then depreciates for several years before returning to its initial level. On the other hand, relative consumption increases on impact as home-bias drives home-consumption higher and thereafter consumption-smoothing prevails to ensure a smooth, downward path.

The dynamics are a bit different when TFP improvements are perfectly anticipated one period in advance, where the correlation between the real exchange rate and relative consumption is negative. Impulse Response Functions (IRFs) are given in figure 3. When faced with unexpected technology improvements the terms of trade depreciate to reflect the scarcity of the foreign good; they depreciate in response to positive news about the future to reflect the fall in the *relative demand* of the home good. The relative price of the home non-tradable good also falls, implying an overall depreciation of the real exchange rate. The intuition is that following the announcement, the home-country enjoys higher future wealth; a demand-side effect that pushes towards an appreciation. For the same reason, though, utilisation increases more in the home-country, increasing relative supply and creating forces towards a depreciation. Given the model's features and the specified parametrization, the latter effect dominates and the real exchange rate depreciates on impact[14]. Thereafter, the real exchange rate follows a downward path for one period when relative consumption increases. This discrepancy in the response of the two variables during the interim-period (i.e. between the announcement and the actual TFP change) drives their correlation down. Abstracting from the impact response, the two variables move in opposite direction for two periods instead of one as was the case for surprise shocks. Had the news arrived two periods in advance, they would be moving so for three periods and so on; which explains why the B-S statistic falls almost monotonically with the length of the interim period[15].

The dynamics of the real exchange rate can be more clearly understood from the equations of the model. With complete markets, the real exchange rate equals the ratio of the marginal utility of consumption, such that in the log-linearised model[16]:

$$\hat{rer}_t = \hat{U}_{c_{2t}} - \hat{U}_{c_{1t}} = A(\hat{c}_{1t} - \hat{c}_{2t}) - B(\hat{n}_{1t} - \hat{n}_{2t})$$
$$=> corr(\hat{rer}_t, \hat{c}_{1t} - \hat{c}_{2t}) = \frac{1}{sd(\hat{rer}_t)}[A\, sd(\hat{c}_{1t} - \hat{c}_{2t}) - B\, corr(\hat{n}_{1t} - \hat{n}_{2t}, \hat{c}_{1t} - \hat{c}_{2t})\, sd(\hat{n}_{1t} - \hat{n}_{2t})] \tag{18}$$

where A and B are positive constants[17] and $sd(.)$ stands for standard deviation. Non-seperability between consumption and leisure in the utility function breaks the tight link between the real exchange rate and relative consumption. When the marginal utility of consumption is not influenced by the leisure choice (i.e. $B = 0$), the real exchange rate moves in direct proportion to relative consumption. Quantitatively, a strong positive correlation between relative consumption and relative hours contributes to a lower correlation between the real exchange rate and relative consumption. Indeed, the correlation between relative consumption and relative hours is positive and high in both versions of the model, a consequence of extremely low wealth effects on labour supply[18]. Allowing shocks to be perfectly anticipated one period in advance has almost no effect on the relative-consumption-relative-hours correlation;

[14]Differently, the social planner chooses an equilibrium with lower prices but higher output for the country that receives the good news and higher prices and lower output for the other.

[15]We analyse the performance of our model to lengthier interim periods later.

[16]This corresponds to the case of GHH preferences, i.e. for $\phi = 0$. When $\phi \neq 0$ the B-S correlation is also influenced by the corss-country difference in X_t and the langrange multiplier on the constraint in equation (9).

[17]$A \approx 4.96$ and $B \approx 4.14$.

[18]When $\phi = 1$ the B-S correlation is 0.54 when shocks are surprises and 0.58 with news-shocks. The correlation between relative consumption and relative hours is significantly lower, especially when shocks are anticipated (0.37).

yet the B-S correlation is significantly lower. The channel through which this works is via a bigger drop in the standard deviation of relative consumption vis-à-vis relative hours, such that the term in square-brackets becomes negative[19]. Low wealth effects on labour supply contribute significantly to the results on two dimensions: first, they allow for a strong positive co-movement between relative consumption and relative hours irrespective of the timing of the shock. Second, following the news-shock hours increase as part of the worldwide economic expansion and the B-S correlation turns negative.

Our work suggests an alternative explanation to the consumption-real exchange rate anomaly through two main channels: strong Balassa-Samuelson effects and news-shocks. Strong Balassa-Samuelson effects are essential to give rise to a negative B-S correlation in economies with complete asset markets. As the terms of trade depreciate in response to productivity improvements to ensure a positive international transmission of technological innovations, a low or negative correlation between the real exchange rate and relative consumption can come about only through a relatively strong appreciation of the relative price of the non-tradable good across countries (see Corsetti, Dedola and Viani 2011). In our model, the Balassa-Samuelson effect is significantly amplified by the imperfect elasticity of substitution of capital services across sectors, resulting in a strong appreciation of the relative price of non-tradables (see figure 2). When the capital elasticity of substitution is less than infinite, and indeed as low as 1.67, the response of the price of the non-tradable good is much stronger reflecting the costly exchange of capital across sectors. Therefore, this imperfect substitutability of capital is an essential element for a correlation between the real exchange rate and relative consumption that is low and quite far from unity - at 0.51 in economies where TFP innovations are not anticipated[20]. Note that in models hinging on the price of non-tradables to explain the consumption-real exchange rate anomaly, an almost unavoidable cost is a low correlation between the real exchange rate and the terms of trade; which in the data is high and positive. Benigno and Thoenissen (2008) also develop a model where the B-S result is achieved via Balassa-Samuelson effects but the correlation between the real exchange rate and the terms of trade is negative in their benchmark case. In the context of our model the correlation between the real exchange rate and the terms of trade remains positive under both

[19]However, as the standard deviation of the real exchange rate is almost twice as high in news-driven economies, the absolute value of the B-S correlation is smaller.

[20]The B-S puzzle is much stronger when capital services are homogeneous and, in these economies, the relative price of the non-tradable good depreciates in response to a shock in tradables' TFP. We analyse in detail the quantitative implications of sectoral capital substitution in the next sub-section.

