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Net foreign asset positions and consumption dynamics in the international economy

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A B S T R A C T

We examine the effect of non-zero, steady-state foreign assets on consumption dynamics in response to productivity shocks in a two-country, dynamic, general equilibrium model. The model generates non-zero steady-state net foreign assets by allowing for different discount factors across countries. As a consequence of discounting differences, individual steady-state consumption profiles are tilted upward or downward. Worldwide shocks to long-run productivity levels lead to dynamics that are absent in standard, symmetric models with equal discount factors. We then compare the model results to those of a VAR in common trend representation for the U.S. versus the rest of the G7. In the data, we find that permanent worldwide productivity shocks lead to net foreign asset and consumption dynamics that are broadly consistent with interpreting the U.S. as the relatively impatient model economy and are not consistent with symmetric models with equal discount factors.

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1. Introduction

There is much interest in the literature in understanding the determinants and consequences of large international asset positions in the short and in the long-run.³ This paper investigates the effect of non-zero, long-run net foreign asset positions on consumption dynamics in the international economy. We do so by constructing a two-country, dynamic, general equilibrium model that generates such non-zero long-run net foreign asset positions starting from first principles. This is important, because we show that the same first principles that determine steady-state net foreign assets have important implications for the dynamics of the economy in response to shocks. We then take a fresh look at G7 data, focusing on the U.S. and treating the aggregate of the remaining G7 countries as the rest of the world. Overall, we find that our empirical evidence is consistent with the predictions of our theoretical model.

Specifically, our theoretical model allows for differences in discount factors across domestic and foreign households. As a consequence, the relatively more patient country runs a steady-state positive asset position relative to the other country. As in [Buiter \(1981\)](#) and [Weil \(1989a\)](#), the presence of overlapping generations ensures that the equilibrium does not collapse to the situation in which the patient country owns the entire world's wealth ([Becker's, 1980](#), result). Discounting differences across countries result in tilted steady-state consumption profiles for individual households. The consumption profiles of households in the relatively patient country display an upward tilt, whereas the consumption profiles of households in the relatively impatient country display a downward tilt. Because of consumption tilting, worldwide productivity shocks can lead to significant adjustments in net foreign assets, an effect that is absent in models with equal discount factors across countries, zero steady-state assets, and flat long-run consumption profiles. In response to a permanent, worldwide productivity increase, households in the relatively patient country accumulate assets, and aggregate per capita consumption reaches its new, higher steady-state level from below. Conversely, households in the impatient country accumulate debt, and aggregate per capita consumption reaches its new, higher steady-state level from above. Countries find it beneficial to engage in asset trade due to asymmetric income effects that stem from different discounting of future utility across countries and the implied tilt in the consumption profiles of individual households. By contrast, such dynamics are altogether absent in models with equal discount factors, as consumption jumps instantly to the new, symmetric steady state in both countries, with no movement in asset holdings following such a shock.

In our empirical work, we first identify a worldwide permanent productivity shock from a vector autoregression (VAR) consistent with our theoretical model. We do so by estimating the VAR in common trend representation after testing for and imposing model-consistent, long-run, cointegration restrictions of the type in [King et al. \(1991\)](#) and [Mellander et al. \(1992\)](#). We then compare the predictions of the theoretical model for consumption and net foreign asset dynamics to the estimated impulse responses following such permanent worldwide shock.

Our empirical analysis shows that, within our sample period, the estimated impulse responses differ across countries in a way that is broadly consistent with our theoretical framework: A positive, permanent worldwide productivity shock increases the foreign indebtedness of the U.S., while the rest of the G7 accumulates net foreign assets. Thus, while the U.S. exhibits the behavior of a less patient economy, the rest of the G7 emerges as a patient economy. Empirical consumption and interest rate responses are also broadly consistent with this interpretation of our theoretical model. We conclude that differences in discount factors leading to non-zero, long-run net foreign asset positions across countries and tilted consumption profiles can help explain consumption and net foreign asset dynamics observed in the data.

The empirical relevance of non-zero net foreign asset positions is documented by [Lane and Milesi-Ferretti \(2001\)](#), among others. They show that, as of 1997, about 41 percent of the industrial countries in their sample had net foreign liabilities in excess of 20 percent of GDP and about 14 percent had net foreign assets in excess of 20 percent of GDP. Similarly, approximately 65 percent of developing

³ For instance, see [Lane and Milesi-Ferretti \(2001, 2002a,b\)](#). [Obstfeld \(2006\)](#) provides a survey and discussion of recent literature.

countries had net foreign liabilities, and about 12 percent had net foreign assets above 20 percent of GDP. More importantly for the issues we address in this paper, they demonstrate that in many cases countries maintained large non-zero net foreign asset positions throughout the 1980s and 1990s.

The existing literature in international macroeconomics has explored several mechanisms that can pin down a non-zero long-run level of net foreign assets.⁴ Of these, the assumptions that households face a cost of adjusting bond holdings (originally introduced by Turnovsky, 1985) or that countries face a debt-elastic interest rate premium on external borrowing (Mendoza and Uribe, 2000, among others) have been most popular in the recent literature for their analytical convenience. Yet, these mechanisms do not pin down long-run foreign asset positions as a function of first principles – for instance, features of preferences and technology. Long-run assets are determined by the exogenously chosen level around which the bond adjustment cost function is centered or by the similarly exogenous centering of the function that defines the interest rate premium. As a consequence, these mechanisms cannot provide a structural interpretation of long-run net foreign asset positions. A contribution of this paper is to show that providing a structural interpretation of steady-state asset positions is important not only to understand the long-run properties of the economy, but also to interpret transitional dynamics in response to shocks in theory and data.

While a range of structural factors may be responsible for non-zero long-run net foreign asset positions (including differences in preferences, technology, demographics, creditworthiness, etc.), we focus on differences in subjective discount factors in the context of a highly simplified model, following Buiter (1981) and Weil (1989a), because this is sufficient for us to highlight both the role of non-zero long-run assets and the importance of a structural interpretation of long-run asset positions in explaining transitional dynamics. Small open economy models also routinely allow for differences in discount factors across countries when they assume that the discount factor of the representative domestic household differs from the market discount factor defined by the world interest rate. However, these models assume that the world interest rate is exogenous, whereas it is endogenous in our general equilibrium model.⁵

By focusing on different discount factors, this paper also complements a few other studies. Masson et al. (1994), in particular, look at heterogeneous demographic factors and fiscal policies to explain net foreign asset dynamics of Germany, Japan, and the U.S., with some success in explaining marked differences in dynamics across countries. Our theoretical and empirical framework differs from theirs in that we allow for full macroeconomic interdependence in general equilibrium. Henriksen (2002) calibrates a model with heterogeneous demographics to the U.S. and Japan and finds that the predicted paths of U.S. and Japanese current accounts are consistent with the data. We construct an empirical counterpart of a two-country model and estimate this empirical model using a larger set of countries. Kraay and Ventura (2000) study the differences in the responses of the current accounts of debtor and creditor countries to transitory changes in income, but they do not link the determination of initial asset positions and the resulting dynamics to specific structural features of the economies they consider.

The rest of the paper is organized as follows. Section 2 presents the theoretical model. Section 3 discusses the implications of differences in discount factors across countries in our model. Section 4 presents model-based impulse responses. Section 5 describes the econometric framework and reports the empirical findings. Section 6 concludes. The appendix contains a description of the data we use in the empirical analysis.

2. The theoretical model

The structure of our model is similar to that in Ghironi (2006), but here we allow for heterogeneity in household discount factors across countries.⁶

⁴ See Schmitt-Grohé and Uribe (2003) for a survey.

⁵ In a closed economy context, Krusell and Smith (1998) show that heterogeneity in household discount factors is important for their incomplete markets model with idiosyncratic uncertainty to match U.S. data.

⁶ Readers who are familiar with Ghironi (2006) may wish to review the main assumptions below and move directly to Section 3.

2.1. The main assumptions

Demographics and household behavior—The world consists of two countries, home and foreign. In each period t , the world economy is populated by a continuum of infinitely lived households between 0 and N_t^W . (A superscript W denotes world variables. Foreign variables are starred.) Each household consumes home and foreign goods, supplies labor, and holds financial assets. As in Weil (1989a,b), households are born on different dates *owning no assets*, but they own the present discounted value of their labor income. The number of households in the home economy, N_t , grows over time at the exogenous rate n , i.e., $N_{t+1} = (1+n)N_t$. We normalize the size of a household to 1, so that the number of households alive at each point in time is the economy's population. Foreign population grows at the same rate as home population. We assume that the world economy has existed since the infinite past and normalize world population at time 0 so that $N_0^W = 1$.

