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International risk sharing and financial shocks

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ABSTRACT

A canonical two-country real business cycle model with complete international asset markets fails to replicate the correlation between relative consumptions and real exchange rates—*i.e.* the *consumption–real exchange rate anomaly* or *Backus-Smith puzzle*. I show that when preferences are non-separable between consumption and leisure, the same two-country model augmented by domestic financial frictions and shocks can account for this correlation. Positive financial shocks create important fluctuations in the labor wedge, inducing firms to demand more labor. These procyclical movements in hours worked significantly affect the marginal utility of consumption and help to explain the correlation between relative consumptions and real exchange rates.

1. Introduction

From data on OECD countries, Backus and Smith (1993) and Kollmann (1995) find that the correlations for many pairs of countries between their real exchange rates and their relative consumptions are negative—I call this correlation the Backus-Smith correlation. This finding is not compatible with two-country real business cycle models that feature complete international asset markets, time-separable preferences and separability of consumption from other variables in the utility function. In fact, these features imply that the relative consumption is proportional to the real exchange rate, hence perfectly positively correlated. Subsequent work have referred to this anomaly as the *Backus-Smith puzzle*.[1] The existence of this puzzle questions the ability of international financial markets to share risk.[2] Specifically, the solution to the social planner's problem makes households consume relatively more when the relative price of consumption is lower (*i.e.* weaker real exchange rate).

In this paper, I explain the puzzle from non-separabilities of consumption and leisure, and the effects of shocks to the borrowing capacity of firms. These financial shocks affect firms' ability to borrow, and are similar to the ones that Jermann and Quadrini (2012) examined. To my knowledge, there are no other studies that examine the role of financial shocks with respect to the Backus-Smith correlation. The framework that I present is also able to account for many other international business cycle stylized facts, such as the high positive level of cross-country correlations in GDP, consumption, and hours worked. As shown in the sensitivity analysis, the results are also robust to various parameterizations–in particular, to the elasticity of substitution between intermediate goods.

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[1] Heathcote and Perri (2014) show that modifying the complete asset market structure of a canonical two-country, two-good model, *i.e.* Heathcote and Perri (2002), to an incomplete asset market structure or to financial autarky does not solve the puzzle. Neither do the various specifications of a monetary model that Chari et al. (2002) examined, *e.g.* non-separable preferences and habit persistence.

[2] I refer the reader to discussions by Corsetti et al. (2012) and Heathcote and Perri (2014).

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The model economy described in Section 3 is based on Backus et al.'s (1994) (hereafter BKK) two-good, two-country model and augmented by working capital requirements and enforcement constraints.[3] Countries are populated by two types of agents: investors that own the firms and workers. The only international financial linkage is through the bond market, as workers are allowed to trade risk-free non-contingent international bonds—*i.e.* incomplete markets.[4] As for the goods market, firms of each country specialize in the production of one good, which are considered intermediate goods. The expenditure good is a bundle that consists of both the Home and Foreign intermediate goods. Real exchange rates emerge as the ratio of the prices of the intermediate goods of the two countries.

The financial frictions that firms face are domestically-based only. First, they have working capital requirements for which they borrow to cover the value of their expenses at the beginning of each period (*i.e. intra-period loan*) and that they need to repay once they receive their revenues. Note that firms also borrow from workers for a longer horizon (*i.e. inter-period debt*). Second, the firms' total borrowing, intra and inter-period, cannot exceed a fraction of the value of their collateral assets. This fraction is subject to exogenous shocks, that I refer to as financial shocks. The borrowing constraint exists in order to prevent costly defaults. In the event of a default in repayment of their loans, borrowers would be able to seize a random fraction of the firms' capital. In equilibrium, it is never optimal for firms to default on their debt.

The mechanism to explain the puzzle is split in two parts. First, since firms have borrowing constraints, they do not pay wages that are equivalent to the value of their marginal product (MPN). Theoretically, the difference between these two variables is a component of the labor wedge—the difference between the marginal rate of substitution between consumption and leisure and the MPN.[5] Financial shocks play a key role in affecting this wedge. In fact, positive shocks tend to close the gap between wages and the MPN, so firms react by increasing their labor demand. This mechanism is similar to the one exposed by Jermann and Quadrini (2012) in order to generate more volatility in hours worked and GDP.

Second, I assume that workers have GHH preferences (proposed by Greenwood et al. (1988)), so that consumption and leisure are non-separable in their utility functions. The use of these preferences is not novel in the open-economy literature, see *e.g.* Correia et al. (1995) and Mendoza (1991). Moreover, Aguiar et al.'s (2013) empirical findings on the elasticity of home production at business cycle frequencies from time use surveys reinforce the choice of these preferences. Non-separability implies that the marginal utility of consumption is a function of consumption and hours worked.

Under incomplete international asset markets, the expected change in the inverse ratio of Foreign over Home marginal utility of consumption is equal to the expected change in the real exchange rate. Home hours worked strongly increase in response to positive Home financial shocks, thereby increasing the Home marginal utility of consumption since preferences are non-separable. This results in an almost perfectly negative Backus-Smith correlation when financial shocks are the only source of shocks, in contrast to the effects of technology shocks, such that the Backus-Smith correlation is highly positive.

When the model is simulated with both shocks and the relative volatility of financial shocks is set to match the contribution of these shocks to explain variations in GDP estimated by Jermann and Quadrini (2012)–approximatively of 40%– the Backus-Smith correlation is slightly below zero as in the data. This underlying mechanism through which the effects of hours worked dominate those of consumption following financial shocks is similar to the one put forward by Raffo (2010) in the presence of investment-specific technology shocks.

The rest of the paper is structured as follows. In Section 2, I present the related literature. In Section 3, I introduce the baseline model that embeds national financial frictions and shocks. In Section 4, I present the parameterization that is based on two of the world's largest financial hubs *i.e.* the United States and the United Kingdom in a period of internationally stronger financial linkages (1984–2010). In Section 5, I present the results of the baseline model and some of its variants and conclude in Section 6.

2. Related literature

My work is complementary to other studies that are able to explain the *Backus-Smith puzzle*. Corsetti et al. (2008) can account for the crucial Backus-Smith correlation from a model that features incomplete asset markets, technology shocks, and a very low elasticity of substitution between Home and Foreign intermediate goods. However, as shown by Thoenissen (2011), their results hinge on the value of this elasticity, in contrast to my results. Specifically, for intermediate values of this elasticity, the mechanism that they propose is not able to account for the puzzle.

Benigno and Thoenissen (2008) underline the importance of non-traded goods for real exchange rate dynamics. Their mechanism relies on the Balassa-Samuelsson effect: an increase in productivity of one of the country's tradable sector leads to an increase in the price of their non-tradable goods that translates into an appreciation of the real exchange rate. Karabarbounis's (2014a) framework features a different type of non-traded good, *i.e.* one that originates from home production. Since the consumption basket is composed of market and non-market goods, a labor wedge emerges as the households' marginal rate of substitution between consumption and leisure (MRS) diverges from the wages paid on the labor market. His

[3] The model is closely related to the work by Perri and Quadrini (2017), whose main focus is to study the international transmission of financial shocks, instead of the degree of international risk sharing. Their model also differs on one important aspect—it features a perfectly integrated equity market. This market structure implies that countries are equally affected by financial shocks regardless of their origins.

[4] This asset market structure is chosen for computational purposes.

[5] See Shimer (2009) for a survey of the literature on the labor wedge and its implications for business cycles.

structural estimation highlights the importance of non-separable preferences and the labor wedge. In my model, the variation in the labor wedge is driven by financial shocks, rather than non-market productivity shocks.

As mentioned earlier in the introduction, I depart from the canonical IRBC model on two fronts, *i.e.* the non-separability of preferences and the addition of financial frictions and shocks. Departures based on other dimensions are examined extensively in the literature to account for the Backus-Smith correlation. One of them is to make use of recursive preferences instead of time-separable preferences (see Colacito and Croce (2013), Kollmann (2016), and Tretvoll (2011)). Among other approaches, Kollmann (2012) underlines limited asset market participation to explain the correlation. Specifically, his model features a high fraction of hand-to-mouth households. Bodenstein (2008) examines the role of limited enforcement of contracts in the international asset markets. In his theoretical model, limited enforcement implies that countries revert to financial autarky when facing a high positive shock.

Domestic financial frictions are also central to the mechanisms proposed by other work that do not address issues related to the Backus-Smith correlation. Neumeyer and Perri (2005) make use of these financial frictions in an open-economy setting to replicate stylized facts of emerging economies business cycles. Iacoviello and Minetti (2006) examine the role of location-sensitive liquidation costs in explaining the high-level of co-movements across industrialized countries. Rouillard (2017) shares the same objective; however, the mechanism involves variations in the wedge between the real interest rate and the marginal product of capital, which is a result of financial frictions. Devereux and Sutherland (2011) investigate the international transmission of financial shocks in an environment where debt and equity markets are integrated internationally. They find that the integration of both types of international asset markets is welfare-improving.

Shocks that emanate from the financial sector have been under the spotlight recently to explain business cycle dynamics and many studies find that their contribution to the fluctuations of main aggregate variables is high. Iacoviello (2015) finds that financial shocks can explain as much as two-thirds of the fall in output. Over the business cycle, Jermann and Quadrini's (2012) variance decomposition from a Bayesian estimation of a model that comprises of eight shocks indicates that financial shocks contribute up to 46.4% of GDP. Nolan and Thoenissen (2009) follow a different approach—their shocks are estimated from a New Keynesian framework that features a financial accelerator. Their median estimate for financial shocks in accounting for output dynamics is 46.6%. As for empirical evidence of the importance of financial shocks for open-economy issues, from the estimation of factor-augmented VARs Abbate et al. (2016) and Helbling et al. (2011) find that the transmission of US financial shocks to major advanced economies and to the rest of the world is considerable.