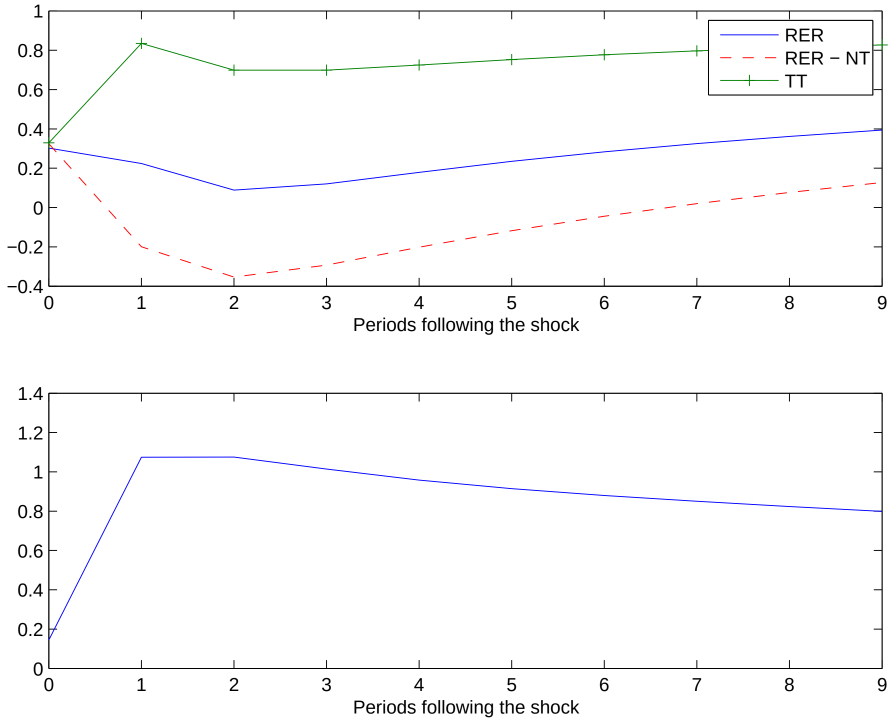

Figure 3: The HBS effect in the benchmark model. The response of relative prices (upper panel), i.e. the real exchange rate (RER), the terms of trade (TT) and the relative price of non-tradables (RER-NT), and relative consumption (lower panel) to one standard deviation expected shock to the tradable-goods sector. Percentage deviations from the steady state.

theoretical economies with unexpected and expected TFP innovations. Notice also that a low correlation between these two relative price measures is not ultimately related to efficiency, as in the model of Benigno and Thoenissen (2008) markets are incomplete[21].

On the other hand, news-shocks contribute to our results by making fluctuations in relative hours an important determinant of movements in the real exchange rate, as shown in equation (18). Corsetti et al (2008) show that a negative B-S correlation can arise in economies where shocks are highly persistent, the trade elasticity of substitution is high (equal to 4) and markets are incomplete. Highly persistent shocks ensure that the gap between the short-run and long-run response of output is sufficiently big; and by consumption-smoothing the increase in the demand of the home good is high enough. Further, high elasticity of substitution is necessary in those cases to ensure that the world economy absorbs the future larger supply of home tradables.

[21] Cole and Obstfeld (1991) and Heathcote and Perri (2002) show that the terms of trade depreciate in response to a productivity shock even in conditions of financial autarky in order to account for the missing financial markets.

And finally, incomplete markets contribute to widening the gap between the wealth effects enjoyed by the consumers of each country; therefore implying a much higher increase in the relative demand of the home good (see also Baxter and Cruccini 1995). Our analysis complements Corsetti et al (2008) and Baxter and Cruccini (1995) by analysing an economy where the shock-process is not only persistent[22] but also innovations are anticipated in advance, and the degree of substitution of tradable goods is equal to two[23]. In that case, we show that a negative correlation between the real exchange rate and relative consumption can also arise in Arrow-Debreu economies.

Our theoretical model has shown that the Backus-Smith puzzle is not necessarily a question of imperfect risk sharing or of a low elasticity of substitution between tradable goods. Instead, a negative B-S correlation can be the efficient allocation in an economy where wealth effects on labour supply are very low, HBS effects are relatively strong, the elasticity of substitution of tradables is within the range of empirical estimates and shocks are anticipated one period in advance. Corsetti et al (2008) propose an alternative mechanism in incomplete markets: TFP improvements endogenously generate wealth effects that are so strong that result in a marked rise in demand and drive up all prices[24]. Their argument is very intuitive and their model matches international business cycle facts on many dimensions. Nevertheless, that mechanism is a sufficient explanation to the Backus-Smith puzzle for as long as the trade elasticity is very low (0.425), quite lower relative to the values often used in the literature (between 1-2); a point made also by Karabarbounis (2010). Corsetti, Dedola and Vianni (2011) document empirically that the channel proposed in Corsetti et al (2008) is important to explain the low degree of international risk sharing. Enders and Müller (2009) support this view by showing that the international transmission mechanism of permanent TFP shocks is consistent with a model where the elasticity of substitution is low and international markets are incomplete.

Stockman and Tesar (1995) were among the first to introduce non-tradables in an otherwise standard model of the international business cycle. Despite some improvements in explaining features of the data compared to models with only tradables (e.g. BKK), they argue that a world-cycle driven by disturbances to both TFP and preferences matches data much better. In a similar vein, we show that allowing for TFP

[22] Remember that the autoregressive parameter of tradables TFP shocks is 0.96 in our model.

[23] When the substitutability of the tradable goods across countries is low, the B-S correlation is positive and high. We perform a sensitivity analysis to this parameter at a later part of the paper.