Households at home and abroad have perfect foresight, though they can be surprised by initial, unexpected shocks. Households maximize intertemporal utility functions. The period utility function in both countries is logarithmic in consumption of a CES world consumption basket and in the amount of labor effort supplied by the household. Domestic households have discount factor β , $0 < \beta < 1$. Foreign households have discount factor $\alpha\beta$, $0 < \alpha \leq 1$. When $\alpha < 1$, foreign households are more impatient than domestic households.⁷

Goods market and production—There are two goods in the world economy. Each country is fully specialized in the production of a country-specific good, performed by a continuum of atomistic, perfectly competitive, infinitely lived firms. Home firms, producing the home good, occupy the interval $[0, a]$; foreign firms, producing the foreign good, are in the range $(a, 1]$. Firms produce output using labor as the only factor of production according to a linear technology that is subject to multiplicative, country-wide productivity shocks.

Asset market—Households in both countries trade a riskless real bond denominated in units of the world consumption basket domestically and internationally.

2.2. Households

Consumers have identical preferences over a real consumption index (C) and leisure ($1 - L$, where L is labor effort supplied in a competitive labor market, and we normalize the endowment of time in each period to 1). At any time t_0 , the representative home consumer j born in period $v \in (-\infty, t_0]$ maximizes the intertemporal utility function:

$$U_{t_0}^{v,j} = \sum_{t=t_0}^{\infty} \beta^{t-t_0} \left[\rho \log C_t^{v,j} + (1-\rho) \log(1-L_t^{v,j}) \right], \quad (1)$$

with $0 < \rho < 1$.

The consumption index is $C_t^{v,j} = [a^{1/\omega} (C_{Ht}^{v,j})^{(\omega-1)/\omega} + (1-a)^{1/\omega} (C_{Ft}^{v,j})^{(\omega-1)/\omega}]^{\omega/(\omega-1)}$, where $\omega > 0$ is the intratemporal elasticity of substitution between consumption of domestic and foreign goods (C_H and C_F , respectively). Foreign agents consume an identical basket of goods. Trade in goods is free. There are no transportation and transaction costs.

The consumer enters a period holding bonds purchased in the previous period. He or she receives interest on these bond holdings, earns labor income, consumes, and purchases new bonds with which he or she will enter the next period. Letting $B_{t+1}^{v,j}$ denote the consumer's holdings of bonds entering $t+1$, the period budget constraint is:

$$B_{t+1}^{v,j} = (1+r_t)B_t^{v,j} + w_t L_t^{v,j} - C_t^{v,j}, \quad (2)$$

⁷ We use logarithmic utility for analytical tractability and, more importantly, because we intentionally choose to be conservative on the importance of wealth effects. These are amplified when steady-state assets are not zero, and they would be even stronger if the elasticity of intertemporal substitution were lower than 1. Assuming logarithmic utility allows us to focus more explicitly on the effect of tilts in consumption profiles generated by heterogeneous discounting.

where r_t is the risk-free world real interest rate between $t - 1$ and t , and w_t is the real wage, both in units of the consumption basket.⁸

The representative home consumer born in period v maximizes the intertemporal utility function (1) subject to the constraint (2). Dropping the j superscript (because symmetric agents make identical choices in equilibrium), optimal labor supply is given by:

$$L_t^v = 1 - \frac{1 - \rho}{\rho} \frac{C_t^v}{w_t}, \tag{3}$$

which equates the marginal cost of supplying labor to the marginal utility of consumption generated by the corresponding increase in labor income.

The first-order condition for optimal holdings of bonds yields the Euler equation:

$$C_t^v = \frac{1}{\beta(1 + r_{t+1})} C_{t+1}^v, \tag{4}$$

for all $v \leq t$.

As usual, first-order conditions and the period budget constraint must be combined with the appropriate transversality condition (omitted) to ensure optimality.

Foreign consumers maximize a similar intertemporal utility function and are subject to an analogous budget constraint as home consumers. The only difference is that the discount factor of foreign households is $\alpha\beta$. Otherwise, a similar labor–leisure tradeoff, Euler equation, and transversality condition hold for foreign households.

2.3. Firms

Output supplied at time t by the representative home firm i is a linear function of labor demanded by the firm⁹:

$$Y_t^{Si} = Z_t L_t^i, \tag{5}$$

where Z_t is exogenous, economy-wide productivity. Production by the representative foreign firm is a linear function of L_t^{*i} , with productivity Z_t^* .

Output demand comes from domestic and foreign consumers. The demand for firm i by the representative domestic household born in period v is $C_{Hit}^v = (RP_t)^{-\omega} C_t^v$, obtained by maximizing C subject to a spending constraint. We denote with RP_t the price of the home good in units of consumption. Atomistic, competitive home firms take this price as given. Aggregating across home households alive at time t , total demand for firm i coming from domestic consumers is $C_{Hit} = (RP_t)^{-\omega} a(1 + n)^t c_t$, where

$$c_t \equiv \frac{a \left[\dots \frac{n}{(1 + n)^{t+1}} C_t^{-t} + \dots + \frac{n}{(1 + n)^2} C_t^{-1} + \frac{n}{1 + n} C_t^0 + n C_t^1 + n(1 + n) C_t^2 \right]}{a(1 + n)^t}$$

is aggregate per capita home consumption of the composite consumption basket.

Given identity of preferences across countries, total demand for firm i by foreign consumers is $C_{Hit}^* = (RP_t)^{-\omega} (1 - a)(1 + n)^t c_t^*$, where c_t^* is aggregate per capita foreign consumption, the definition of

⁸ Given that individuals are born owning no financial wealth, because they are not linked by altruism to individuals born in previous periods, $B_v^v = 0$. As noted before, however, individuals are born owning the present discounted value of their labor income.

⁹ Because all firms in the world economy are born at $t = -\infty$, after which no new firms appear, it is not necessary to index output and labor demands by the firms' date of birth.

which is similar to that of c_t . (Absence of transportation and transaction costs implies that the price of the home good in units of consumption is the same at home and abroad.)

Total demand for home firm i is obtained by adding the demands originating in the two countries:

$$Y_t^{Di} = (RP_t)^{-\omega} \hat{c}_t^W, \tag{6}$$

where \hat{c}_t^W is aggregate (as opposed to aggregate per capita) world demand of the composite good: $\hat{c}_t^W \equiv N_t c_t + N_t^* c_t^*$.¹⁰

Perfect competition results in prices equal to marginal costs, so that:

$$RP_t = \frac{w_t}{Z_t}. \tag{7}$$

Using the market clearing conditions $Y_t^{Si} = Y_t^{Di}$, $\hat{c}_t^W = \hat{Y}_t^{SW} = \hat{Y}_t^{DW} (= \hat{Y}_t^W)$, and the expressions for firm i 's supply and demand, labor demand can be written as:

$$L_t^i = RP_t^{-\omega} \frac{\hat{Y}_t^W}{Z_t}. \tag{8}$$

Ceteris paribus, firm i 's labor demand is a decreasing function of real output price and productivity. It is an increasing function of world consumption demand. Optimal behavior by foreign firms results in similar price and labor demand equations.¹¹

2.4. Aggregation

2.4.1. Households

We present only the equations for the home economy here. Equations for foreign are similar, except for variables being starred and β replaced by $\alpha\beta$.

Aggregate per capita labor supply equations are obtained by aggregating labor–leisure tradeoff equations across generations and dividing by total population at each point in time. The aggregate per capita labor–leisure tradeoff is:

$$L_t = 1 - \frac{1 - \rho}{\rho} \frac{c_t}{w_t}. \tag{9}$$

Aggregate labor supply rises with the real wage and decreases with consumption.

The consumption Euler equation in aggregate per capita terms features an adjustment for consumption by the newborn generation at time $t + 1$:

$$c_t = \frac{1 + n}{\beta(1 + r_{t+1})} \left(c_{t+1} - \frac{n}{1 + n} c_{t+1}^{t+1} \right). \tag{10}$$

The adjustment for consumption of newborn generations at $t + 1$ in the Euler equations for aggregate per capita consumption ensures steady-state determinacy and provides the degree of freedom necessary for existence of a well defined, *non-degenerate* steady state when discount factors differ across countries.

Newborn households hold no assets, but they own the present discounted value of their labor income. Using the Euler equation (4) and a newborn household's intertemporal budget constraint, it is possible to show that the household's consumption in the first period of its life is a fraction of its human wealth, h :

¹⁰ Where necessary for clarity, we use a "hat" to differentiate the aggregate level of a variable from the aggregate per capita level.