3. The business-cycle model

The baseline model is an extension of the two-good, two-country model developed by BKK. In fact, domestic financial markets are examined in more details as they encompass frictions and shocks. In this respect, the model shares similarities with Perri and Quadrini (2017). As mentioned in the last section, these frictions are limited to domestic financial markets. I depart from BKK by assuming that there are two categories of households in each country: investors and workers. Their fractions in total population are respectively $1 - \varpi$, and ϖ. Investors own the domestic firms and consume their dividends, while workers work, consume their labor income, and trade financial assets (*i.e* loans to domestic firms and international bond traded with households from abroad). Firms in each country specialize in the production of one good, so that the expenditure is the aggregation of the domestically-produced good and the imported good. They face working capital requirements and have borrowing constraints in a similar fashion to Hart and Moore (1994) and Jermann and Quadrini (2012). Note that the complete derivation of the recursive problems of the firms, investors, and workers appears in Appendix B.

3.1. Production

There are two stages to production. Firms use labor n_{it} and capital k_{it} to produce intermediate goods. I assume a Cobb-Douglas production function:

$$y_{it} = A_{it} k_{it-1}^{\mu} n_{it}^{1-\mu} \tag{1}$$

where the subscript i takes two values: H for Home and F for Foreign. The parameter μ corresponds to the fraction of capital in output, and A_{it} to the country-specific TFP shock.

Firms in each country produce differentiated goods. The Home country specializes in good a and the Foreign country in good b. The expenditure good that is used for consumption and investment motives is a bundle consisting of goods a and b, as shown from the following equation:

$$G(a_{Ht}, b_{Ht}) = \left[\omega^{\epsilon+1} a_{Ht}^{-\epsilon} + (1-\omega)^{\epsilon+1} b_{Ht}^{-\epsilon}\right]^{-\frac{1}{\epsilon}}, \tag{2}$$

$$G(a_{Ft}, b_{Ft}) = \left[(1-\omega)^{\epsilon+1} a_{Ft}^{-\epsilon} + \omega^{\epsilon+1} b_{Ft}^{-\epsilon}\right]^{-\frac{1}{\epsilon}} \tag{3}$$

where the subscripts correspond to the country in which the final stage of production takes place, $\omega > 0.5$ governs the degree of home bias, and the elasticity of substitution between Home and Foreign intermediate goods is given by $\sigma = 1/(1+\epsilon)$.

Since firms are operating in a perfectly competitive market, the equilibrium prices of goods a and b are given by their marginal products:

$$p_{Hit} = \partial G(a_{it}, b_{it})/\partial a_{it}, \quad p_{Fit} = \partial G(a_{it}, b_{it})/\partial b_{it}. \tag{4}$$

where the first subscript of the prices corresponds to the location of the production of the intermediate good and the second subscript to the location of the final good's production. For example, p_{HHt} corresponds to the price of good a in the Home country with $i = \{H, F\}$.

The price level of the final good is an aggregate of these two goods:

$$P_{Ht} = \left(\omega p_{HHt}^{\frac{\epsilon}{1+\epsilon}} + (1-\omega) p_{FHt}^{\frac{\epsilon}{1+\epsilon}}\right)^{\frac{1+\epsilon}{\epsilon}}. \tag{5}$$

3.2. Real exchange rate and terms of trade

For the Home economy, real exchange rates are defined as the ratio of these prices in the Foreign and Home countries:

$$Z_{Ht} = \frac{P_{Ft}}{P_{Ht}} = \frac{\left(\omega p_{FHt}^{\frac{\epsilon}{1+\epsilon}} + (1-\omega) p_{HHt}^{\frac{\epsilon}{1+\epsilon}}\right)^{\frac{1+\epsilon}{\epsilon}}}{\left(\omega p_{HHt}^{\frac{\epsilon}{1+\epsilon}} + (1-\omega) p_{FHt}^{\frac{\epsilon}{1+\epsilon}}\right)^{\frac{1+\epsilon}{\epsilon}}}. \tag{6}$$

The definition of terms of trade in this framework is the price of good b in terms of the price of good a:

$$\begin{aligned} TOT_{Ht} &= \frac{p_{FHt}}{p_{HHt}} = \frac{1-\omega}{\omega}\left(\frac{a_{Ht}}{b_{Ht}}\right)^{1+\epsilon} \\ &= \frac{p_{FFt}}{p_{HFt}} = \frac{\omega}{1-\omega}\left(\frac{a_{Ft}}{b_{Ft}}\right)^{1+\epsilon}. \end{aligned} \tag{7}$$

Note that for the Foreign economy, real exchange rates and terms of trade are simply the inverse of the values for the Home economy.

3.3. Firms

Since the final good is the *numéraire*, the relative price of intermediate goods is p_{iit} and the intermediate firms' revenues from sales correspond to $p_{iit}y_{it}$. Firms' spending is the sum of the wage bill $w_{it}n_{it}$, investment x_{it}, and dividends d_{it} paid to shareholders. Their net borrowing corresponds to $e^P_{it} - R_{it-1}e^P_{it-1}$, where e^P_{it} corresponds to the level of *inter-period debt* and R_{it} to the interest rate. The following budget constraint combines revenues, spending, and borrowing as follows:

$$p_{iit}y_{it} + e^P_{it} = d_{it} + x_{it} + R_{it-1}e^P_{it-1} + w_{it}n_{it}. \tag{8}$$

Capital's law of motion is simply given by $k_{it} = (1-\delta)k_{it-1} + x_{it}$, where δ corresponds to the depreciation rate. I assume that firms collect revenues only after having paid their factors of production and dividends only after having borrowed. Hence, in order to cover these expenses, they contract *intra-period loans* l_{it}:

$$l_{it} = R_{it-1}e^P_{it-1} - e^P_{it} + d_{it} + x_{it} + w_{it}n_{it}. \tag{9}$$

It is an identity that these loans correspond exactly to output. Firms may decide to renege on their total debt *i.e.* the sum of *intra-period loans* and *inter-period debt*. However, in this case I assume that lenders would be able to repossess a stochastic fraction—λ_{it}, *i.e.* the financial shock—of the value of the firms' capital holdings. Therefore, in equilibrium, firms never default and workers impose the following borrowing constraint:

$$\lambda_{it}k_{it} \geqslant l_{it} + e^P_{it}. \tag{10}$$

This borrowing constraint is the equilibrium result of an enforceability problem for which it is assumed that firms have all the bargaining power. The complete derivation of the problem is described in Appendix A of Perri and Quadrini (2017). The firms' objective is to maximize the discounted stream of dividends. Since they face a borrowing constraint, they do not pay factors of production the values of their marginal products. The firms' first order condition with respect to labor is as follows:

$$p_{iit}y_{n_{it}} = \frac{w_{it}}{1-\vartheta_{it}} \tag{11}$$

where $y_{n_{it}}$ corresponds to the marginal product of labor and ϑ_{it} to the Lagrange multiplier on the borrowing constraint. A relaxed borrowing constraint, caused by a positive financial shock for example, leads to lower levels of the Lagrange multiplier ϑ_{it}. Firms adjust their labor demand according to this condition and this appears crucial in explaining the Backus-Smith puzzle. This is further explored in Section 5.

3.4. Investors

Investors hold shares of domestic firms only. This assumption will be relaxed in the sensitivity analysis section to allow them to hold shares of foreign firms as well. They derive utility from consuming the final goods intertemporally as follows: $E_0\sum_{t=0}^{\infty}\gamma^t \ln c_{it}^P$, where γ corresponds to their discount factor. They face the following budget constraint:

$$s_{it}\left(d_{it}+p_{it}^s\right)=c_{it}^P+p_{it}^s s_{it+1} \tag{12}$$

where s_{it} corresponds to shares and p_{it}^s to their market price. In equilibrium, their stochastic discount factor corresponds to that of the firms'.

3.5. Workers

Workers maximize the discounted sum of period-specific utilities, as follows:

$$E_0\sum_{t=0}^{\infty}\beta^t U(c_{it}^W, n_{it}).$$

where β corresponds to their discount factor and c_{it}^W to their consumption of final goods. Their period-specific utility functions are non-separable and are based on the work of Greenwood et al. (1988):

$$U(c_{it}^W, n_{it})=\ln\left(c_{it}^W-\frac{\zeta}{\eta}n_{it}^{\eta}\right),$$

where $\zeta>0, \eta>1$, and c_{it}^W is their consumption of final goods.

As mentioned in the firms' section, workers lend to firms. Loans are of two types – *intra-period* l_{it} and *inter-period* e_{it}^W. They also trade an international bond with workers from abroad f_{it} that is denominated in terms of the Foreign's final good. Workers are paid for the hours worked and consume c_{it}^W. The budget constraint for the Home-country workers is the following:[6]

$$R_{Ht-1}e_{Ht-1}^W+Z_{Ht}R_{t-1}f_{Ht-1}+w_{Ht}n_{Ht}=c_{Ht}^W+e_{Ht}^W+Z_{Ht}f_{Ht}. \tag{13}$$

The key first order condition to explain the lack of international risk sharing is the one with respect to the international bond.[7] In conjunction with the FOCs with respect to consumption, the following equation emerges:

$$E_t\hat{u}_{c_{Ft+1}^W}-E_t\hat{u}_{c_{Ht+1}^W}=E_t\hat{z}_{Ht+1} \tag{14}$$

where $\hat{x}_t$ is equal to the growth rate of X_t, *i.e.* $\hat{u}_{c_{Ft+1}^W}=\log\left(U_{c_{Ft+1}^W}/U_{c_{Ft}^W}\right), \hat{u}_{c_{Ht+1}^W}=\log\left(U_{c_{Ht+1}^W}/U_{c_{Ht}^W}\right)$, and $\hat{z}_{Ht+1}=\log\left(Z_{Ht+1}/Z_{Ht}\right)$. Therefore, expected changes in marginal utilities of consumption are proportional to expected changes in real exchange rates under incomplete asset markets.