[24] Although their model features non-tradable goods, strong HBS effects are not essential for their results. Additionally, their model exhibits deviations from the law of one price for tradables due to the presence of (non-tradable) distribution services in the production of tradable goods.

disturbances to be anticipated brings the model-results into greater conformity with the data; especially with what concerns the relation between relative prices, quantities and consumption bundles[25]. Our work shares some similarities with Stockman and Tesar (1995): in both studies demand-side effects come about from the exogenous process of the model, and both type of disturbances - i.e. news-shocks and taste-shocks - do not increase current efficiency. Nevertheless, taste-shocks cannot be very accurately estimated in the data (Mandelman et al 2011), unlike TFP disturbances. At the same time, our exogenous process is consistent with empirical evidence that TFP innovations are to a large extent anticipated and can have important implications for cyclical fluctuations (Beaudry and Portier 2006).

Raffo (2010) proposes an alternative story to explain the consumption-real exchange rate anomaly, hinging on investment-specific technology (IST) shocks (see also Rabanal et al 2008). As he explains, such shocks cause big shifts in domestic absorption, such that aggregate demand exceeds supply and the terms of trade have to appreciate to clear the market. How appealing this mechanism can be, it implies a low, if not negative, correlation of investment across countries. The non-tradables sector in our model and the strength of the Balassa-Samuelson effect decrease the importance of this mechanism and can provide a low B-S correlation without huge differences in relative investment[26]. Raffo's work has also been criticised by Mandelman et al (2011). They show that once IST shocks are estimated in the data they do not appear to provide a sufficient explanation to some well-known puzzles in international economics. In our model we fit exogenous sectoral-TFP shocks as estimated in the data.

Finally, our work adds to the growing literature of expected innovations. Beaudry and Portier (2004, 2007) and Jaimovich and Rebelo (2009) develop models that are consistent with within-country news-driven cycles, whereas Beaudry, Dupaigne and Portier (2011) extend the latter to international co-movements. We show that news-shocks can also help us better understand movements in relative prices. To our knowledge, Opazo (2006) was the first to consider news-shocks as a possible explanation of the B-S puzzle via demand-side effects, but in his model investment and employment in both countries *fall* in response to news and the unconditional cor-

[25]Coresttí et al (2008) also analyse taste-shocks in their model to show that an economy with Arrow-Debreu securities can also be compatible with a negative B-S correlation as these disturbances weaken the tight link between relative consumption and relative marginal utility.

[26]Note that investment-specific shocks and news-shocks to TFP share a common feature: they do not affect current aggregate efficiency, resembling taste-shocks. Yet, our model is successful in generating a negative B-S correlation and a positive cross-country investment correlation.

relation of investment across countries is negative[27]. Moreover, the theoretical B-S correlation is low but not negative. Our model improves on Opazo's work by generating world expansions following improved technological prospects, a negative B-S statistic and positive unconditional correlations. In a similar spirit, Nam and Wang (2010)[a] observe that the US terms of trade and real exchange rate appreciate when US labour productivity is high[28]. They show that this behavior can be replicated in an incomplete markets model with monopolistic competition, sticky prices and producer currency pricing driven by expected shocks to permanent productivity. Our analysis complements theirs since we show that a negative B-S correlation need not be necessarily connected to lack of risk sharing, imperfect competition, money or other frictions in news-driven environments.

4.2 Imperfect Substitutability of Capital Services

The simple Balassa-Samuelson model has difficulty replicating observed movements in relative prices. If factors are homogeneous, movements in the price of non-tradables depend on relative factor shares across sectors ($\alpha_T - \alpha_N$) and changes to sectoral capital-labour ratios. Empirically, however, there seems to be little evidence on the massive sectoral shifts in capital-labour ratios required to produce large movements in the price of non-tradable goods (Mendoza and Uribe 2000). Thereby, allowing capital to be sector-specific can be potentially promising as the prices would react to reflect the degree of substitutability. This section analyses quantitatively this channel.

The consumption-real exchange rate anomaly arises in a world where capital services are perfectly substitutable (function $g(.)$ in equation (5) is linear). Statistics for this economy are given Table 3. For a comparison with the benchmark case, we reproduce graph 2 under economies with perfect substitutability of capital (figure 4). The reaction of the terms of trade is not very different in the two economies. On the other hand, the reaction of the relative price of non-tradables is much different, appreciating strongly in the benchmark model but depreciating in economies with homogeneous capital (see figure 5). Therefore, the Balassa-Samuelson channel is strong

[27] Note also that Opazo (2006) assumes news to be an imperfect public signal.

[28] Enders and Müller (2009) show that technology shocks as identified in a SVAR with long-run restrictions appreciate the US terms of trade. Corsetti et al (2006) obtain a similar response to permanent TFP shocks in manufacturing, their proxy for the tradables sector. Alquist and Chinn (2002) show that a one percentage point increase in the US - Euro Area productivity differential can imply up to a five percent appreciation in the dollar-euro real exchange rate, we get similar results using SVAR and cointegration methods to identify permanent world technology shocks (Lambrias 2011). Interestingly, Nam and Wang (2010)[b] show that news-shocks to technology are associated with a US terms of trade appreciation whereas unexpected disturbances are associated with a depreciation.

Table 3: Homogeneous Capital Model

	Data	Unexpected Shocks	News Shocks
St. Deviation relative to GDP			
Consumption	0.81	0.64	0.61
Investment	3.50	1.89	1.97
Hours	0.78	0.69	0.69
Real Exchange Rate	2.91	0.26	0.25
Terms of Trade	2.04	0.45	0.39
Correlation between real GDP and			
Real Net Exports	-0.56	-0.10	-0.33
International co-movements			
Output	0.35	0.21	0.16
Consumption	0.25	0.30	0.26
Hours	0.12	0.25	0.22
Investment	0.21	0.13	0.08
Correlation between RER and			
Rel. Consumption	-0.51	**0.95**	**0.65**
Rel. Output	-0.46	0.93	0.56
Terms of Trade	0.72	0.95	0.85
Real NX over GDP	0.35	0.12	0.31

Actual data are from UPENN World Tables, 1970-2011 at annual frequency. Both empirical and model-generated data are HP-filtered with a smoothing parameter equal to 100. Theoretical moments are asymptotic.