¹¹ Although all firms in each country demand the same amount of labor in equilibrium, we leave the i superscript on labor demand to differentiate labor employed by an individual firm from aggregate per capita employment, which will be denoted by dropping the superscript.

$$C_t^t = \rho(1 - \beta)h_t, \tag{11}$$

where h is defined as the present discounted value of the households' lifetime endowment of time in terms of the real wage: $h_t \equiv \sum_{s=t}^{\infty} R_{t,s} w_s$, with $R_{t,s} \equiv \left[\prod_{u=t+1}^s (1 + r_u) \right]^{-1}$, $R_{t,t} \equiv 1$. The dynamics of h are determined by:

$$h_t = \frac{h_{t+1}}{1 + r_{t+1}} + w_t. \tag{12}$$

Aggregating the budget constraint (2) across generations alive at each point in time yields the law of motion for home's aggregate per capita net foreign assets:

$$(1 + n)B_{t+1} = (1 + r_t)B_t + w_t L_t - c_t. \tag{13}$$

A similar equation holds for B_{t+1}^* . For the bond market to be in equilibrium, aggregate home assets (liabilities) must equal aggregate foreign liabilities (assets), i.e., it must be $\widehat{B}_t + \widehat{B}_t^* = 0, \forall t$. In aggregate per capita terms, it must be:

$$aB_t + (1 - a)B_t^* = 0. \tag{14}$$

2.4.2. Firms

Aggregate per capita output in units of consumption in each economy is obtained by expressing each firm's production in units of the world basket, multiplying by the number of firms, and dividing by population. It is:

$$y_t = RP_t Z_t L_t. \tag{15}$$

For given employment and productivity, each country's real GDP rises with the relative price of the good produced in that country, as this is worth more units of the consumption basket. Eqs. (7) and (15) imply that GDP is equal to labor income, or $y_t = w_t L_t$.

Aggregate per capita labor demand is:

$$L_t = RP_t^{-\omega} \frac{y_t^W}{Z_t}, \tag{16}$$

where y_t^W is aggregate per capita world production of the composite good, equal to aggregate per capita world consumption, c_t^W . It is $y_t^W = ay_t + (1 - a)y_t^*$ and $c_t^W = ac_t + (1 - a)c_t^*$, $y_t^W = c_t^W$ to ensure market clearing.¹²

3. The implications of heterogeneous discounting

3.1. Steady state

In this subsection we summarize the main features of the solution for the steady state of our model, denoting steady-state levels of variables with overbars.¹³

It is known, at least since Becker (1980), that a standard representative agent model with identical discount factors across agents (i.e., $n = 0, \alpha = 1$) results in indeterminacy of the steady-state distribution of net foreign assets. This happens because the representative agent model features no connection between consumption growth and assets in the Euler equation for aggregate per capita consumption,

¹² Substituting $y_t = w_t L_t$ into Eq. (13) and using the resulting equation and its foreign counterpart in conjunction with Eq. (14) yields $y_t^W = c_t^W$: Consistent with Walras' Law, asset market equilibrium implies goods market equilibrium, and vice versa.

¹³ Details of the solution for the steady state of our model, as well as any other technical detail or result not reported in this version of the paper, are available from the authors on request.

as can be easily seen by setting $n = 0$ in Eq. (10). As a consequence, setting consumption to be constant in steady state only pins down the steady-state interest rate, but provides no restriction to determine steady-state assets. If discount factors differ across agents with no other modification to the standard model ($n = 0$, $\alpha < 1$), the distribution of wealth across agents ends up collapsing into one in which the most patient household owns all the wealth. The impatient household's consumption converges to zero asymptotically, and the patient one's diverges to infinite. Buiter (1981) and Weil (1989a) demonstrated that models with overlapping generations in which households are not linked by intergenerational altruism can deliver a non-degenerate distribution of asset holdings across countries. Our model achieves precisely the same goal by assuming $n > 0$ and absence of intergenerational linkages in the form of altruism or government transfers.

In particular, the presence of consumption by a newborn generation at time $t + 1$ in the aggregate Euler equation (10) when $n > 0$ is central to the model's ability to pin down a unique steady-state level of assets under our assumptions. Because households are born with no assets, their consumption in the first period of life is a function only of their human wealth. But this also determines a household's initial choice of asset accumulation. Hence, a link is introduced between aggregate per capita consumption growth and asset accumulation in the aggregate Euler equation. The link operates through the discrepancy between assets of agents already alive at each point in time and assets of newborn agents (zero). It is through this link that a unique steady-state level of aggregate per capita net foreign assets is determined, and it is through the same link that the economy returns to this steady state following temporary shocks: Entry of new households with no assets eventually "wipes out" the effects of shocks on aggregate per capita variables because the proportion of households that enter after the shock becomes progressively larger relative to those who are already alive at the time of the shock.¹⁴ This mechanism to ensure steady state determinacy and stationarity operates regardless of heterogeneity in discount factors across countries. In particular, the mechanism ensures that long-run aggregate per capita consumption remains strictly positive in the impatient economy and finite in the patient one: Even if consumption of individual impatient households approaches zero asymptotically as their age tends to infinite along the steady-state path, entry in each period of progressively larger cohorts of newborn households with strictly positive consumption (function of human wealth at birth) ensures that long-run aggregate per capita consumption remains constant and bounded away from zero. Similarly, entry of progressively larger cohorts of new households with finite consumption in the patient country keeps aggregate per capita consumption constant and finite. In turn, this implies a non-degenerate long-run distribution of aggregate per capita assets across countries.¹⁵

To demonstrate the influence of differences in discounting across countries, we start with the special case in which all preference parameters are identical across domestic and foreign households ($\alpha = 1$) but initial steady-state productivity levels \bar{Z} and \bar{Z}^* may differ (possibly as a consequence of previous, asymmetric, permanent movements in productivity).¹⁶

When $\alpha = 1$, steady-state levels of labor effort are identical across countries ($\bar{L}/\bar{L}^* = 1$), and net foreign assets are zero ($\bar{B} = \bar{B}^* = 0$), regardless of relative productivity (\bar{Z}/\bar{Z}^*). This happens because, when consumers' intertemporal preferences are identical at home and abroad, given a common world interest rate, households in the two countries have identical incentives to borrow or lend. (The desired slope of the consumption profile is the same for each domestic and

¹⁴ Alternative mechanisms for pinning down steady-state assets and ensuring stationary responses to temporary shocks explored in the literature (such as costs of adjusting asset holdings, endogenous discount factors, or debt-elastic interest rate premia) all operate in similar fashion by introducing a connection between consumption growth and assets in the Euler equation.

¹⁵ See Ghironi (2006) for additional details on the working of the overlapping-generations model in the case $\alpha = 1$.

¹⁶ We will consider the consequences of shocks to home and foreign productivity starting from initial steady-state levels \bar{Z} and \bar{Z}^* below. Although we shall argue that differences in discounting are the fundamental source of structural heterogeneity across countries in our model, we allow initial steady-state levels of productivity to differ for calibration purposes, as this will make it possible for our benchmark calibration to reproduce features of average data for the economies we consider in our empirical work.

foreign household.) In this case, the only possible steady-state equilibrium is one in which $\bar{r} = (1 - \beta)/\beta$ and net foreign assets are zero even if $\bar{Z}/\bar{Z}^* \neq 1$. If $\alpha = 1$ and $\bar{Z}/\bar{Z}^* \neq 1$, domestic and foreign GDPs in units of consumption differ ($\bar{y} \neq \bar{y}^*$), and so do consumption levels ($\bar{c} \neq \bar{c}^*$), but consumption equals GDP in each country, so that net foreign assets are zero. Since $\bar{y} = \bar{w}\bar{L}$ and $\bar{y}^* = \bar{w}^*\bar{L}^*$, $\bar{L} = \bar{L}^*$ when $\alpha = 1$ implies that the different GDP levels generated by different productivity levels translate into different real wages and labor incomes across countries.¹⁷ In particular, the more productive country has a higher steady-state real wage and consumption and a lower relative price for the same labor effort as the less productive country.¹⁸

In the general case $\alpha < 1$, we can write the solution for \bar{r} , \bar{B} , and cross-country ratios of any pair of other endogenous variables \bar{x} and \bar{x}^* as functions of the steady-state productivity ratio \bar{Z}/\bar{Z}^* . The characteristics of these functions depend on the values of structural parameters, and the steady-state levels of \bar{r} , \bar{B} , and other endogenous variables can be obtained numerically given assumptions on \bar{Z} and \bar{Z}^* .¹⁹ Consider the following two examples:

1. If $\alpha < 1$ and $\bar{Z} = \bar{Z}^* = 1$, a wide range of plausible parameterizations yields $\bar{B} > 0$ ($\bar{B}^* < 0$), $\bar{c} > \bar{c}^*$, $\bar{L} < \bar{L}^*$, $\bar{w} > \bar{w}^*$, $\bar{R}P > \bar{R}P^*$, $\bar{y} < \bar{y}^*$. If domestic agents are more patient than foreign, they accumulate steady-state assets, which make it possible to sustain relatively higher consumption with a smaller labor effort. Lower labor supply generates a higher equilibrium real wage and relative price. The labor effort differential prevails on the relative price differential in generating lower GDP at home than abroad, where higher GDP is required to pay interest on the accumulated debt.
2. If $\alpha < 1$ and $\bar{Z} = 1$ is sufficiently smaller than \bar{Z}^* , the same plausible parameter values as in Example 1 yield $\bar{B} > 0$ ($\bar{B}^* < 0$), $\bar{c} < \bar{c}^*$, $\bar{L} < \bar{L}^*$, $\bar{w} < \bar{w}^*$, $\bar{R}P > \bar{R}P^*$, $\bar{y} < \bar{y}^*$. Sufficiently higher productivity in the more impatient country causes the steady-state real wage differential to switch sign, so that the real wage is now higher in the foreign economy. This induces foreign agents to consume more, and their consumption rises above that of domestic agents, with an increase in the size of the foreign economy's debt.

Heterogeneity in discounting across countries implies the presence of tilts in the steady-state consumption and labor effort profiles of *individual* households at home and abroad. To see this, observe that, when $\alpha < 1$, $\beta(1 + \bar{r}) > 1$ and $\alpha\beta(1 + \bar{r}) < 1$. In conjunction with the Euler equation (4) and its foreign counterpart, this implies that the steady-state consumption profiles of individual home households display an upward tilt, whereas there is a downward tilt in the steady-state consumption profiles of foreign households. The Euler equation and the labor–leisure tradeoff for an individual household make it possible to verify that the steady state is also characterized by a downward (upward) tilt in the labor effort of individual home (foreign) households.²⁰

The tilt of individual consumption profiles determines whether a country is a steady-state creditor or debtor. The intuition is simple: Given a constant real wage, the only way for home households to sustain an increasing consumption profile with decreasing labor effort is by accumulating assets. Since there is no home household with negative financial assets in steady state, home aggregate per capita net foreign assets must be positive. As we shall see, the tilt of steady-state individual consumption profiles has important consequences also for the dynamics of the economy in response to shocks.

¹⁷ We assume that labor does not move across countries. Given a steady-state real wage differential, we motivate absence of long-run labor flows by appealing to the presence of prohibitive costs of relocating abroad that more than offset the welfare differential implied by differences in real wages.

¹⁸ If $\alpha = 1$ and $\bar{Z} = \bar{Z}^* = 1$, the steady state is symmetric in all respects: $\bar{r} = (1 - \beta)/\beta$, $\bar{B} = \bar{B}^* = 0$, $\bar{c} = \bar{c}^* = \bar{L} = \bar{L}^* = \bar{y} = \bar{y}^* = \rho$, $\bar{w} = \bar{w}^* = \bar{R}P = \bar{R}P^* = 1$. See Ghironi (2006) for the details of the solution in this case.

¹⁹ For the reasons discussed above, the functions are such that, if $\alpha = 1$, it is $\bar{B} = 0$, $\bar{L}/\bar{L}^* = 1$ and $\bar{c}/\bar{c}^* \geq 1$ if $\bar{Z} \geq \bar{Z}^*$.

²⁰ As we noted above, the entry of new households with no assets in each period ensures that aggregate per capita consumption and labor effort are constant even if consumption (labor effort) is increasing (decreasing) relative to the previous period for each individual home household in steady state, and opposite tilts characterize foreign households.

3.2. Dynamics

The aggregate model of Section 2.2 can be safely log-linearized around the steady state. The assumptions that $n > 0$ and newborn households enter the economy with no assets generate stationary dynamics following non-permanent shocks because the steady state is uniquely determined.²¹

We solve the log-linear model with the method of undetermined coefficients following Campbell (1994). In what follows, we use sans serif fonts to denote percent deviations from the steady state and focus on the model solution in terms of the minimum state vector, which at time t consists of the predetermined levels of net foreign assets and the (gross) risk-free real interest rate (the endogenous states) and the current levels of domestic and foreign productivity (the exogenous states), i.e., $[B_t, r_t, Z_t, Z_t^*]'$.²² The solution of the model can then be written as $[B_{t+1}, r_{t+1}, x_t', x_t^{*'}] = \Xi[B_t, r_t, Z_t, Z_t^*]'$, where x_t (x_t^*) is a (column) vector of endogenous, non-state, home (foreign) variables and Ξ is a matrix of elasticities of endogenous variables to the endogenous and exogenous components of the state vector.

In the solution, we assume that productivity levels at home and abroad obey AR(1) processes in all periods after the time of an initial impulse ($t=0$ in the impulse responses below): $Z_t = \phi Z_{t-1}$, $Z_t^* = \phi Z_{t-1}^*$, $0 \leq \phi \leq 1$. Of course, if $\phi = 1$, impulses to productivity cause the economy to eventually settle at a new steady state that differs from the initial one.

Two important implications for off-steady-state dynamics emerge from our model. First, non-zero steady-state net foreign assets introduce an additional channel through which the past history of the economy matters for current dynamics relative to the model with zero steady-state assets. The predetermined, risk-free interest rate is an additional state variable in the solution. The intuition is simple. If steady-state net foreign assets are zero (if $\alpha = 1$), the effect of the interest burden on previously accumulated debt is lost in the log-linearization of the laws of motion for domestic and foreign net foreign assets. This is no longer the case when steady-state assets differ from zero. Thus, the effect of net foreign asset accumulation on cross-country differences in the levels of other endogenous variables is amplified relative to a model with zero steady-state net foreign assets.

Second, worldwide productivity shocks – which have no impact on the current account in the symmetric version of the model – affect net foreign asset accumulation. This is reflected in the impossibility to write the deviation of net foreign assets from the steady-state as a function of the cross-country productivity differential. The effect of worldwide shocks on asset accumulation comes through various channels: The tilts in the consumption profiles of individual households described above trigger asset trade for given world interest rate as a consequence of heterogeneous discounting of future utility. In turn, the resulting differences in consumption dynamics across countries generate differences in relative price and GDP movements. Finally, if the shocks are not permanent, they also affect the world interest rate and the interest rate burden (or income) on previously accumulated assets, further altering the current account.

4. Impulse responses

In this section, we discuss heterogeneity in dynamics after productivity shocks using the impulse responses implied by a plausible parameterization of the model. This helps us build intuition to interpret the empirical responses in Section 5.

4.1. Parameterization

We interpret periods as quarters and choose the following benchmark parameter values: $\beta = 0.99$ (a standard choice), $\alpha = 0.9999$ (so that the foreign discount factor is 0.9899), $\omega = 3$, $\rho = 0.33$, $a = 0.5$ (countries have equal size), $n = 0.01$, $\bar{Z} = 1$, and $\bar{Z}^* = 1.29$.

²¹ In the representative agent model with $n = 0$, the consumption differential across countries is a random walk, and all shocks have permanent consequences via wealth redistribution regardless of their temporary or permanent nature.

²² Ghironi (2006) shows that the log-linear model has a unique solution when $\alpha = 1$ and steady-state productivities are equal across countries. While we cannot verify determinacy analytically when the steady state is asymmetric, we do not find an excessive number of stable roots when solving the model numerically.

We choose α very close to 1 because even small differences between the foreign and home discount factors result in very large steady-state net foreign asset positions in the model of this paper. To avoid overstating the effect of non-zero steady-state assets, we choose a value of α such that the long-run ratio of debt to quarterly GDP for the foreign economy is approximately 35 percent on an annualized GDP basis. The value of ω is in (the lower portion of) the range of estimation results from the trade literature on the U.S. and OECD countries (Feenstra, 1994; Harrigan, 1993; Lai and Trefler, 2002; Shiells et al., 1986).²³ The choice of ρ implies that households in both countries spend one third of their time working in the symmetric steady-state world. Our benchmark parameter values are plausible for G7 countries.²⁴ If we think of the U.S. as the relatively impatient country, consistent with the evidence in favor of a lower propensity to save for U.S. households relative to European and Asian ones, our data suggest that the labor productivity gap between the U.S. and the rest of the G7 has been approximately 30 percent. We discuss the consequences of different values for α , ω , and the ratio \bar{Z}/\bar{Z}^* below.