From the GHH preferences specified in the workers' problem, the marginal utility of consumption corresponds to $\left(c_{it}^W-\frac{\zeta}{\eta}n_{it}^{\eta}\right)^{-1}$. Hence, large fluctuations in hours worked can break the link between real exchange rates and relative consumptions. GHH preferences also dampen the wealth effect; consequently, changes in the labor supply are proportional to changes in wages as can be seen from the first order condition with respect to hours worked:

$$\zeta n_{it}^{\eta-1}=w_{it}. \tag{15}$$

3.6. Labor wedge

The labor wedge is defined as the difference between the MPN and the MRS. From the workers' optimization problem, it can be shown that the MRS is always equal to wages. Hence, movements in the labor wedge originate entirely from the financial shocks that create a varying gap between the MPN and wages. In a similar fashion to Karabarbounis (2014a), I present theoretical, τ_{it}, and empirical, τ_{it}^e, expressions of the labor wedge. From Eq. (11), the theoretical labor wedge is as follows:

$$\tau_{it}=\frac{p_{iit}y_{nit}}{w_{it}}=(1-\vartheta_{it})^{-1}. \tag{16}$$

Note that the two-good structure involves different valuations of the MPN and the MRS. This needs to be taken into account when measuring the labor wedge. The empirical counterpart is the following:

[6] The only difference for Foreign workers' budget constraint is that the real exchange rate does not show up.

[7] As an alternative to the international bond, I could allow households to lend to firms that are located in a different country as well, in similar fashion to Devereux and Yetman (2010). Since international asset markets are frictionless, this alternative specification would give the same results.

$$\tau^{e}_{it} = \frac{p_{iit}(1-\mu)y_{it}/n_{it}}{P_{it}\zeta n_{it}^{\eta-1}} \tag{17}$$

where $\frac{P_{it}}{p_{iit}} = \left(\omega + (1-\omega)TOT_{it}^{\frac{\epsilon}{1+\epsilon}}\right)^{\frac{1+\epsilon}{\epsilon}}$. The use of GHH preferences implies that consumption is excluded from the MRS as wealth effects are dampened. Moreover, terms of trade deviations do not contribute much to the variations in the labor wedge.

3.7. Shocks

The baseline model features four shocks: two TFP shocks and two financial shocks that follow a multivariate autoregressive process:

$$\Omega_t = \Gamma\Omega_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim N(0, \Sigma) \tag{18}$$

where $\Omega_t = [A_{Ht}, A_{Ft}, \lambda_{Ht}, \lambda_{Ft}]'$ and $\varepsilon_t = [\varepsilon_{A_{Ht}}, \varepsilon_{A_{Ft}}, \varepsilon_{\lambda_{Ht}}, \varepsilon_{\lambda_{Ft}}]'$. The parameter Σ corresponds to the variance–covariance matrix.

3.8. Market clearing

Intermediate goods produced are ensured to be used as inputs in the production of final goods:

$$y_{Ht} = a_{Ht} + a_{Ft}, \tag{19}$$

$$y_{Ft} = b_{Ht} + b_{Ft.} \tag{20}$$

For the final goods' market, total production of intermediate goods is equal to domestic absorption:

$$c^{P}_{it} + c^{W}_{it} + x_{it} = G(a_{it}, b_{it}) \quad \text{where} \quad i = \{H, F\}. \tag{21}$$

The *inter-period debt*'s clearing condition is:

$$(1-\varpi)e^{P}_{it} + \varpi e^{W}_{it} = 0. \tag{22}$$

The international bonds market clears:

$$Z_{Ht}f_{Ht} + f_{Ft} = 0. \tag{23}$$

3.9. Recursive competitive equilibrium

Definition 1. In each country (where $i = \{H, F\}$ and $j = \{H, F\}$, but $i \neq j$), a recursive competitive equilibrium is defined as a set of functions for

(i) workers' policies $c^{W}_{i}(\mathbf{s}), n_i(\mathbf{s}), f_i(\mathbf{s}), e^{W}_{i}(\mathbf{s})$;
(ii) investors' policies $c^{P}_{i}(\mathbf{s})$
(iii) firms' policies $d(\mathbf{s}; k, e^{P}_{i}), n(\mathbf{s}; k, e^{P}_{i}), k(\mathbf{s}; k, e^{P}_{i})$ and $e^{P}_{i}(\mathbf{s}; k, e^{P}_{i})$;
(iv) firms' value $V(\mathbf{s}; k, e^{P}_{i})$;
(v) aggregate prices for each country $w(\mathbf{s}), R(\mathbf{s}), R_i(\mathbf{s}), p_{ii}(\mathbf{s}), p_{ij}(\mathbf{s}), P_i(\mathbf{s})$ and $m(\mathbf{s}, \mathbf{s}')$;
(vi) law of motion for the aggregate state $s' = \Psi(s)$.

Such that:

(i) workers' policies satisfy conditions (35)–(37);
(ii) investors' policies satisfy conditions (34);
(iii) firms' policies are optimal and $V(\mathbf{s}; k, e^{P}_{i})$ satisfies the Bellman's Eq. (28);
(iv) wages, interest rates, and prices clear the labor, bond markets, intermediate goods markets (19) and (20), and the stochastic discount factor is $m(\mathbf{s}, \mathbf{s}') = \gamma U_{c^{P\prime}}/U_{c^{P}}$;
(v) the resource constraint (21) is satisfied;
(vi) the law of motion in each country $\Psi(s)$ is consistent with individual decisions and the stochastic processes for A_i and λ_i.

4. Calibration

In this section, I report parameters that govern the shock processes and other parameters that are related to preferences, technology, and credit. The persistence and variance–covariance matrices are estimated from data on the UK and the US. Data sources and the construction of some of these variables are available in Appendix A.

Table 1
Parameterization of shock processes.

TFP shocks only	$\widehat{\Gamma} = \begin{bmatrix} 0.999 & 0 & 0 & 0 \\ 0 & 0.999 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$	$\hat{\sigma}_{A_{US}} = 0.0062$ $\hat{\sigma}_{A_{UK}} = 0.0062$ $\hat{\rho}_{A_{US},A_{UK}} = 0.19$
Financial shocks only	$\widehat{\Gamma} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0.979 & -0.01 \\ 0 & 0 & -0.01 & 0.979 \end{bmatrix}$	$\hat{\sigma}_{\lambda_{US}} = 0.011$ $\hat{\sigma}_{\lambda_{UK}} = 0.011$ $\hat{\rho}_{\lambda_{US},\lambda_{UK}} = 0.27$
Both shocks	$\widehat{\Gamma} = \begin{bmatrix} 0.993 & 0.01 & -0.027 & -0.071 \\ 0.01 & 0.993 & -0.071 & -0.027 \\ 0.035 & 0.025 & 0.974 & 0.002 \\ 0.025 & 0.035 & 0.002 & 0.974 \end{bmatrix}$	$\hat{\sigma}_{A_{US}} = 0.0061$ $\hat{\sigma}_{A_{UK}} = 0.0061$ $\hat{\sigma}_{\lambda_{US}} = 0.0102$ $\hat{\sigma}_{\lambda_{UK}} = 0.0102$
	$\hat{\rho} = \begin{bmatrix} 1.00 & & & \\ 0.15 & 1.00 & & \\ 0.229 & -0.021 & 1.00 & \\ -0.021 & 0.229 & 0.150 & 1.00 \end{bmatrix}$	

4.1. Technology and financial shocks

First, I present the method that I use to extract these shocks. Second, I show the results of the estimation procedure.

In a similar fashion to Jermann and Quadrini (2012), I log-linearize the intermediate-good production functions and consider technology shocks as Solow residuals:

$$\widehat{A_{it}} = \widehat{Y_{it}} - \mu\widehat{k_{it-1}} - (1-\mu)\widehat{n_{it}} \tag{24}$$

where $\widehat{Y_{it}}, \widehat{k_{it}}$ and $\widehat{n_{it}}$ are deviations in logarithms from a linear trend. For example, $\widehat{Y_{it}} = \log(Y_{it}) - \widehat{\beta_0} - \widehat{\beta_1}t$ where $\widehat{\beta_0}$ and $\widehat{\beta_1}$ are estimated from an OLS regression.

In order to retrieve financial shocks, I assume that the firms' borrowing constraint, Eq. (10), always binds. In the simulation of the baseline model, this constraint does not always bind for large positive shocks. However, for a reasonable calibration of the shocks' variance, these events occur with low probability.[8] The approximated value of these shocks is:

$$\widehat{\lambda_{it}} \approx -\widehat{k_{it}} + \frac{1}{\bar{e^P} + \overline{Y}}\left(\bar{e^P}\widehat{e^P_{it}} + \overline{Y}\widehat{Y_{it}}\right). \tag{25}$$

$\bar{e^P}$ and $\overline{Y}$ correspond to steady-state levels.

After retrieving the shocks $(\widehat{A_{Ht}}, \widehat{A_{Ft}}, \widehat{\lambda_{Ht}}, \widehat{\lambda_{Ft}})$, I substitute their values in Eq. (18) and estimate the persistence and variance parameters by maximum likelihood. I impose symmetry to the matrices, so that persistence, spill-over, and variance parameters are the same for both countries. I present the results in Table 1 for the estimation of technology and financial shocks only, and for both types of shocks. The parameters $\hat{\sigma}$ and $\hat{\rho}$ correspond to the estimated standard errors of the shocks and to the estimated correlations of innovations.