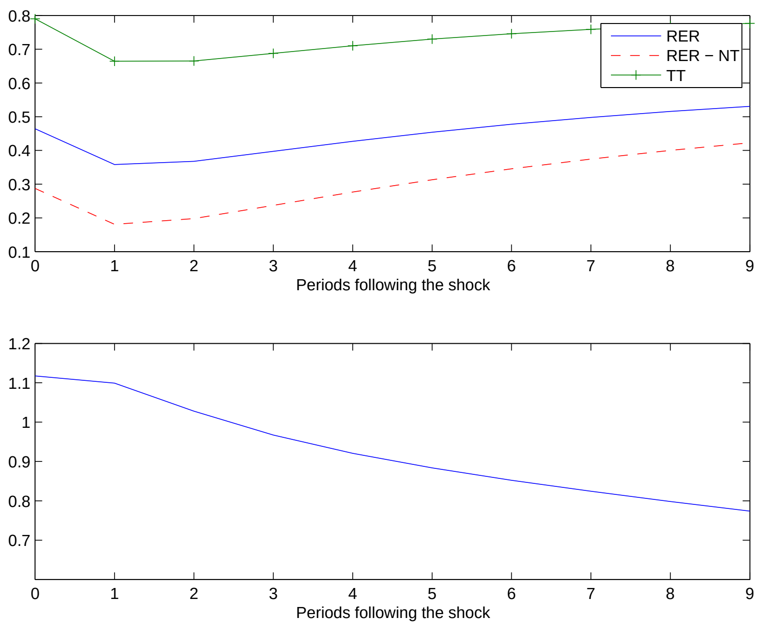

Figure 4: The HBS effect in the model with homogeneous capital. The response of relative prices (upper panel), i.e. the real exchange rate (RER), the terms of trade (TT) and the relative price of non-tradables (RER-NT), and relative consumption (lower panel) to one standard deviation unexpected shock to the tradable-goods sector. Percentage deviations from the steady state.

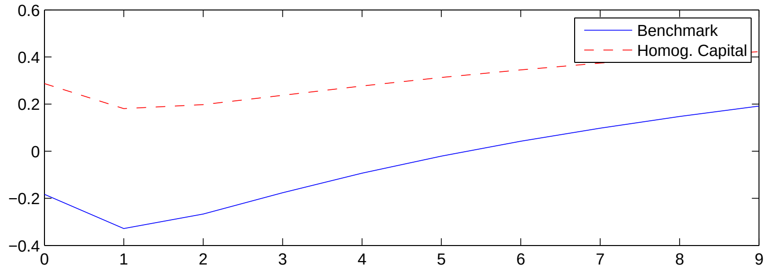

Figure 5: The response of the relative price of non-tradables (RER-NT) to one standard deviation unexpected shock to the tradable-goods sector in the benchmark model (straight line) and in the model with homogeneous capital (dashed line). Percentage deviations from the steady state.

and significant in the benchmark model whereas it is hardly present in economies where capital services are homogeneous across sectors as the price of non-tradables moves in line with the terms of trade.

The reason why the response of the the price of non-tradable goods is different across the two economies is because imperfect capital substitutability creates a bias towards tradables, as it can be seen by the relative response of capital services across sectors ($S_{T1t} - S_{N1t}$ in figure 6, lower panel)[29]. The difference in the capital allocated across sectors is much higher in the benchmark economy compared to the perfect-substitutability case. Similarly, the lower the substitutability of capital the higher this difference, as can be seen in the response of $S_T - S_N$ for $\varepsilon = 1.45$ and the associated response of P_N (figure 6, upper panel). More intense use of capital in the tradables sector boosts the marginal product of labour and consequently the wage; exactly in line with the Balassa-Samuelson doctrine but only stronger. To demonstrate this argument through the equations of the model, using the first order conditions of capital and labour across sectors and doing some algebra gives:

$$\tilde{P}_N = \underbrace{\frac{\alpha_T}{\alpha_N}\frac{Z_T}{Z_N}\left(\frac{S_T}{N_T}\right)^{\alpha_T - 1}\left(\frac{S_N}{N_N}\right)^{-\alpha_N - 1}}_{HBS\,effect}\underbrace{\left(\frac{S_T}{S_N}\right)^{1/\varepsilon}}_{Effect\,of\,g(.)} \tag{19}$$

where $\tilde{P}_N$ is the relative price of the non-tradable good to the intermediate good a, i.e. $\tilde{P}_N = P_N/q_a$. In the classic Balassa-Samuelson framework movements in the non-tradables' price occur due to differences in factor intensities ($\alpha_T - \alpha_N$) and sectoral capital-labour shares. Allowing for $\varepsilon < \infty$ provides an additional source of fluctuations in P_N and consequently the real exchange rate. From the prespective of equation (18), when $\varepsilon \to \infty$ the standard deviation of relative consumption is higher

[29]For what follows, the analysis is within country one.