The benchmark parameter values above result in the steady-state configuration of Example 2 above, which is consistent with several stylized facts for the U.S. vis-à-vis the rest of the G7: $\bar{B} > 0$ ($\bar{B}^* < 0$), $\bar{c} < \bar{c}^*$, $\bar{L} < \bar{L}^*$, $\bar{w} < \bar{w}^*$, $\bar{R}P > \bar{R}P^*$, $\bar{y} < \bar{y}^*$. Relative consumer impatience causes the model-U.S. economy to accumulate a steady-state debt against the rest of the world. Nevertheless, higher productivity results in higher real wage, GDP, consumption, and labor effort (the latter is higher than abroad for the need to pay interest on the accumulated debt). Larger U.S. GDP comes with a lower price of U.S. goods relative to the patient economy (home). Numerical values for the steady-state levels of variables are in Table 1, which also displays the values of the elasticities of endogenous variables to the state vector in the log-linear model solution. (Elasticities to productivity depend on the persistence of shocks, ϕ . We assume $\phi = 1$ below.)

4.2. A permanent world productivity shock

We focus on the case of a permanent increase in world productivity because this is where the implications of our model are most striking for the parameter values above.²⁵

In the familiar symmetric model with zero steady-state net foreign assets, a permanent increase in world productivity results in no movement in net foreign assets. GDP, the real wage, and consumption in both countries increase immediately by the full amount of the shock. There are no changes in labor effort, relative prices, and the terms of trade (RP_t/RP_t^*). Anticipating the permanent consequences of the shock, agents in both countries simply find it optimal to consume the entire consumption value of the increase in productivity in all periods without adjusting their labor effort.²⁶

In contrast, asymmetry of the steady-state results in interesting dynamics following a permanent shock to world productivity. This is illustrated in Fig. 1, which shows the impulse responses to a 1 percent, permanent increase in productivity at home and abroad (i.e., $\phi = 1$).

The home economy accumulates assets over time in response to the shock, the foreign economy accumulates debt. Eventually, the increase in home assets (foreign debt) converges to an amount equal to the increase in world productivity. A permanent productivity shock has no effect on the risk-free interest rate.²⁷ It follows that the dynamics in Fig. 1 do not originate in the effect of changes in the

²³ Chironi (2006) shows that lower (higher but finite) values of ω reduce (amplify) the elasticities of cross-country differentials to net foreign asset accumulation in the symmetric version of the model. Consistent with Cole and Obstfeld (1991) and Corsetti and Pesenti (2001), there is no role for asset accumulation if $\omega = 1$ and steady-state assets are zero.

²⁴ Although the average rate of quarterly population growth for the U.S. between 1973:1 and 2000:3 has been 0.0025, extending the model to incorporate probability of death as in Blanchard (1985) would make it possible to reproduce the dynamics generated by $n = 0.01$ with a lower rate of entry of new households by choosing the proper value of the probability of death. The choice of $n = 0.01$ thus mimics the behavior of a more complicated, yet largely isomorphic setup.

²⁵ Theoretical and empirical impulse responses to transitory, country-specific shocks are available from the authors.

²⁶ In the case of a permanent asymmetric shock—say, to home productivity—net foreign assets do not move, as home agents still find it optimal to consume the entire value of the shock in all periods without changing their labor effort. However, consumption and GDP increase by less than the shock, because the terms of trade of the home economy deteriorate due to the relative increase in the supply of home goods. See Chironi (2006) for details.

²⁷ It can be shown that, if α is close to 1 and steady-state home labor effort is close to foreign (a condition that is satisfied in our example), the solution for the risk-free, world interest rate can be written approximately as $r_{t+1} \approx -a(\bar{w}/\bar{w}^W)(1-\phi)Z_t - (1-a)(\bar{w}^*/\bar{w}^W)(1-\phi)Z_t^*$. Therefore, permanent shocks have no effect on the interest rate.

Table 1

The benchmark solution

Steady-state levels				
$\bar{r} = 0.01015554120$,	$\bar{B} = 0.5588806661$			
$\bar{L} = 0.3299443011$,	$\bar{L}^* = 0.3300470075$			
$\bar{w} = 1.045291364$,	$\bar{w}^* = 1.238564933$			
$\bar{y} = 0.3448879285$,	$\bar{y}^* = 0.4087846498$			
$\bar{c} = 0.3449748265$,	$\bar{c}^* = 0.4086977516$			
Elasticities				
	B_t	r_t	$\phi = 1$	
			Z_t	Z_t^*
B_{+1}	0.9924	0.9924	0.0039	0.0037
r_{t+1}	0.0000	0.0000	0.0000	0.0000
RP_t	0.0028	0.0028	-0.1823	0.1794
RP_t^*	-0.0024	-0.0024	0.1538	-0.1514
L_t	-0.0085	-0.0085	0.0044	0.0041
L_t^*	0.0072	0.0072	-0.0037	-0.0035
w_t	0.0028	0.0028	0.8177	0.1794
w_t^*	-0.0024	-0.0024	0.1538	0.8486
h_t	0.0017	0.0017	0.8200	0.1784
h_t^*	-0.0013	-0.0013	0.1549	0.8465
y_t	-0.0057	-0.0057	0.8222	0.1835
y_t^*	0.0048	0.0048	0.1501	0.8451
c_t	0.0070	0.0070	0.8156	0.1774
c_t^*	-0.0059	-0.0059	0.1556	0.8504

interest rate on the burden of (income from) the initial steady-state debt (assets).²⁸ Home and foreign households find it beneficial to engage in further asset trade without changes in the interest rate due to asymmetric income effects that stem from different discounting of future utility across countries and the implied tilt in the consumption profiles of individual households.

To see this, note that, after a permanent productivity shock that has no effect on the world interest rate, the home current account is determined by:

$$CA_t = w_t - \tilde{w}_t + \frac{\beta(1 + \bar{r}) - 1}{1 + \bar{r}} W_t, \quad (17)$$

where \tilde{w}_t is the annuity value of the real wage at the steady-state interest rate \bar{r} ($\tilde{w}_t \equiv (\bar{r}/(1 + \bar{r})) \sum_{s=t}^{\infty} (1/(1 + \bar{r}))^{s-t} w_s$), and W_t is beginning-of-period aggregate per capita wealth at the interest rate \bar{r} ($W_t \equiv (1 + \bar{r}) B_t + \sum_{s=t}^{\infty} (1/(1 + \bar{r}))^{s-t} w_s$). The foreign current account obeys a similar equation, with $\alpha\beta$ replacing β , and it satisfies the constraint $aCA_t + (1 - a)CA_t^* = 0$. The term $w_t - \tilde{w}_t$ in Eq. (17) captures the effect of consumption smoothing. If the real wage is above its permanent level and is expected to decline, consumption smoothing pushes the current account into surplus. The term $((\beta(1 + \bar{r}) - 1)/(1 + \bar{r}))W_t$ captures the effect of consumption tilting. Relative patience of home households implies an upward tilt in individual household consumption profiles since $\beta(1 + \bar{r}) > 1$. Therefore, *ceteris paribus*, consumption tilting contributes to home current account surplus. Conversely, the downward tilt of foreign household consumption profiles implied by $\alpha\beta(1 + \bar{r}) < 1$ pushes the foreign current account in the direction of deficit.

At time 0, when the shock happens, home wealth W unambiguously increases, because the real wage w increases in all periods. Given $\beta(1 + \bar{r}) > 1$, this tends to increase the home current account through the consumption tilting channel. However, the path of the home real wage in Fig. 1 is

²⁸ Notice that this does not detract from the observation we made in the Introduction that endogeneity of the interest rate is among the features that differentiate our model from small open economy models that assume heterogeneous discounting but an exogenous world interest rate. This is so because, even if the interest rate remains at its steady-state level after permanent shocks, the steady-state interest rate is endogenous and such that $1/\beta < 1 + \bar{r} < 1/(\alpha\beta)$.