4.2. Preferences and technology parameters

The remaining parameters are set so that they match some steady-state targets and one moment outside the steady-state. Following the two-country real business cycle literature, I assume symmetry—*i.e.* both countries are the same size and their parameters are also the same. I report them in Table 2. Following Campbell and Mankiw (1990), who find that half of the households are borrowing-constrained, I set the number of investors and workers in both countries to be equal ($\varpi = 0.5$). The workers' discount factor, β, is equal to 0.99—a value that corresponds to an annual real interest rate of 4%. The investors' discount factor is lower, γ=0.97, in order for them to have some incentives to borrow. In that regard, I follow Bernanke et al.'s (1999) calibration, since the interest rate premium is two percentage points. The parameter η is set to 1.67, which corresponds to a labor Frisch elasticity of 1.5. Also, in the utility function, the parameter ζ is set to 4.2 in order for workers to allocate 30% of their time to work.

Capital depreciates at a $\delta = 0.025$ quarterly rate and the share of capital, μ, in the production function is 0.36. For the final goods production, I assume that in the steady state the fraction of imported intermediate goods corresponds to 15%, therefore $\omega = 0.85$. From 1984 to 2010, this number is also the average fraction for the United States. The elasticity of substitution between intermediate goods produced in the Home and in the Foreign countries is set to $\sigma = 0.85$, which seems to be an

[8] As a robustness check, I simulate the model with OccBin – a toolkit developed by Guerrieri and Iacoviello (2015) that proposes a piecewise linear solution to occasionally binding constraints. The results obtained from this method are almost identical to the ones obtained from a log-linearization around the steady-state for which the constraints are always binding.

Table 2
Parameterization of preferences, technology, and credit.

Symbol	Value	Definition
ϖ	0.5	Share of investors in the economy
Preferences		
β	0.99	Workers discount factor
γ	0.97	Investors discount factor
η	1.67	Parameter controlling the labor wage elasticity
ζ	4.2	Labor disutility weight
Technology		
μ	0.36	Capital share
δ	0.025	Capital depreciation
ω	0.85	Weight on domestic good
$\sigma = 1/(1+\epsilon)$	0.85	Elasticity of substitution between intermediate goods
Credit		
$\bar{\lambda}$	0.288	Enforcement parameter

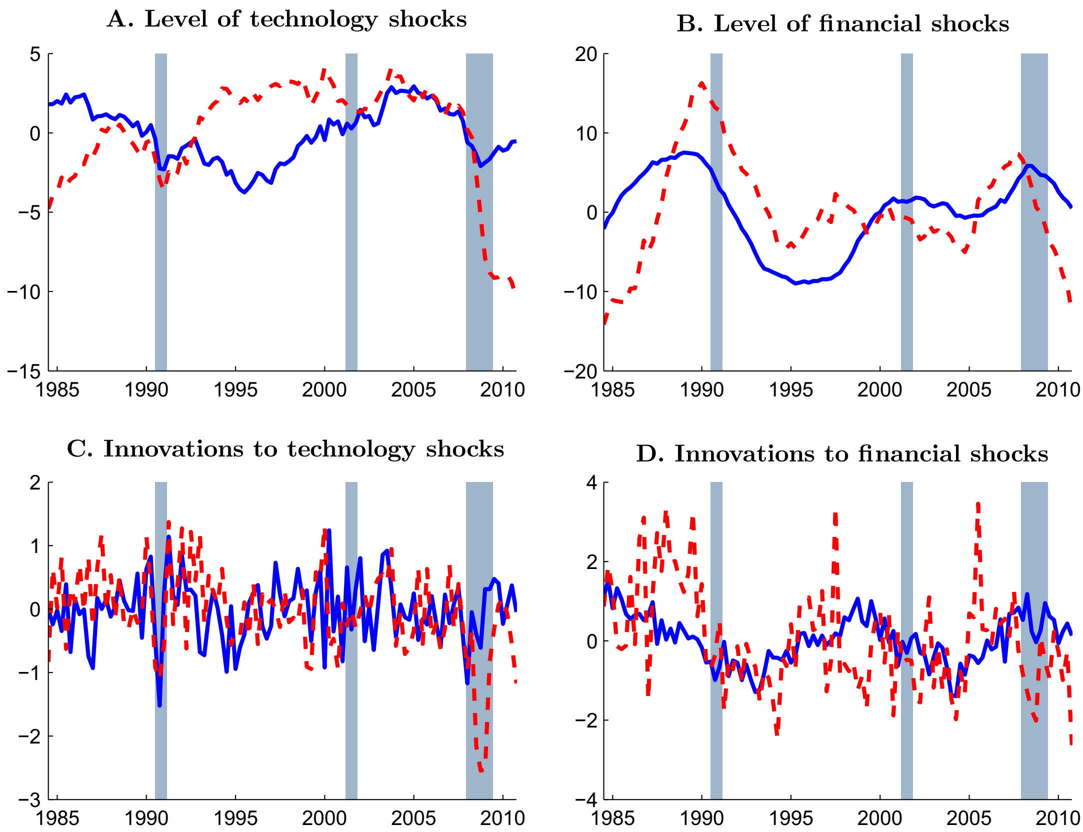

Fig. 1. Time series of technology and financial shocks. The solid blue lines correspond to the US, and the dashed red line to the UK. The grey shaded areas represent the corresponding NBER recession for the US. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

intermediate value and is the one reported by Bodenstein (2011). I test the robustness of my results with respect to the value of this parameter in the sensitivity analysis section. The enforcement parameter, $\bar{\lambda}$, is estimated by matching the relative standard deviation of hours worked on output. I chose this moment because financial shocks significantly affect the labor wedge and labor demand. In fact, the larger value $\bar{\lambda}$ takes, the larger are the estimated variance of financial shocks and the volatility of hours worked over real GDP. The estimate of $\bar{\lambda}$, 0.288, corresponds to a low leverage scenario for capital, but is close to the estimate, 0.1965, of a similar parameter by Jermann and Quadrini (2012).

4.3. Time series of technology and financial shocks

Prior to turning to the analysis of impulse responses and business cycle statistics, Fig. 1 presents the behavior of the estimated technology and financial shocks throughout time. As can be seen in panel B of Fig. 1, it appears that the UK financial shock is more volatile than its US counterpart. In effect, the variable that measures banking loans to non-financial firms displays a standard deviation that is 1.66 times greater for the UK. Moreover, falls in the financial shocks are tied with the onset of recessions. The drop in financial shocks takes place a few quarters before the 1990–1991 recession. However, during the 2001 recession, financial shocks remain at the same level. Finally, the decline in financial shocks lags the beginning of the Great Recession.

5. Results of the business cycle estimation

I linearize the system of equations that combines firms, investors and workers' FOCs, and the constraints they face, and I examine the dynamics around the steady state. First, I analyze the impulse responses to technology and financial shocks. Second, I compare business cycle statistics generated by the baseline model to the data.

5.1. Impulse responses

In Figs. 2 and 3, I present impulse responses of key variables to one-percent temporary technology and financial shocks that hit the Home economy. The high correlations between Home and Foreign aggregate variables can be assessed from the responses presented in Fig. 2. Contrary to the effects of technology shocks, the effects of financial shocks are short-lived,

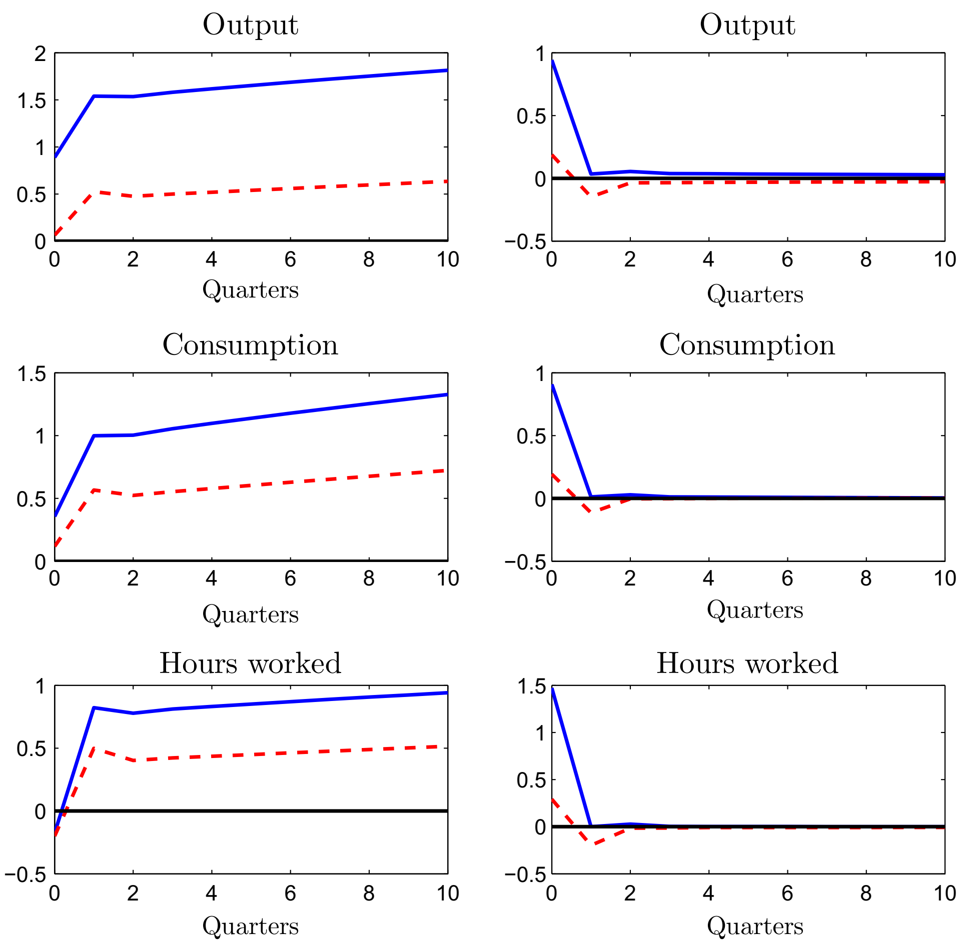

Fig. 2. Impulse responses (aggregate variables). The left side panels illustrate the responses to a one percent temporary Home TFP shock, while the right side panels illustrate the responses to a one percent temporary Home financial shock. The solid blue lines correspond to the Home economy and the dashed red lines to the Foreign economy. Responses are all measured in percent deviations from their steady state. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