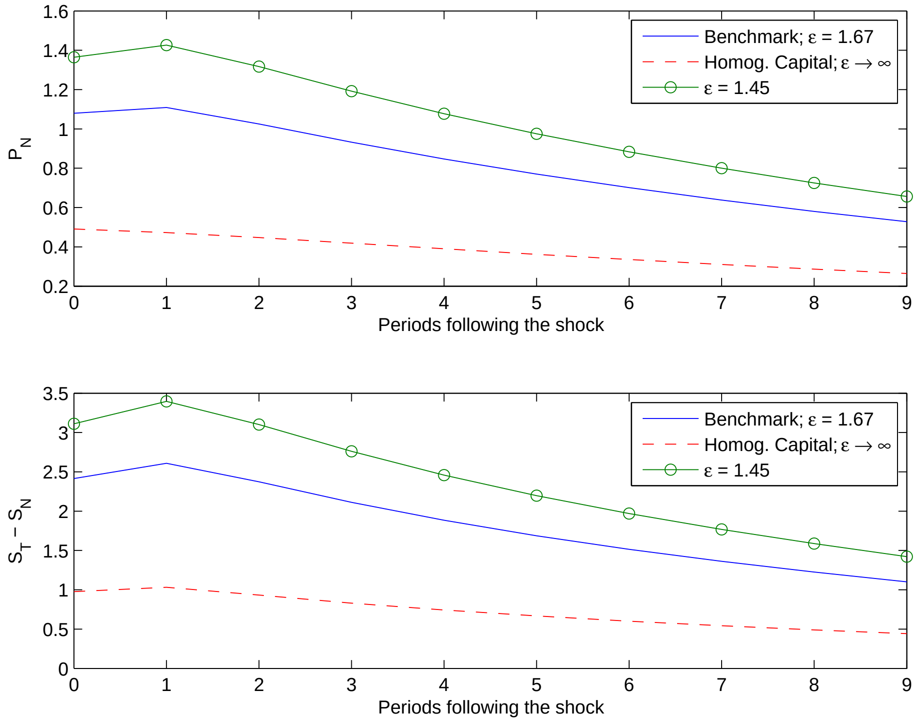

Figure 6: Response of the price of non-tradables (P_N, upper panel), and the capital services differential across sectors ($S_T - S_N$, lower panel) to an unexpected shock to tradables TFP, for different values of ε. Percentage deviations from steady-state.

and hours lower. Thus, the B-S correlation is positive and high.

Finally, we evaluate the importance of imperfect capital substitutability to the results by plotting the variation in the B-S correlation as a function of ε in figure 7. The bulk of the effect is felt for values of the elasticity of substitution between one and two and the correlation between the real exchange rate and relative consumption reaches 0.90 already for $\varepsilon = 3.2$. Empirical evidence is not sufficient to justify any particular parametrization of ε. However, what our exercise has shown is that if this parameter is determined as a minimum distance estimator between some key theoretical and empirical moments of the real exchange rate, it can be consistent with a negative B-S correlation as well. As explained, the contribution towards the quantitative outcomes of the model comes through an amplification of the Balassa-Samuelson effect. However, the intuition by which expected shocks lower the consumption-real exchange rate correlation still holds. Even with homogeneous capital, the B-S correlation in news-driven economies is by 30 percentage points lower than when shocks are surprises (Table 3), while being consistent with international co-movements and news-driven expansions.

At this point it is also worth emphasising that a negative correlation in the bench-

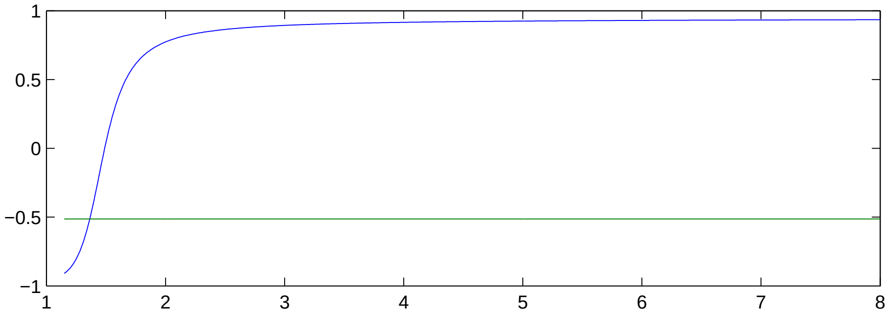

Figure 7: The correlation between the real exchange rate and relative consumption for different values of elasticity of substitution of capital services - ε. The horizontal line shows the corresponding empirical statistic.

mark economy is the efficient allocation. Given the friction in capital markets, the social optimum is such that much more capital services are allocated to the tradables sector and the B-S correlation is negative. Put differently, consumption being higher where it is more expensive is the price to pay for efficiency in a world where - among other things - capital markets are characterised by the function above. On the other hand, absent any frictions in the financial markets, the social planner chooses a more even distribution of capital which has much lower impact on the marginal product of labour, the wage and finally the price of non-tradables[30].

4.3 Variable Capacity Utilisation

Jaimovich and Rebelo (2008, 2009) show that variable capacity utilisation in a small open-economy and a closed-economy set-up can induce economic expansions in response to productivity news-shocks. On the other hand, Baxter and Farr (2005) show how utilisation in a two-country, incomplete markets model can help to explain the co-movement problem, while increasing the variability of economic aggregates (see also Burnside and Eichenbaum 1996). We combine both of these findings in our model to show that variable utilisation is an important element for re-producing empirically relevant movements in relative prices as well.

Table 4 presents the quantitative features of a model where utilisation of capital is fixed at the steady-state value, for economies driven by traditional and expected disturbances. Although the B-S correlation is now lower than in the benchmark model with unexpected innovations (0.06), it is still positive and actually slightly higher in

[30]This intuition shares some similarities with Kocherlakota and Pistaferi (2007) who show that the B-S puzzle can be a result of imperfect functioning of financial markets within, rather than across, borders.

Table 4: Fixed Capacity Model

	Data	Unexpected Shocks	News Shocks
St. Deviation relative to GDP			
Consumption	0.81	0.61	0.57
Investment	3.50	2.03	2.15
Hours	0.78	0.64	0.63
Real Exchange Rate	2.91	0.50	0.52
Terms of Trade	2.04	0.58	0.61
Correlation between real GDP and			
Real Net Exports	-0.56	-0.11	-0.08
International co-movements			
Output	0.35	0.09	0.06
Consumption	0.25	0.38	0.23
Hours	0.12	0.15	0.11
Investment	0.21	-0.15	-0.05
Correlation between RER and			
Rel. Consumption	-0.51	**0.06**	**0.10**
Rel. Output	-0.46	-0.24	-0.20
Terms of Trade	0.72	0.17	0.22
Real NX over GDP	0.35	0.80	0.81

Actual data are from UPENN World Tables, 1970-2011 at annual frequency. Both empirical and model-generated data are HP-filtered with a smoothing parameter equal to 100. Theoretical moments are asymptotic.

news-driven economies. Whether shocks are pure surprises or anticipated does not significantly change the properties of the model. Moreover, the fixed-capacity model does not exhibit positive international co-movements as the unconditional correlation of investment is negative under both expected and unexpected disturbances. Further, absent variable capacity utilisation the model fails to generate news-driven expansions as investment falls in both countries on impact[31], the response of employment is null in both countries and output increases only in country one but remains stagnant in country two. As expected, consumption increases in both countries due to perfect international portfolio diversification. Finally, we observe a remarkable fall in the variability of output (not shown), illustrating the amplification effect of varying capital services (Jaimovich and Rebelo 2009, Burnside and Eichenbaum 1996, Baxter and Farr 2005).