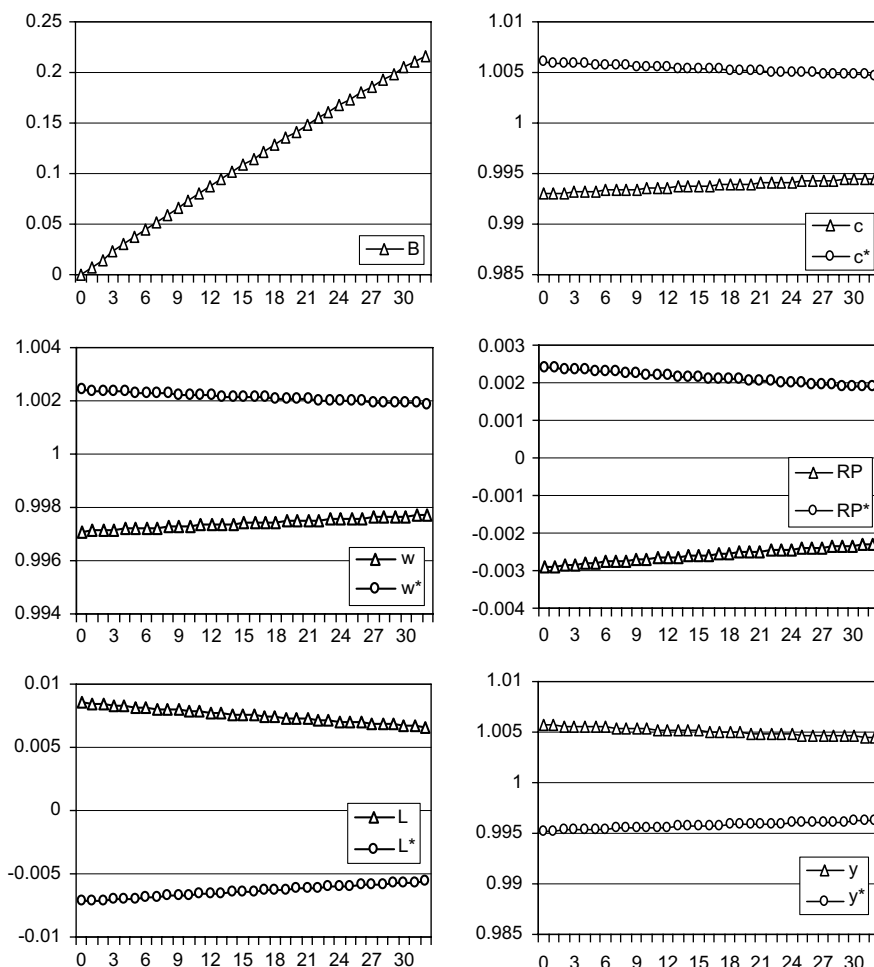


Fig. 1. Permanent world productivity shock, benchmark.

increasing over time. Therefore, the consumption smoothing channel in Eq. (17) would dictate that the home current account should worsen. What we observe is an improvement in home's net foreign asset position, i.e., an increase in home's current account above the steady state. Based on Eq. (17), this is driven by the fact that the consumption tilting channel prevails on the pure smoothing one. The steady-state incentive of home households to postpone consumption implicit in the upward tilt of individual home consumption profiles results in home households lending more than in the initial steady state. Conversely, the relative impatience of foreign consumers induces them to anticipate consumption and borrow more against their permanently higher human wealth.

Consistent with different incentives to postpone or anticipate consuming, consumption increases in both countries at time 0, but it does so by less than the full amount of the productivity shock at home and by more in the foreign economy. Consumption then increases over time in the home economy and decreases abroad, as foreign households must pay interest on an increasing debt. In the long-run, the consumption increase in both the home and foreign countries reflects the full amount of the world shock.

Different consumption responses to the shock generated by relative patience versus impatience and their general equilibrium consequences for labor effort and real wages motivate different short-run relative price movements across countries. The relative price of home goods falls, because the home

real wage does not increase as much as productivity on impact, while the relative price of foreign goods rises, yielding a deterioration of home's terms of trade. Relative prices return to the initial steady state over time. There is no long-run effect of the permanent change in asset positions on relative prices because the permanent, worldwide productivity shock eventually results in GDP and consumption increases of the same size as the shock both at home and abroad.

Equilibrium labor effort increases at home (decreases abroad), reflecting the expansionary (contractionary) effect of a lower (higher) relative price on labor demand. After the initial jump, labor effort slowly returns to the original steady state in both countries. The real wage increases on impact at home and abroad. It increases by more than productivity in the foreign economy, which explains the increase in the foreign relative price, and the decrease in equilibrium labor effort in the foreign country. Both the domestic and the foreign real wages converge over time to a higher steady-state level that reflects the full amount of the world productivity shock. Like consumption, the domestic real wage increases over time, while the foreign real wage decreases.

GDP also increases in both countries. As for consumption, in the long-run, the increase reflects the full amount of the world shock, since both relative prices and labor effort return to their original levels. In the short-run, GDP increases by more in the patient, less productive economy (home) and then decreases toward the new steady-state level. Foreign GDP increases over time. Therefore, changes in labor effort prevail on relative price movements in determining the direction of GDP changes.

The key for the dynamics in Fig. 1 is the difference in consumption responses implied by patience versus impatience, the lending and borrowing that this generates, and the adjustment of relative prices and the terms of trade that takes place as a consequence. When households in different countries capitalize wealth effects differently due to heterogeneity in subjective discount factors, long-run consumption differs from long-run labor income in each country, and even symmetric, permanent productivity shocks end up redistributing demand across countries in a way that induces agents to adjust their labor effort over time rather than keeping it unchanged. Consumption tilting then results in accumulation of assets (or debt) during the transition dynamics. In the long-run, the foreign economy has a permanently larger debt—and its new long-run consumption and GDP levels remain higher than those at home, as in the initial steady state.

4.3. Sensitivity analysis

We consider four alternative parameterizations to verify the robustness of the results in Fig. 1. In Scenario 1, we remove the steady-state productivity differential and let $\bar{Z} = \bar{Z}^* = 1$; in Scenario 2, we return to $\bar{Z} = 1 < \bar{Z}^* = 1.29$, but consider a lower value of α , equal to 0.999; in Scenario 3, we return to $\alpha = 0.9999$ and keep $\bar{Z} = 1 < \bar{Z}^* = 1.29$, but assume $\omega = 1.5$, in line with the international real business cycle literature (for instance, Backus et al., 1994); finally, in Scenario 4, we assume $\alpha = 0.9999$, $\bar{Z} = \bar{Z}^* = 1$, and $\omega = 1.5$.

The impulse responses after a 1 percent permanent increase in world productivity for these scenarios are in Fig. 2, which reproduces also those for the benchmark parameterization (Scenario B) to facilitate comparison. The qualitative pattern of the responses is the same in all scenarios, and it is driven by the same intuitions. The impulse responses are also very similar on quantitative grounds. Only Scenario 2 deviates significantly from the benchmark, because the lower value of α accentuates the tilts in consumption profiles that are responsible for the dynamics in the figure. Even in Scenario 4, very small heterogeneity in discounting and a value of ω that is not much different from 1 still deliver dynamics that are quantitatively similar to those of the benchmark case. We conclude from this analysis that the consequences of heterogeneous discounting are robust to our assumptions on initial steady-state productivity and substitutability across home and foreign goods.

5. Empirical analysis

In this section, we provide empirical evidence in support of our theoretical model of consumption and net foreign asset dynamics with different discount factors. Specifically, we estimate impulse responses of key endogenous variables to a worldwide, permanent productivity shock and compare them with those of the theoretical model. We focus on worldwide, permanent productivity shocks