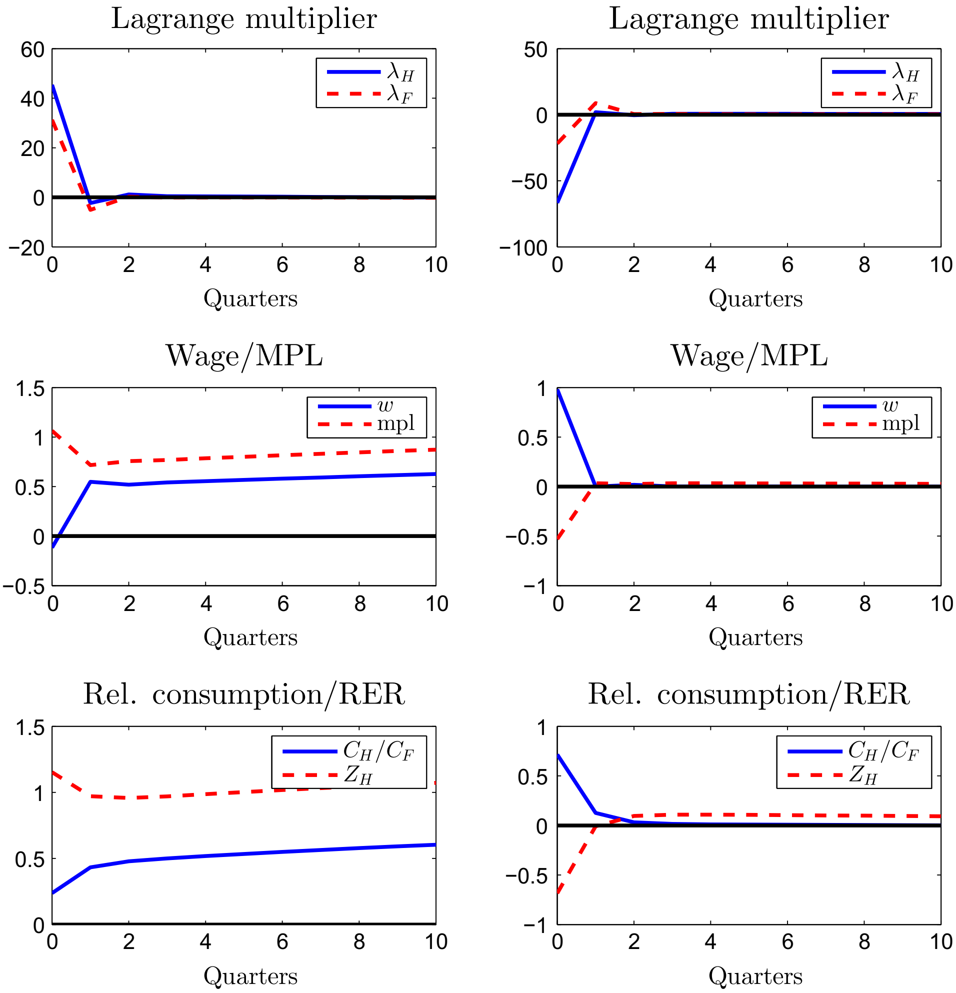

Fig. 3. Impulse responses (labor wedge and the *Backus-Smith puzzle*). The left side panels illustrate the responses to a one percent temporary Home TFP shock, while the right side panels illustrate the responses to a one percent temporary Home financial shock. Responses are all measured in percent deviations from their steady state.

despite the high value (0.974) of its persistence parameter. The impulse responses presented by Jermann and Quadrini (2012) are smoother because the financial frictions that they put forward are different. Specifically, they assume that firms face a quadratic adjustment cost to changes in dividends. The two bottom panels on the right side of Fig. 3 are the most important in studying the Backus-Smith correlation. As shown in Eq. (11), a labor wedge between wages and the marginal product of labor arises due to working capital requirements. A positive shock relaxes the amount of *intra-period loans* that firms are required to contract. As a consequence, firms raise their demand for labor. In equilibrium, wages are higher following a positive shock in order to induce workers to allocate more time at work, while the marginal product of labor is lower because labor increases more proportionally with capital.[9]

Since preferences are non-separable between consumption and leisure, sizeable variations in hours worked break the link between relative consumptions and real exchange rates. Contrary to separable preferences for which there would be a perfect correlation between the real exchange rate and relative consumptions. In order to shed light on the role played by financial frictions, I substitute ζn_{Ht}^{η} and ζn_{Ft}^{η} from the firms' labor demand conditions (11) and workers' labor supply (15) in Eq. (14), so that:

[9] Galí et al. (2007) and Karabarbounis (2014b) invalidate firms-based variations in the labor wedge as they present empirical evidence that points to much greater deviations of the MRS from wages. However, the way that wages are measured cannot be directly compared to their theoretical counterparts. On that note, Arellano et al. (2016), whose framework embeds financial frictions that induce firms-side variations in the labor wedge, reply that the long-term relationship between employees and employers is not taken into account in theoretical models. Moreover, Bils et al. (2014) find that firms-based variations are at least as important as workers-based variations when they focus on self-employed and intermediate inputs.

Table 3
Business cycle statistics.

Model:		Baseline		
Shocks:		TFP	Financial	Both
	Data			
Volatility				
Standard deviations (in percent)				
GDP	**1.27**	1.13	1.00	1.66
Standard deviations relative to GDP				
Consumption	**0.94**	0.68	0.97	0.7
Hours worked	**1.03**	0.65	1.58	1.04
Labor wedge	**1.19**	0.56	1.56	0.93
Real exchange rate	**5.24**	1.12	0.89	0.87
Autocorrelation				
Real exchange rate	**0.72**	0.62	−0.12	0.53
Domestic correlations with GDP				
Labor wedge	**−0.27**	−0.01	−0.99	−0.59
Net exports/GDP	**−0.59**	0.07	−0.43	−0.31
International correlations				
GDP_{US}, GDP_{UK}	**0.76**	0.4	0.62	0.5
C_{US}, C_{UK}	**0.63**	0.76	0.62	0.57
N_{US}, N_{UK}	**0.68**	0.81	0.6	0.58
X_{US}, X_{UK}	**0.6**	0.63	−0.86	0.03
Backus-Smith correlations				
$C_{US}/C_{UK}, Z$	**−0.22**	0.85	−0.98	−0.06
$\Delta C_{US}/C_{UK}, \Delta Z$	**−0.11**	0.65	−0.996	−0.58
Non-binding constraints, in percent		2.66	9.98	10.3
Variance decomposition				
(percent of GDP explained by fin. shocks)		0	100.00	38.37

Statistics in the first column for the *volatility*, *autocorrelation*, and *domestic correlations* sections are the average of the US and UK time series described in Appendix A from 1984Q1 to 2010Q4, except for the real exchange rate and net exports for which the US statistics are reported. The *international correlations*, *autocorrelation*, and Backus-Smith correlations are calculated from the US and UK time series. I also report the fraction of periods for which the borrowing constraints are not binding and the average proportion of GDP's variance attributed to financial shocks. All series have been logged (except for relative consumptions and real exchange rates in differences) and Hodrick-Prescott filtered with a smoothing parameter of 1600.

$$\frac{E_t\Delta c^W_{Ht+1} - \frac{(1-\mu)}{\eta}E_t\Delta[Y_{Ht+1}(1-\vartheta_{Ht+1})]}{E_t\Delta c^W_{Ft+1} - \frac{(1-\mu)}{\eta}E_t\Delta[Y_{Ft+1}(1-\vartheta_{Ft+1})]} = E_t\Delta Z_{Ht+1}. \tag{26}$$

Under complete markets, this equation boils down to:

$$\frac{c^W_{Ht} - \frac{(1-\mu)}{\eta}Y_{Ht}(1-\vartheta_{Ht})}{c^W_{Ft} - \frac{(1-\mu)}{\eta}Y_{Ft}(1-\vartheta_{Ft})} = Z_{Ht}.$$

Hence, the Backus-Smith correlation can be explained by two factors: (i) the non-separability of preferences, and (ii) the incompleteness of international asset markets. In the sensitivity analysis section, I will show that the former factor largely dominates for a parameterization of the elasticity of substitution that is close to one. In the following lines, I discuss the role of non-separable preferences. As can be seen in Fig. 3, Lagrange multipliers deviate significantly from their steady state levels; hence, they also contribute significantly to real exchange dynamics as shown by Eq. (26). From the bottom right panel, the opposite response of relative consumptions and real exchange rates is striking. [10]

5.2. Quantitative analysis

5.2.1. Baseline model

In Table 3, I present various moments (volatility, autocorrelation, domestic correlations with GDP, and international correlations) that are generated by the baseline model. I then compare them to the data. With the exception of real exchange rate and net exports, all standard deviations, autocorrelations and domestic correlations are averages of the UK and US data. I examine the roles of technology and financial shocks separately to account for these moments; additionally, I also observe

[10] It has to be noted that relative consumptions, as measured from the model, consist in the ratio of the sum of investors and workers' consumptions. However, the fluctuations in this variable are mostly driven by workers' consumption or the category of agents that are linked internationally. Specifically, for the baseline model with both shocks, the correlation between the workers' relative consumptions and the real exchange rate is −0.03, and the correlation in the growth of the latter two variables is −0.56.