Figure 8 shows the response of the price of non-tradables in the benchmark economy, one where utilisation is fixed (equivalently, costs of adjusting it are infinite: $\frac{\delta_2}{\delta_1} \to \infty$) and one where capital services are homogeneous ($\epsilon \to \infty$). As it can be seen, both non-homogeneous capital and variable utilisation serve to reinforce the

[31] In the case of country two it remains negative for four periods.

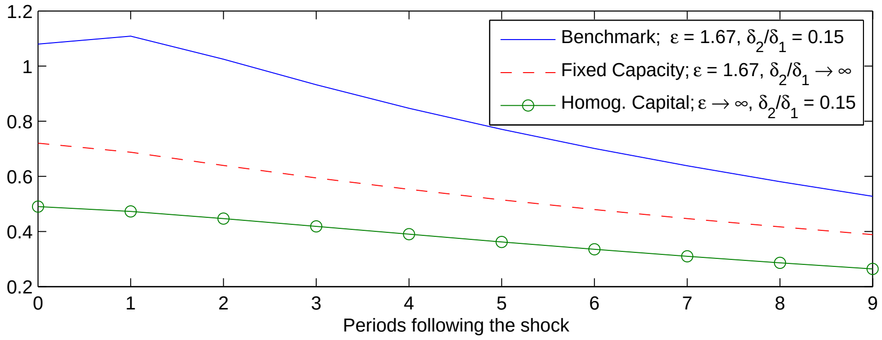

Figure 8: IRFs of the price of non-tradables (P_N) in the benchmark economy (straight line), under fixed capacity (dashed line) and under homogeneous capital (line with circles) to an unexpected shock to the tradables sector in country one. Percentage deviations from steady-state.

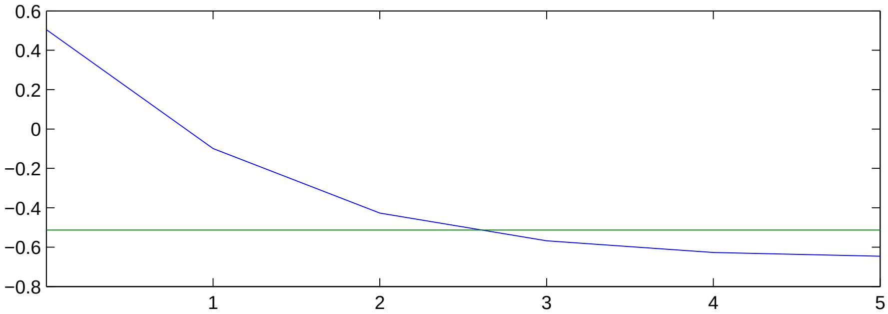

Figure 9: The correlation between the real exchange rate and relative consumption according to the length of the interim period. The horizontal line shows the corresponding empirical statistic.

HBS effect; but the former seems to be more important.

5 Sensitivity Analysis

5.1 Length of news

In this section, we check the sensitivity of our results to varying the length of the arrival of news between zero and five periods.

Figure 9 shows that the B-S correlation falls monotonically with the length of the interim period. News-shocks also contribute to higher (relative) volatility in the relative price of aggregate consumption and the relative price of non-tradables; but to less volatile terms of trade (Table 5).

As we have shown in an earlier part of our work, the terms of trade depreciate by less in response to a news-shock when this refers to a TFP improvement further

Table 5: Standard-deviation relative to output: Cross-country prices under different lengths of the interim period

News	Real exchange rate	Terms of Trade	Relative price of NT
q=0	0.12	0.45	0.23
q=1	0.21	0.39	0.40
q=2	0.30	0.33	0.55
q=3	0.35	0.29	0.63
q=4	0.37	0.27	0.66
q=5	0.38	0.26	0.66

in the future; and remain pretty stable until the change is materialised (Lambrias 2012)[32]. This behavior is consistent with both less volatile terms of trade and a lower real exchange rate - relative consumption correlation. Regarding the volatility in the price of non-tradables, this tends to be higher with expected shocks since these goods cannot be transferred neither across countries nor through time.

5.2 Trade Elasticity

To match the B-S correlation, our model requires a relatively high degree of trade elasticity, but still within the range of values estimated in empirical studies. Figure 10 reports the correlation of the real exchange rate with relative consumption for different values of the trade elasticity of substitution. The correlation falls almost monotonically and for values up to 3.38 it is always lower when shocks are anticipated. It changes sign at $\theta = 2.43$ and $\theta = 1.81$ for unexpected and expected shocks respectively.

Corsetti, Dedola and Vianni (2011) show that for explanations of the B-S puzzle hinging on the relative price of non-tradables, it must be that output fluctuations are mostly driven by tradables, trade elasticity is high, and the elasticity of substitution between tradables and non-tradables is below one. Indeed, our model satisfies these conditions and their results follow even in a complete-market world[33].

Corsetti et al (2008) show that a low elasticity of substitution can trigger strong wealth effects once the complete-market assumption is relaxed; leading to a negative

[32]The reason is because the strength of the impulse and the adjustment of relative demand across countries is lower the longer it takes for technology to improve. At the same time, most of the depreciation necessary to clear the market occurs on impact, since no new information arrives between the signal and the realisation. For a detail exposition of the latter mechanism in the context of the BKK model see Lambrias (2012).

[33]Benigno and Thoenissen (2008) impose the same conditions in an incomplete markets model.