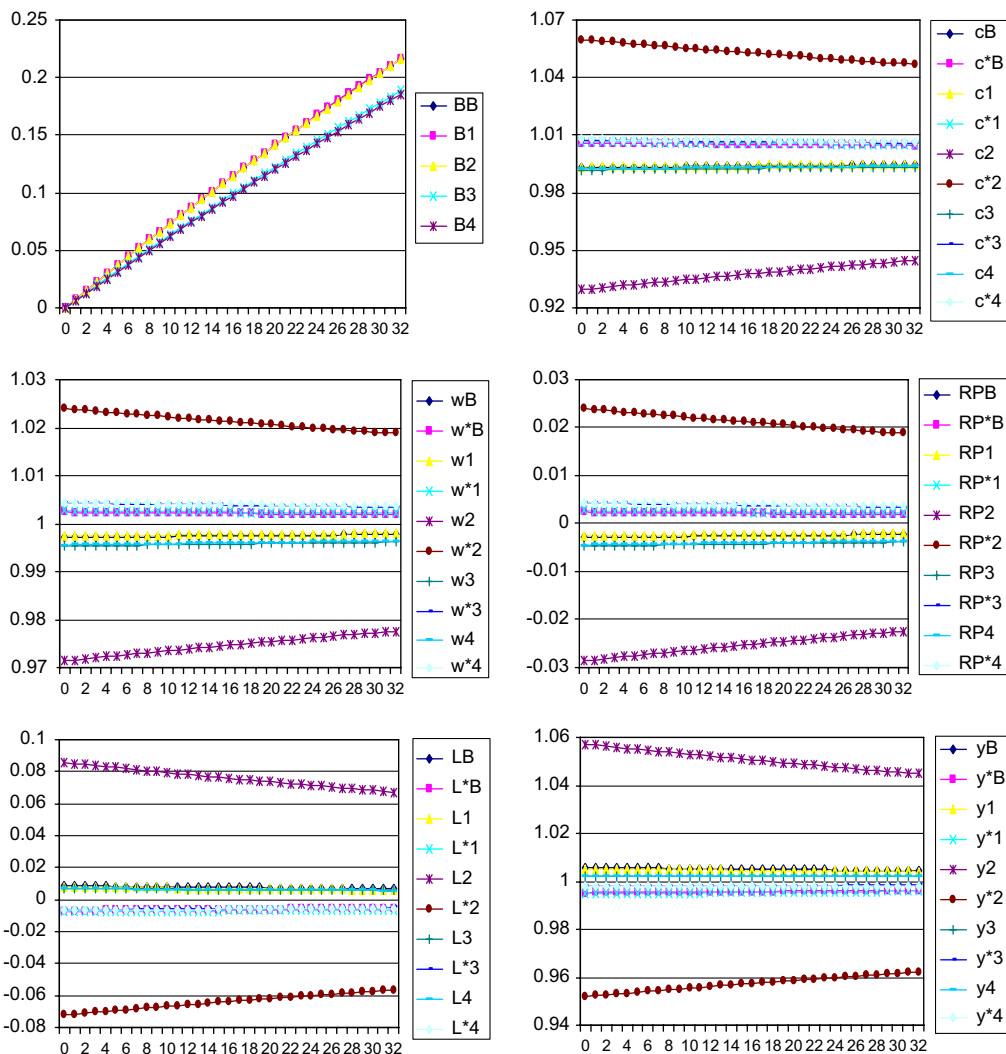


Fig. 2. Permanent world productivity shock, alternative parameterizations.

because our theoretical model yields not only quantitatively but also qualitatively different predictions, compared to symmetric models with equal discount factors, on the responses to these shocks.

To this end, we first build an empirical counterpart of our theoretical model, and then identify a permanent, worldwide productivity shock within this empirical model. We focus on the G7 countries and, to build an empirical, two-country model, we label the U.S. as the “home” economy and an aggregate of the remaining G7 countries as the “foreign” economy. This yields an empirical framework with two economies of comparable size.²⁹ The choice of the variables included in the empirical model

²⁹ We have also analyzed Germany and Japan as the empirical “home” economy. We do not report these results to conserve space. See footnote 40 for a brief discussion. Notice that, in Section 4, we thought of the foreign economy in the model as the U.S. In this section, we label the U.S. as the “home” economy of the empirical model, and we argue that its behavior is consistent with the relatively impatient (foreign) economy of the theoretical model.

is based on the minimum state vector of the log-linear solution of the theoretical model. As noted in Section 4, the minimum state vector consists of four variables: home and foreign productivity, net foreign assets, and the risk-free real interest rate. Our empirical model thus includes these four variables plus home and foreign consumption. This specification allows us to interpret the potential influence of consumption tilting on net foreign asset and consumption dynamics.³⁰

To estimate this empirical model, we construct a quarterly data set. The primary sources of our data are the OECD's *Analytical Database*—which provides comparable data on *business sector* output, consumption, employment, and hours worked—and quarterly net foreign assets constructed by Christopher Baum based on the annual series of Lane and Milesi-Ferretti (2001). The sample is 1977:Q1–1997:Q4. The availability of consistent net foreign asset data is the main variable that constrains our analysis. We use business sector real output per hour worked as our measure of labor productivity. Labor productivity and consumption series for the rest of the G7 economy are aggregates (not weighted averages). Net foreign asset data are vis-à-vis the rest of the world (not the remaining G7). The real interest rate is *ex post* and a country-specific measure. All nominal variables are converted into U.S. dollars at constant PPP exchange rates, and consumption and net foreign assets are expressed in per capita terms.³¹

The next step in the analysis involves identification of a worldwide, permanent productivity shock within our empirical model. We identify such a shock as the innovation to the (only) common stochastic trend in a VAR for home and foreign consumption, home and foreign labor productivity, net foreign assets, and the risk-free real interest rate. Specifically, to achieve this, we assume (i) a long-run, cointegration relation between home and foreign productivity, and (ii) a set of long-run, cointegration relations between the remaining variables and labor productivity. We then test these assumptions and estimate the response of this cointegrated VAR to an innovation to the common productivity trend. Note that we do not impose short-run restrictions on the system dynamics (including domestic and foreign productivity levels) and we can leave the remaining five temporary shocks (including a temporary worldwide productivity shock) unidentified without affecting the interpretation of our results. Thus, while our empirical analysis focuses only on worldwide permanent productivity shocks, the framework used to estimate their dynamic effects does not rule out the presence of other shocks (as in Ireland, 2004).

5.1. Identification

To identify a permanent worldwide productivity shock, we follow King et al. (1991) and Mellander et al. (1992), and we use a common trend representation for the VAR in levels for the six variables described above, interpreting the innovation to the only common trend in the model as the worldwide productivity shock.³² To proceed in this manner, we specify and test on the data (i) a long-run, cointegration relation between home and foreign productivity, and (ii) a set of four cointegration relations between productivity and the remaining variables in the system.

First, we assume that home and foreign labor productivity levels are cointegrated, and hence share a common stochastic trend, with cointegration vector given by the long-run relation observed in the data over the sample period. Thus, in log-levels, we have:

$$\log \bar{Z} = \gamma_1 \bar{Z} + \gamma_2 \log \bar{Z}^*, \quad (18)$$

where $\gamma_1 \bar{Z} > 0$ and $\gamma_2 \geq 0$. Such a cointegrating relation is consistent with stochastic growth models in which worldwide technological progress determines long-run growth and with models of technological diffusion (e.g., Nelson and Phelps, 1966; Barro and Sala-i-Martin, 1995, Chapter 8).

³⁰ Note that our benchmark empirical comparison will be consistent also with the implication of the theoretical model that labor supply in the patient country is on average lower than in the impatient country.

³¹ The Data Appendix contains details on data sources and variables.

³² Note that such a shock does not necessarily increase *measured* labor productivity in both countries by the same amount, on impact or during adjustment. Both the numerator and denominator of our empirical labor productivity measure (business sector output per hour worked) are endogenous in the theoretical model and respond differently across countries to a permanent, worldwide productivity shock when discount rates are asymmetric.

Second, we derive the remaining four cointegration relations from a linear approximation to the steady state of our theoretical model. It can be shown that the model delivers three *non-linear* steady-state relations for domestic consumption relative to foreign (\bar{c}/\bar{c}^*), home net foreign assets (\bar{B}), and the risk-free real interest rate (\bar{r}) as functions of the steady-state productivity ratio (\bar{Z}/\bar{Z}^*). Since there are no closed form expressions for these functions, we assume that \bar{r} and \bar{B} are such that³³:

$$\log(1 + \bar{r}) = \gamma_1^{\bar{r}} + \gamma_2^{\bar{r}}(\log \bar{Z} - \log \bar{Z}^*), \quad (19)$$

$$\log \bar{B} = \gamma_1^{\bar{B}} + \gamma_2^{\bar{B}}(\log \bar{Z} - \log \bar{Z}^*). \quad (20)$$

Steady-state consumption levels can then be written as:

$$\log \bar{c} = \gamma_1^{\bar{c}} + \gamma_2^{\bar{c}} \log \bar{Z} + \gamma_3^{\bar{c}} \log \bar{Z}^*, \quad (21)$$

$$\log \bar{c}^* = \gamma_1^{\bar{c}^*} + \gamma_2^{\bar{c}^*} \log \bar{Z} + \gamma_3^{\bar{c}^*} \log \bar{Z}^*. \quad (22)$$

Finally, combining (19)–(22) with (18) gives:

$$\begin{aligned} \log \bar{Z} &= \gamma_1^{\bar{Z}} + \gamma_2^{\bar{Z}} \log \bar{Z}^*, \\ \log \bar{B} &= \gamma_1^{\bar{B}'} + \gamma_2^{\bar{B}'} \log \bar{Z}, \\ \log(1 + \bar{r}) &= \gamma_1^{\bar{r}'} + \gamma_2^{\bar{r}'} \log \bar{Z}, \\ \log \bar{c} &= \gamma_1^{\bar{c}'} + \gamma_2^{\bar{c}'} \log \bar{Z}, \\ \log \bar{c}^* &= \gamma_1^{\bar{c}^*'} + \gamma_2^{\bar{c}^*'} \log \bar{Z}^*, \end{aligned} \quad (23)$$

where the γ' coefficients are functions of the coefficients in Eqs. (18)–(22).