Table 4
Sensitivity analysis statistics.

Model:	Data	Baseline	$\sigma = 0.62$	$\iota = 0.75$	$\eta = 1.25$	$\eta = 2$	*JQ shocks*	*Fin. autarky*
Volatility								
GDP	**1.27**	1.66	1.65	1.65	2.15	1.47	1.23	1.85
Std. dev. relative to GDP								
Consumption	**0.87**	0.7	0.69	0.71	0.86	0.6	0.88	0.77
Hours worked	**1.03**	1.04	1.06	1.03	1.17	0.96	1.25	1.18
Labor wedge	**1.19**	0.93	0.96	0.92	0.71	1.16	1.18	1.32
Real exchange rate	**5.24**	0.87	1.32	0.77	0.71	0.95	1.00	1.21
Autocorrelation								
Real exchange rate	**0.72**	0.53	0.68	0.48	0.6	0.46	0.26	−0.19
Domestic corr. with GDP								
Labor wedge	**−0.27**	−0.59	−0.62	−0.58	−0.64	−0.55	−0.69	−0.71
Net exports/GDP	**−0.59**	−0.31	−0.37	−0.33	−0.32	−0.29	−0.49	–
International corr.								
GDP_{US}, GDP_{UK}	**0.76**	0.5	0.53	0.51	0.57	0.48	0.3	0.16
C_{US}, C_{UK}	**0.63**	0.57	0.61	0.54	0.62	0.55	0.39	−0.02
N_{US}, N_{UK}	**0.68**	0.58	0.54	0.63	0.63	0.58	0.41	−0.04
X_{US}, X_{UK}	**0.6**	0.03	0.12	0.11	0.04	0.02	−0.64	0.7
Backus-Smith correlations								
$C_{US}/C_{UK}, Z$	**−0.22**	−0.06	−0.18	0.05	−0.13	0.03	−0.47	0.94
$\Delta C_{US}/C_{UK}, \Delta Z$	**−0.11**	−0.58	−0.47	−0.53	−0.54	−0.56	−0.82	0.99
Non-binding constraints, in percent		10.3	11.33	10.22	8.28	12.4	8.83	21.04
Variance decomposition								
Percent of GDP explained by fin. shocks		38.37	40.49	37.22	44.33	34.31	55.48	52.62

See the notes below Table 3 for a description of the data. Statistics of column 2 are generated from the estimation of the baseline model, and statistics of columns 3–7 are generated from variations of this model for some key parameters. Column 3 corresponds to a lower elasticity of substitution between Home and Foreign intermediate goods; column 4 to a lower parameter of equity home bias; column 5 (6) to a higher (lower) labor Frisch elasticity; column 7 to the persistence and variance of shocks of Jermann and Quadrini (2012); and column 8 to financial autarky. All series have been logged (except relative consumptions and real exchange rates in differences) and Hodrick-Prescott filtered with a smoothing parameter of 1600.

financial shocks in conjunction with technology shocks. I also report the fraction of periods where the borrowing constraints are not binding and, from a variance decomposition, I report the percentage of GDP that is explained by financial shocks. I refer the reader to Tables 5 and 6 in the appendix for additional statistics.

A first observation is that the hours worked and labor wedges are more volatile in the presence of financial shocks. Financial shocks allow the labor wedge to be unambiguously countercyclical. The baseline model is also able to replicate quite well the labor wedge dynamics in the data. This assertion is based on the correlations between the theoretical and empirical H-P filtered labor wedges represented by Eqs. (16) and (17). The correlation is 0.57 for the US and 0.26 for the UK.[11] These results are in line with the mechanism put forward in the previous section. The same mechanism also explains the strong negative correlation between relative consumptions and real exchange rates, and the correlation in the growth of the latter two variables. The importance of financial shocks is also measured by the contribution of these shocks to GDP dynamics. At 38.37%, it is slightly lower than other studies, *e.g.* Jermann and Quadrini (2012): 46.4%, and Nolan and Thoenissen (2009): 46.6%.

The baseline model with financial shocks as the only source of shocks is also able to replicate the high level of international correlation in output and the negative correlation between net exports and GDP. These issues are secondary to the main focus of this paper, however it is important to show that financial shocks are not accounting for the Backus-Smith correlation at the expense of other open-economy puzzles. The uncovered interest rate parity (UIP) is key in understanding how these shocks propagate from a county to another. From the workers of both countries' first order conditions with respect to international bonds, the UIP is as follows:

$$\frac{Z_{Ht} E_t U_{c^W_{Ht+1}}}{E_t\left(Z_{Ht+1} U_{c^W_{Ht+1}}\right)} R_{Ht} = R_{Ft}. \tag{27}$$

A positive temporary financial shock in the Home economy drives its real interest rate up as firms' demand for borrowing increases. This shift in the interest rate is transmitted to the Foreign economy from the UIP condition. As seen in the previous section, Home workers expect an appreciation of the real exchange rate (fall in Z_{Ht}); however, from the parameterization presented in the previous section, this appreciation is too small in magnitude to offset the rise in the interest rate. The mechanism that leads to positive effects on labor demand and output in the Foreign economy diverges from the one that takes place in the Home economy. Facing a higher interest rate, Foreign firms reduce their level of *inter-period debt*. Their borrow-

[11] The theoretical labor wedges, derived from Eq. (16), are retrieved by feeding the baseline model with the financial and technology shocks that are presented in Section 4.1, and the empirical labor wedges correspond to the ratio of variables as shown in Eq. (17).

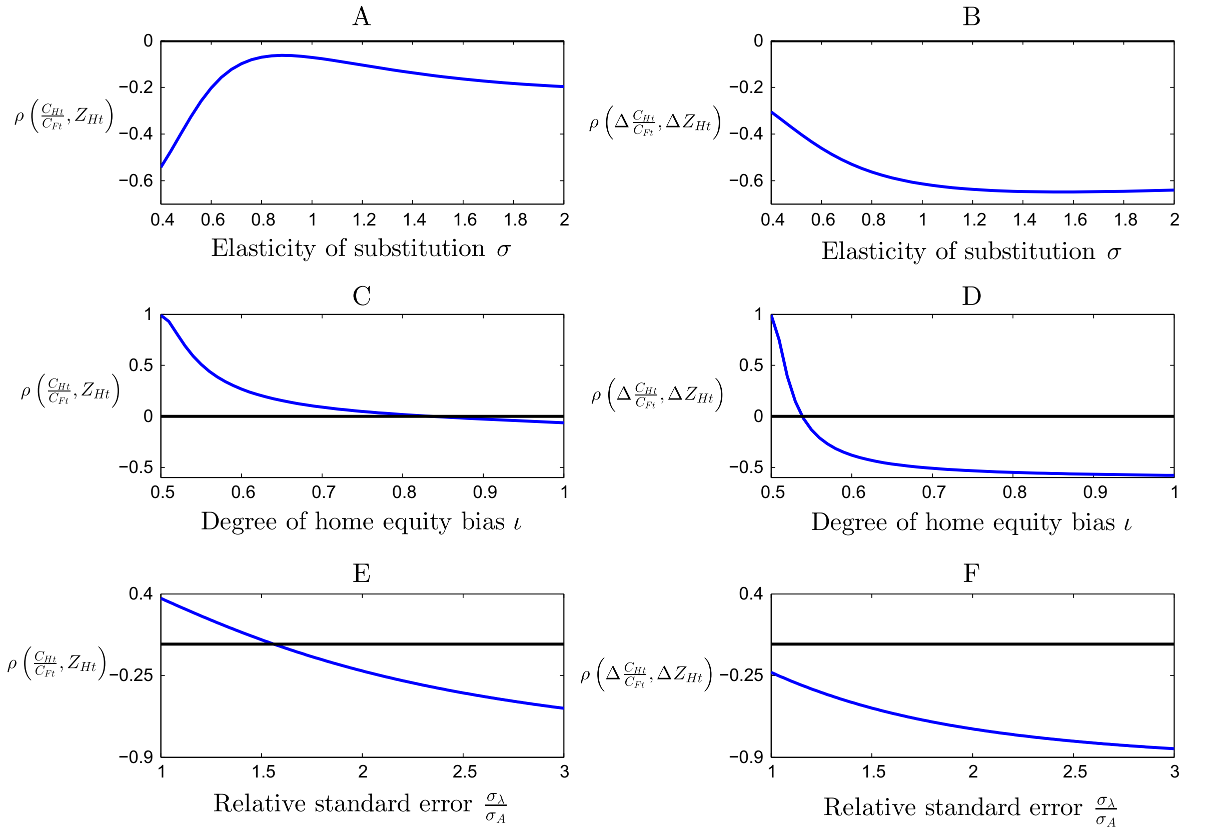

Fig. 4. Sensitivity of the Backus-Smith correlations to the elasticity of substitution between intermediate goods, to the level of home equity bias, and to the relative standard error of financial innovations. Panels A, C, and E illustrate correlations between relative consumptions and real exchange rates, and panels B, D, and F illustrate correlations between the growth rates in relative consumptions and in real exchange rates. Panels A and B illustrate the sensitivity of Backus-Smith correlations to the elasticity of substitution between intermediate goods σ; panels C and D the sensitivity to the level of home equity bias ι; panels E and F the sensitivity to the relative standard error of financial innovations relative standard error of financial innovations $\frac{\sigma_\lambda}{\sigma_A}$.

ing constraint is relaxed, so that the Lagrange multiplier associated with it and the labor wedge shrink. Consequently, it allows these firms to demand more labor at the expense of lower investment. Since hours worked account for a larger share of output, Foreign output increases.