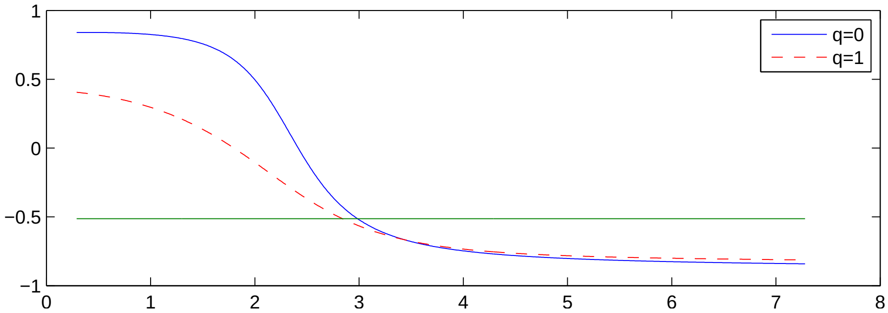

Figure 10: The correlation between the real exchange rate and relative consumption for different values of the trade elasticity of substitution, given unexpected shocks (solid lines) and shocks expected one period in advance (dashed lines). The horizontal line shows the corresponding empirical statistic.

B-S correlation[34]. On the other hand, a BKK-type of model with complete markets and only tradables is consistent with an appreciation in the terms of trade following a TFP shock for as long as trade-elasticity is high[35]. Our theoretical economy with strong HBS effects - triggered by imperfectly substitutable capital services - and news-shocks is consistent with a negative B-S correlation for a range of reliable values of trade elasticity (1.8-2). Finally, even for values of trade elasticity below one, where the model produces a strong and positive B-S correlation, allowing shocks to be forecastable decreases its value significantly.

5.3 Level of adjustment costs to investment

The lower the adjustment costs to investment, the lower the correlation between the real exchange rate and relative consumption. The intuition is discussed in Raffo (2010): a lower value for this parameter is associated to a more responsive investment leading to large shifts in domestic absorption and relative demand. Table 6 gives theoretical moments of an economy where adjusting the flow of investment is costless and shocks are surprises. The B-S correlation is negative and very strong.

This suggests that news-shocks may not be needed as an additional source for a negative B-S correlation. In light of the above, we estimate the elasticity of sub-

[34]Low, and particularly below one, elasticity of substitution is associated with higher volatility of prices across countries (Corsetti et al 2008, Raffo 2010, Heathcote and Perri 2002) and can be instructive about the implications of models under different asset-market structures (Heathcote and Perri 2002, Cole and Obstfeld 1991).

[35]We replicate the BKK model to show that this is the case for $\theta > 6.5$. Consistently, Enders and Müller (2009) show that the estimated value of trade elasticity in such a model is high, at 3.098. In line with Corsetti et al (2008), their estimated value for the incomplete-market counterpart of this model is 0.230.

Table 6: Model with zero investment-adjustment costs

	Data	Unexpected Shocks	$\varepsilon = 2.05$
St. Deviation relative to GDP			
Consumption	0.81	0.56	0.58
Investment	3.50	2.09	2.04
Hours	0.78	0.65	0.67
Real Exchange Rate	2.91	0.12	0.10
Terms of Trade	2.04	0.34	0.35
Correlation between real GDP and			
Real Net Exports	-0.56	-0.49	-0.48
International co-movements			
Output	0.35	0.12	0.12
Consumption	0.25	0.27	0.26
Hours	0.12	0.20	0.20
Investment	0.21	0.02	0.02
Correlation between RER and			
Rel. Consumption	-0.51	**-0.40**	**0.23**
Rel. Output	-0.46	-0.46	0.17
Terms of Trade	0.72	0.10	0.64
Real NX over GDP	0.35	0.88	0.49

Actual data are from UPENN World Tables, 1970-2011 at annual frequency. Both empirical and model-generated data are HP-filtered with a smoothing parameter equal to 100. Theoretical moments are asymptotic.

stitution of capital services in a similar manner as before, assuming that adjusting the flow of investment incurs zero costs. That gives a value of ϵ equal to 2.05. The theoretical moments of an economy where shocks are pure surprises, $\epsilon = 2.05$ and $\kappa = 0$ are given in the last column of Table 6.

The most notable difference is the B-S correlation which, in this case, is positive and equal to 0.23 compared to -0.10 in the benchmark case with news-shocks. Moreover, the model fails to produce a negative correlation between the real exchange rate and relative output. In terms of international co-movements the two models produce similar results whereas the relative volatility of the real exchange rate is almost the double in the benchmark model[36]. Overall, our model economy with mild investment adjustment costs and expected innovations to TFP can be consistent with a negative B-S correlation, compared to an economy with zero investment adjustment costs and surprise shocks; while generating news-driven booms.

[36]Indeed, the benchmark model performs better in terms of quadratic deviations of theoretical real exchange rate moments to empirical ones; as well as overall (i.e. all moments in the table).

6 Conclusion

We propose a fully flexible, complete-market model of the international business cycle that can be consistent with two major empirical facts: positive cross-country co-movements of economic aggregates and a low correlation between relative consumption and its relative price. We show that the latter is not necessarily connected to market inefficiency and limited risk sharing, rather it can arise as the efficient allocation in an economy where wealth effects on labour supply are low, the price of non-tradables plays an important role for real exchange rate determination and innovations to technology are anticipated. We analyse how sector-specific capital can have dire consequences for movements in relative prices across countries in the context of the Harrold-Balassa-Samuelson framework. Finally, the novelty of the paper is to lay down the theoretical foundations, in line with Jaimovich and Rebelo (2009), that are consistent with unconditional moments in prices and quantities, but also with news-driven economic expansions.