TFP shocks also lead to positive international co-movements in this environment. As shown by Rouillard (2017), this is related to the domestic financial frictions that create a wedge between real interest rates and the marginal product of capital. On the negative side, the baseline model is not able to account for the high levels of volatility of the real exchange rate. Its persistence is also lower than in the data due to the fact that the effects of financial shock on quantities are short-lived. However, this is not specific to my model as many other frameworks that feature stationary shocks also generate low volatilities and persistence. On this note, Heathcote and Perri (2014) argue that nominal exchange rates largely contribute to this specific long-standing puzzle. In fact, this constitutes a different issue that goes beyond the scope of this paper.

5.2.2. Sensitivity analysis

In this section, I perform a sensitivity analysis of the correlation between relative consumptions and real exchange rates. I also assess the performance of the model and its variants in replicating other key moments. Business cycle statistics are reported in Table 4 where the first and second columns correspond respectively to empirical statistics and results of the baseline model. In column 3, the statistics presented are generated from a model that differs from the baseline model on one dimension: the elasticity of substitution between intermediate goods takes a lower value, $\sigma = 0.62$. This is the value that Rabanal et al. (2011) use for their low elasticity scenario. As shown by Heathcote and Perri (2002), a lower value amplifies the volatility of the real exchange rate, yet it is still far below its empirical counterpart. Note that the Backus-Smith correlation is relatively lower.

In order to analyze the role of the elasticity of substitution, Fig. 4 displays the correlation between relative consumptions and real exchange rates in Panel A; the correlation in the growth in the latter two variables in Panel B. As mentioned in Section 5.1, for values of the elasticity that differ from one, the incompleteness of international asset markets also play a role to explain the Backus-Smith correlation. In fact, Cole and Obstfeld (1991) are the first ones to show that a unitary elasticity of substitution in an incomplete markets environment ensures that terms of trade dynamics allows workers to be perfectly insured as it is the case in complete markets. Panels A and B display non-monotonic functions for different values of the elasticity of substitution. Nevertheless, it appears that the negative sign of the correlations is robust to higher values of trade elasticities. On that note, this is not the case for high values in the model of Corsetti et al. (2008) for their baseline parameterization of technology shocks to the tradable goods sector. For values of the elasticity of substitution lower than 0.6, there is an additional channel at play that correspond to the wealth effects suggested by Corsetti et al. (2008).

So far, investors have been excluded from holding shares from firms that are abroad—the equity market is autarkic up until now. In column 4, I relax this assumption, so that, in each country, domestic investors own a fraction $\imath > 0.5$ of shares from domestic firms. Hence, the parameter $\imath$ corresponds to the degree of home equity bias.[12] As such, in equilibrium, the investors' consumption corresponds to $c_{it}^{P} = \imath d_{it} + (1 - \imath) Z_{it} d_{jt}$ where $i \neq j$. For a home equity bias that corresponds to 75%, the Backus-Smith correlations are slightly greater than the ones generated by the baseline model. In Panels C and D of Fig. 4, I plot this correlation for a wide range of the parameter that controls the degree of home equity bias. In the absence of bias ($\imath = 0.5$), the effects of financial shocks are the same in both countries which is specifically the propagation channel emphasized by Perri and Quadrini (2017). This also implies that the consumption adjusted by the real exchange rate is the same for both countries. The main finding here is that a low degree of home equity bias is enough to significantly pull down the Backus-Smith correlation.

In columns 5 and 6, I present statistics for a higher and lower labor Frisch elasticities that correspond to $(\eta - 1)^{-1}$ for GHH preferences. A higher elasticity implies that workers adjust more their labor supply in response to changes in wages as seen in Eq. (15), and a lower elasticity implies the reverse. This explains the greater volatility of hours worked and the larger fraction of GDP that is explained by financial shocks in column 5. Since the effects of financial shocks are more important for labor and output dynamics, the Backus-Smith correlation decreases in comparison with the baseline model.

The persistence and spill-over parameters of the TFP and financial shocks that are presented in Table 1 differ from the ones presented by Jermann and Quadrini (2012).[13] In column 7, I use the calibrated values of their two shocks to simulate the baseline model. The fraction of output explained by financial shocks is greater which leads to lower Backus-Smith correlations. Moreover, international correlations are lower due to the absence of international spill-overs of shocks. In Panels E and F of Fig. 4, I present the sensitivity of the Backus-Smith correlations to the relative standard errors of innovations to financial shocks. Panel E suggests that these innovations need to be at least 60% greater than innovations to TFP in order for Backus-Smith correlations to be negative. For the US and the UK, this criteria is met. For other countries, more work should be done to measure the relative volatility of their financial shocks. Nonetheless, we can affirm that financial shocks help to explain the dynamics of relative consumptions and real exchange rates.

Finally, I examine the effects of changing the international asset market structure in column 8. In fact, I assume that workers can no longer trade international bonds. However, the two-good structure of the model ensures that trade still exists for intermediate goods. First, cross-country correlations are significantly reduced with financial autarky as the UIP no longer holds. Therefore, the channel described in the previous section for the propagation of financial shocks is shut down. Second, real exchange rates are more volatile since net exports are always equal to zero. Specifically, compared to the incomplete assets market structure, firms export more and import less in response to positive financial and TFP shocks. As a result, this creates greater movements in international prices in a similar fashion to Heathcote and Perri (2002). Third, the absence of trade balance deficits causes relative consumptions to co-move with real exchange rates. In fact, the production of the country that is hit by the financial or TFP shock increases relatively more than in the baseline model, so that the price of the intermediate good falls. Due to home bias in production of the final good, the real exchange rate in the Home economy depreciates, so that it is positively correlated with relative consumption.

6. Conclusion and extensions

Financial shocks and non-separabilities between consumption and leisure can account for the *consumption–real exchange rate anomaly*. This is the main result that arises from a two-good, two-country model augmented by domestic financial frictions. Financial shocks create large fluctuations in the labor wedge that significantly affect the marginal utility of consumption. These fluctuations are so large that they reverse the link between relative consumptions and real exchange rates and account for the Backus-Smith correlation.

Exchange-rate pass-through (ERPT) is perfect in the framework presented. However, empirical measures of ERPT suggest that it is far from being perfect and that deviations of prices from relative purchasing power parity significantly affect international efficiency—see *e.g.* Burstein and Gopinath (2014). In fact, Strasser (2013) finds that the rate of ERPT is almost two times greater for financially-constrained firms than for unconstrained firms. As such, some work should be carried out to examine the relative importance of inefficiencies based on incomplete ERPT and the lack of financial integration. This

[12] I am grateful to an anonymous referee for her/his suggestion to pay attention to equity market segmentation.

[13] Specifically, the persistence matrix is: $\Gamma = \begin{bmatrix} 0.9457 & 0 & -0.0091 & 0 \\ 0 & 0.9457 & 0 & -0.0091 \\ 0.0321 & 0 & 0.9703 & 0 \\ 0 & 0.0321 & 0 & 0.9703 \end{bmatrix}$ and the standard errors are $\sigma_A = 0.0045$ and $\sigma_\lambda = 0.0098$.

research would require an extension to the baseline model, so that firms heterogeneity and different pricing decisions would have to be embedded.

Acknowledgements

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Appendix A. Data sources and construction of variables

A.1. United States

Variable name: CPI
Source: BLS
Definition: U.S. City Average (Quarter Average, Seasonally Adjusted)

Variable name: Price Index for Nonfarm Business Value Added
Source: BEA, NIPA, Table 1.3.4
Definition: Index 2005 = 100 (Seasonally Adjusted)

Variable name: Net New Borrowing
Source: Federal Reserve Board, Table F.101
Definition: Net increase in credit markets instruments of non-financial business (Quarter Average, Seasonally Adjusted)
Deflator used: Price Index for Business Value Added

Variable names: Business Value Added (Y_{US})
Source: NIPA 1.3.6
Deflator: Index for business value added (NIPA 1.3.4) (seasonally adjusted)

Variable names: Real Consumption (C_{US})
Real Net Exports of Goods and Services (NX_{US})
Source: BEA, NIPA, Table 1.1.6
Definition: Billions of chained (2005) dollars (Seasonally adjusted)

Variable names: Total Employment
Hours worked per worker
Source: Ohanian and Raffo (2012)
Definition: The product of these two variables is equal to N_{US}

Variable names: Consumption of Fixed Capital in Non-Financial Corporate Business
Consumption of Fixed Capital in Non-Financial Non-Corporate Business
Source: Federal Reserve Statistical Release, Flow of Funds, Table F.8
Definition: Millions of US Dollars (Quarterly)
Deflator used: Business Value Added

A.2. United Kingdom

Variable name: CPI
Source: OECD, Prices
Definition: All items (seasonally adjusted with X12-ARIMA)

Variable name: Domestic Loans (e_{UK})
Source: Bank of England, LPQVVOJ
Definition: Quarterly amounts outstanding of monetary financial institutions' sterling net lending to private non-financial corporations (Seasonally Adjusted)
Deflator used: CPI

Variable name: Consumption (C_{UK})
Source: OECD, Quarterly National Accounts
Definition: Chained-volume estimates (2005 in pounds) (seasonally adjusted)

Variable names: Gross domestic product index (seasonally adjusted) (Y_{UK}); Gross Fixed Capital Formation: Total GFCF (seasonally adjusted); Total capital consumption (seasonally adjusted)
Source: ONS (YBEZ, NPQT, CIHA)
Definition: Millions of pounds

Variable names: Total Employment; Hours worked per worker
Source: Ohanian and Raffo (2012)
Definition: The product of those two variables is equal to N_{UK}

A.3. Construction of variables

K_{US} is constructed recursively in the same way as described in the appendix of Jermann and Quadrini (2012). I pick the initial value of K_{US} for the first quarter of 1952 such that the capital-output ratio does not exhibit any trend over the period 1952–2010. *Depreciation* corresponds to the sum of *Non-Financial Corporate and Non-Corporate Business Consumption of Fixed Capital* and *Investment* to *Capital Expenditures in Non-Financial Business*.

$$K_{USt+1} = K_{USt} - Depreciation + Investment$$

For the United Kingdom, the recursion is similar to the one described for the United States and in this case the period is slightly shorter: 1955–2010. *Investment* corresponds to *Total Gross Fixed Capital Formation* and *Depreciation* to *Total Capital Consumption*.

Inter-period debt e_{USt} is also constructed recursively in the same way as described in the appendix of Jermann and Quadrini (2012). The initial value for the (nominal) stock of debt is set to 94.12, which is the value reported in the balance sheet data from the Flow of Funds in the first quarter of 1952 for the nonfarm non-financial business (Table B.102, line 22).

$$e_{USt+1} = e_{USt} + NetNewBorrowing$$

The real exchange (Z_H) corresponds to the ratio of the UK and the US CPIs multiplied by the quarterly average nominal exchange rate that is retrieved from the FRED database of the St. Louis Fed.

Appendix B. Recursive formulation and first order conditions

B.1. Firms' problem

The firms' recursive problem is the following:

$$V(\mathbf{s_i}; k_i, x_i, e_i^P) = \max_{d_i, n_i, k_i', e_i^{P\prime}} \{d_i + Em_i' V(\mathbf{s_i}'; k_i', e_i^{P\prime})\} \tag{28}$$

$$\text{subject to :} \quad p_{ii} y_i + e_i^{P\prime} - w_i n_i = d_i + k_i' - (1-\delta)k_i + R_i e_i^P, \tag{29}$$

$$\lambda_i k_i' \geqslant e_i^{P\prime} + p_{ii} y_i. \tag{30}$$

The value of firms, $V(\mathbf{s_i}; k_i, x_i, e_i^P)$ corresponds to the sum of the discounted stream of dividends where m_i corresponds to the stochastic discount factor. Output y_i is priced in terms of the expenditure good. Firms optimize with respect to $n_i, e_i^{P\prime}$, and k_i'. The FOCs are as follows:

$$Y_{ni} = \frac{w_i}{1-\vartheta_i}, \tag{31}$$

$$1 = Em_i'R_i' + \vartheta_i, \tag{32}$$

$$1 = \lambda_i\vartheta_i + Em_i'(p_{ii}y_{k'i}(1-\vartheta_i') + 1 - \delta). \tag{33}$$

where ϑ_i corresponds to the Lagrange multiplier associated to the borrowing constraint. Eq. (31) corresponds to the FOC with respect to labor. Eq. (32) refers to an Euler equation augmented with a borrowing constraint. Eq. (33) corresponds to the FOC with respect to capital.

B.2. Investors' problem

Investors optimize their problem by picking consumption and the quantity of shares. The combination of their FOCs correspond to the following Euler equation:

$$\frac{p_{it}^s}{c_{it}^P} = \gamma\frac{E_t(d_{it+1} + p_{it+1}^s)}{c_{it+1}^P}. \tag{34}$$

B.3. Workers' problem

The workers' FOCs are as follows:

$$\frac{Z_{Ht}U_{c_{Ht}^W}}{E_t\left(U_{c_{Ht+1}^W}Z_{Ht+1}\right)} = \frac{U_{c_{Ft}^W}}{E_t\left(U_{c_{Ft+1}^W}\right)}, \tag{35}$$

$$\frac{Z_{Ht}E_tU_{c_{Ht+1}^W}}{E_t\left(Z_{Ht+1}U_{c_{Ht+1}^W}\right)}R_{Ht} = R_{Ft} = R_t, \tag{36}$$

$$\zeta n_{it}^{\eta-1} = w_{it}, \tag{37}$$

The FOC with respect to consumption combined to FOcs with respect to the international bond for both Home and Foreign workers gives Eq. (35). The combination of FOCs with respect to the international bond and *inter-period debt* corresponds to Eq. (36),that is also called the uncovered interest rate parity (UIP). Eq. (37) represents the relationship between wages and labor supply.

Appendix C. Additional statistics

Tables 5 and 6 complement Tables 3 and 4 in providing additional statistics.

Table 5
Business cycle statistics.

Model:		Baseline		
Shocks:		TFP	Financial	Both
	Data			
Volatility				
Standard deviations (in percent)				
GDP	**1.27**	1.13	1.00	1.66
Standard deviations relative to GDP				
Consumption	**0.94**	0.68	0.97	0.7
Hours worked	**1.03**	0.65	1.58	1.04
Labor wedge	**1.19**	0.56	1.56	0.93
Investment	**3.99**	2.07	3.85	3.49
Real exchange rate	**5.24**	1.12	0.89	0.87
Net exports/GDP	**0.37**	0.08	0.38	0.24
Autocorrelation				
Real exchange rate	**0.72**	0.62	–0.12	0.53

Table 5 (*continued*)

Model:		Baseline		
Shocks:		TFP	Financial	Both
Domestic correlations with GDP				
Consumption	**0.87**	0.96	0.999	0.92
Hours worked	**0.75**	0.82	0.999	0.87
Investment	**0.75**	0.91	0.66	0.83
Labor wedge	**−0.27**	−0.01	−0.99	−0.59
Net exports/GDP	**−0.59**	0.07	−0.43	−0.31
International correlations				
GDP_{US}, GDP_{UK}	**0.76**	0.4	0.62	0.5
C_{US}, C_{UK}	**0.63**	0.76	0.62	0.57
N_{US}, N_{UK}	**0.68**	0.81	0.6	0.58
X_{US}, X_{UK}	**0.6**	0.63	−0.86	0.03
Backus-Smith correlations				
$C_{US}/C_{UK}, Z$	**−0.22**	0.85	−0.98	−0.06
$\Delta C_{US}/C_{UK}, \Delta Z$	**−0.11**	0.65	−0.996	−0.58
Non-binding constraints, in percent		2.66	9.98	10.3
Variance decomposition				
(Percent of GDP explained by fin. shocks)		0	100.00	38.37

Table 6
Sensitivity analysis statistics.

Model:	Data	Baseline	$\sigma = 0.62$	$\iota = 0.75$	$\eta = 1.25$	$\eta = 2$	*JQ shocks*	*Fin. autarky*
Volatility								
GDP	**1.27**	1.66	1.65	1.65	2.15	1.47	1.23	1.85
Std. dev. relative to GDP								
Consumption	**0.87**	0.7	0.69	0.71	0.86	0.6	0.83	0.77
Hours worked	**1.03**	1.04	1.06	1.03	1.17	0.96	1.25	1.18
Labor wedge	**1.19**	0.93	0.96	0.92	0.71	1.16	1.18	1.32
Investment	**3.99**	3.49	3.35	3.45	2.75	3.91	4.00	2.39
Real exchange rate	**5.24**	0.87	1.32	0.77	0.71	0.95	1.00	1.21
Net exports/GDP	**0.37**	0.24	0.2	0.22	0.22	0.25	0.36	–
Autocorrelation								
Real exchange rate	**0.72**	0.53	0.68	0.48	0.6	0.46	0.26	−0.19
Domestic corr. with GDP								
Consumption	**0.87**	0.92	0.9	0.93	0.94	0.92	0.95	0.93
Hours worked	**0.75**	0.87	0.87	0.88	0.93	0.83	0.89	0.9
Labor wedge	**−0.27**	−0.59	−0.62	−0.58	−0.64	−0.55	−0.69	−0.71
Investment	**0.75**	0.83	0.84	0.85	0.79	0.84	0.78	0.57
Net exports/GDP	**−0.59**	−0.31	−0.37	−0.33	−0.32	−0.29	−0.49	–
International corr.								
GDP_{US}, GDP_{UK}	**0.76**	0.5	0.53	0.51	0.57	0.48	0.3	0.16
C_{US}, C_{UK}	**0.63**	0.57	0.61	0.54	0.62	0.55	0.39	−0.02
N_{US}, N_{UK}	**0.68**	0.58	0.54	0.63	0.63	0.58	0.41	−0.04
X_{US}, X_{UK}	**0.6**	0.03	0.12	0.11	0.04	0.02	−0.64	0.7
Backus-Smith correlations								
$C_{US}/C_{UK}, Z$	**−0.22**	−0.06	−0.18	0.05	−0.13	0.03	−0.47	0.94
$\Delta C_{US}/C_{UK}, \Delta Z$	**−0.11**	−0.58	−0.47	−0.53	−0.54	−0.56	−0.82	0.99
Non-binding constraints, in percent		10.3	11.33	10.22	8.28	12.4	8.83	21.04
Variance decomposition								
Percent of GDP explained by fin. shocks		38.37	40.49	37.22	44.33	34.31	55.48	52.62

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