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7 Appendix

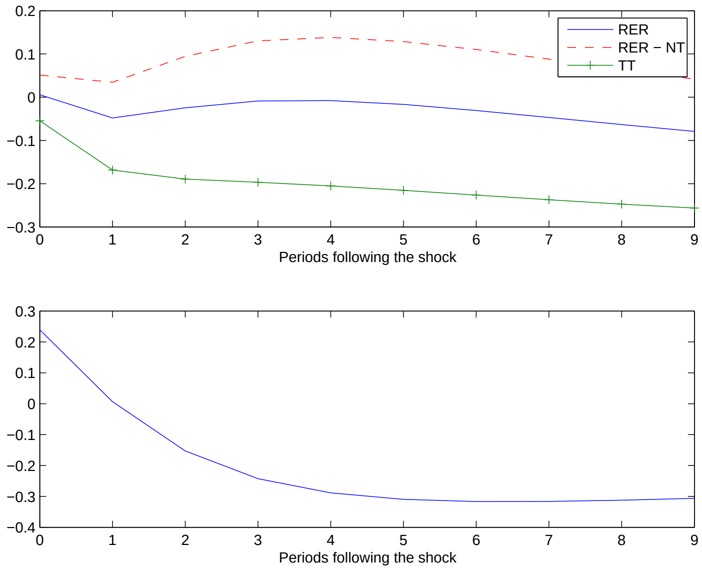
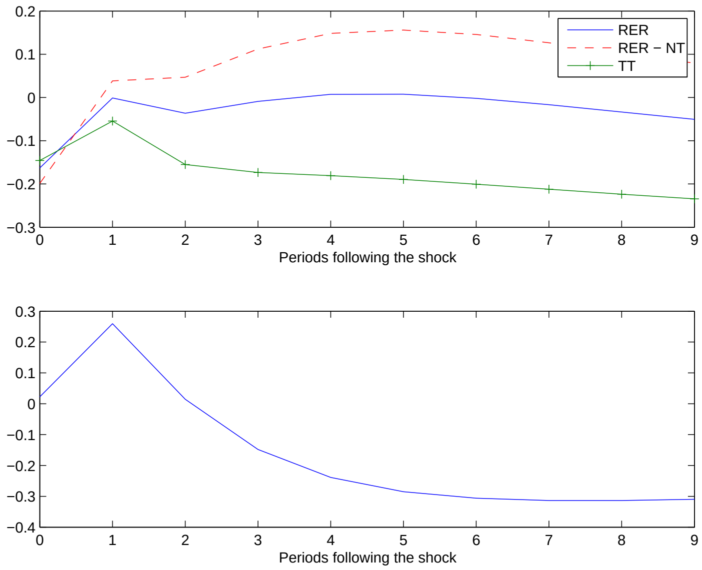


Figure 11: The HBS effect in the benchmark model. The response of relative prices (upper panel), i.e. the real exchange rate (RER), the terms of trade (TT) and the relative price of non-tradables (RER-NT), and relative consumption (lower panel) to one standard deviation unexpected shock to the non-tradable-goods sector. Percentage deviations from the steady state.



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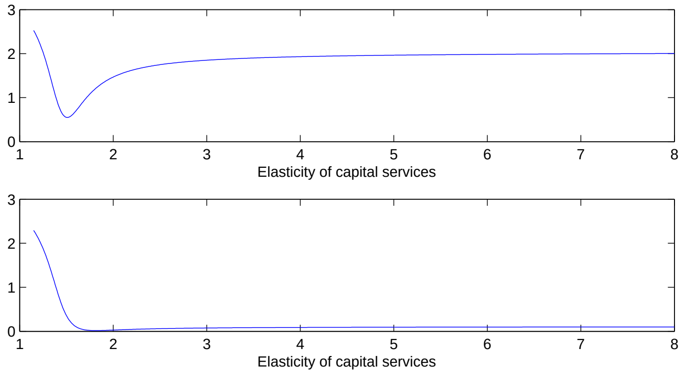

Figure 13: The upper panel shows values of the quadratic loss function in all three moments, i.e. the correlation between the real exchange rate and relative output, terms of trade, and net exports over GDP ratio. The lower panel shows values of this function when taking into account only the last two moments. In both cases, moments are equally weighted and estimations were carried out in economies where shocks are surprises. On the horizontal axis are values of the elasticity of substitution in capital services ε.

Table 7: Baseline Model - HP Filter = 6.25

	Data	Unexpected Shocks	News Shocks
St. Deviation relative to GDP			
Consumption	0.77	0.59	0.54
Investment	3.67	2.00	2.14
Hours	0.78	0.67	0.65
Real Exchange Rate	2.00	0.16	0.28
Terms of Trade	1.71	0.50	0.42
Correlation between real GDP and			
Real Net Exports	-0.50	-0.06	-0.36
International co-movements			
Output	0.48	0.21	0.13
Consumption	0.33	0.31	0.23
Hours	0.09	0.25	0.20
Investment	0.47	0.13	0.07
Correlation between RER and			
Rel. Consumption	-0.20	**0.69**	**-0.05**
Rel. Output	-0.21	0.64	-0.21
Terms of Trade	0.62	0.86	0.45
Real NX over GDP	0.08	0.60	0.86

Actual data are from UPENN World Tables, 1970-2011 at annual frequency. Both empirical and model-generated data are HP-filtered with a smoothing parameter equal to 6.25. Theoretical moments are asymptotic.

Acknowledgements
I thank Patrick Fève, Martial Dupaigne, Christian Hellwig, Franck Portier, Evi Pappa, Roberto Pancrazi, Gilles Saint-Paul, Ahmat Jidoud, Eric Mengus, Samuele Centorrino, Fabrice Collard, Paolo Guarda, Olivier Pierrard, Luca Dedola, Luca Marchiori, participants at the EABCN meeting on "Global Spillovers and Economic Cycles" at Banque de France in May 2013 and seminar participants in Frankfurt, Luxembourg and Toulouse for useful comments and discussions. All remaining errors and omissions are mine. The views expressed in this article are those of the author and do not necessarily reflect those of the European Central Bank or the Eurosystem.

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ISSN	1725-2806 (online)
ISBN	978-92-899-2194-7
DOI	10.2866/949206
EU catalogue No	QB-AR-16-063-EN-N