The system (23) contains five linear relations in six variables. If the six variables are $I(1)$ and the five relations are $I(0)$, these represent a set of long-run, cointegration relations, and the six variables must share a single common stochastic trend by definition of cointegration. Consistent with a range of long-run growth models, we *interpret* an innovation to this unique common stochastic trend as a permanent, *worldwide* productivity shock. With this interpretation in mind, we now turn to testing and estimation of our empirical model.

5.2. Cointegration results

We conducted the cointegration analysis in a VAR in (log) levels with two lags as suggested by standard lag-selection criteria. To ensure residual normality, no autocorrelation, and homoscedasticity, we also included a set of seasonal dummy variables in this VAR. To avoid introducing too many dummy variables, we estimated the system on the sub-sample 1980:Q1–1994:Q4. Thus, our sample period stops right before the beginning of the recent period of productivity growth acceleration in the United States.³⁴

Overall, the evidence for the United States and the rest of the G7 is supportive of our assumptions (i) and (ii) above. Table 2 reports the results of the Johansen cointegration procedure applied to the specified VAR, the five estimated cointegration relations in (23) and a test on the (over-identifying) restrictions implicit in these relations, and misspecification test statistics at the system level.³⁵ Table 2,

³³ We re-scaled the data on B by a positive number to ensure that its logarithm is always well defined.

³⁴ For the period 1995–1997, in fact, U.S. labor productivity and net foreign assets exhibit unusual behavior compared to the rest of the sample. At the same time, our full sample ends in 1997:Q4, which prevents us from testing and treating this last period as a different regime.

³⁵ Estimated VAR equations are not reported but are available on request.

panel A shows that there is only one eigenvalue clearly close to zero in our six-variable VAR, suggesting the presence of five stationary components consistent with our hypotheses (i) and (ii) above. Further, if we impose the hypothesis of five stationary components on this six-variable system, consistent with (23), the implied over-identifying restrictions cannot be rejected by the data (and by a wide margin – see panel B). However, in a bivariate system, the null hypothesis of cointegration between home and foreign productivity levels is rejected by our relatively short time series data (results not reported). Also, in the six-variable system described above, the Johansen test on the cointegration rank of the VAR suggests the rank is three (panel A). But, if home and foreign productivity levels are entered exogenously to form a four-variable VAR system (Table 2, panel C), the Johansen test on the cointegration rank suggests that the system is full rank. We conclude from this body of evidence that cointegration of productivity levels is the one long-run relation that, among the five relations in (23), does not statistically fit our relatively short data series perfectly. Nonetheless, we view this long-run relation as an *economically* plausible “identifying assumption” in our empirical model.³⁶

Further, the view that cointegration of productivity levels is an economically plausible assumption is supported by the economic and statistical significance of the estimated cointegration relations. The coefficients of the estimated cointegration relations have all the right signs and are statistically significant (standard errors in parentheses; see Table 2, panel B).³⁷ These estimates suggest that productivity was growing faster in the rest of the G7 than in the U.S. during our sample period. This is consistent with productivity convergence in the G7, where the U.S. is the more productive economy and the remaining G7 productivity levels are catching up (Baumol, 1986).³⁸ The results also show that the response of net foreign assets to movements in worldwide productivity is economically significant. By contrast, productivity does not affect the real interest rate in the long-run, matching the theoretical model, which predicts that permanent changes in global productivity have no effect on the real interest rate.

We conclude that the cointegration results are broadly consistent with the linear cointegration relations in (23) and allow us to identify global productivity shocks in a model- and data-consistent manner.

5.3. Impulse responses

We now turn to the estimated impulse responses of the six variables in our VAR.³⁹ Fig. 3 reports the point estimates and two standard error bands for all impulse responses to a one-standard-deviation innovation to the common stochastic productivity trend. The results are strikingly consistent with the main predictions of our theoretical model. Theoretical impulse responses predict that, on impact, the less patient economy reduces its foreign assets (or increases its foreign debt), while the more patient economy accumulates assets, in response to a worldwide, permanent productivity shock. Thus, if we interpret the U.S. as the relatively impatient economy, the strong, negative, and statistically significant empirical response of U.S. net foreign assets (LBT1S_US in Fig. 3) to such a shock is consistent with the impulse responses shown in Fig. 1.

Consumption responses for the United States and the rest of the G7 (LC_US and LCEX_US, respectively) are also noteworthy for their consistency with the predictions of our theoretical model. On impact, consumption increases in both the United States and the rest of the G7. Then,

³⁶ Notice that, in the absence of cointegration between home and foreign productivity, these economies would diverge over time. Productivity convergence within the G7 is also empirically defensible (see below). Furthermore, it is not uncommon to have a degree of statistical weakness in applied cointegration analysis. For instance, both King et al. (1991) and Mellander et al. (1992) encounter such statistical weakness in their cointegration tests, nevertheless implement the common trend analysis. (In their cases, they find the right number of cointegration vectors, but the data reject the identification restrictions they impose from economic theory.)

³⁷ All coefficients in the system (23) should be positive (negative, in Table 2, panel B, because reported on the left-hand side of the cointegration relation), except, possibly, γ_2^* , the coefficient on home productivity in the interest rate equation.

³⁸ Notice that our benchmark calibration is consistent with these estimates of the long-run relation between domestic and foreign productivity, which point to the U.S. as more productive than the rest of the G7 economy.

³⁹ We followed Mellander et al. (1992) to estimate the VAR model in common trend representation and used the RATS code written by Anders Warne.

Table 2

Cointegration analysis (1980:Q1–1994:Q4)

Panel A: Johansen procedure (with productivity entered endogenously)					
Eigenvalue		Loglik.		Rank	
		1298.406		0	
0.51379		1320.040		1	
0.42826		1336.812		2	
0.34351		1349.438		3	
0.26254		1358.574		4	
0.11075		1362.095		5	
4.2240e–005		1362.096		6	
Rank<=		Trace test		[Prob.]	
0		127.38		[0.000]**	
1		84.114		[0.002]**	
2		50.569		[0.026]*	
3		25.318		[0.155]	
4		7.0449		[0.579]	
5		0.0025		[0.960]	
Panel B: Estimated cointegration vectors (with productivity entered endogenously)					
Z_US	1.0000	–1.8527 (0.053)	0.0000	5.6363 (0.068)	0.0000
ZEX_US	–0.6000 (0.0000)	0.0000	–1.0000	0.0000	0.0000
C_US	0.0000	1.0000	0.0000	0.0000	0.0000
CEX_US	0.0000	0.0000	1.0000	0.0000	0.0000
NFA_US	0.0000	0.0000	0.0000	1.0000	0.0000
R_US	0.0000	0.0000	0.0000	0.0000	1.0000
LR test of over-identifying restrictions: Chi ² (3) = 2.1357 [0.5447] [Prob.]					
Panel C: Johansen procedure (with productivity entered exogenously)					
Eigenvalue		Loglik.		Rank	
		842.0402		0	
0.51864		865.4368		1	
0.31170		877.3895		2	
0.23755		886.0684		3	
0.10407		889.5851		4	
Rank<=		Trace test		[Prob.]	
0		95.090		[0.000]**	
1		48.297		[0.000]**	
2		24.391		[0.001]**	
3		7.0333		[0.008]**	
Panel D: Specification tests					
Vector autocorrelation test (lags 1–4)		F(64,119) = 1.2069		[0.1881] [Prob.]	
Vector normality test		Chi ² (8) = 13.184		[0.1057] [Prob.]	
Vector heteroskedasticity test		F(200,193) = 0.70217		[0.9933] [Prob.]	

U.S. consumption reaches its new steady state from *above*, whereas foreign consumption reaches the new steady-state from *below*. These dynamic patterns are consistent with the predictions of our theory, if again we interpret the U.S. as the less patient economy, and the foreign economy as the more patient one.⁴⁰

⁴⁰ When we estimate the system with Japan as the empirical home economy and the rest of the G7 excluding Japan as the foreign economy, the response of foreign assets to productivity has the opposite sign to that of the U.S. system, while the responses of both foreign assets and consumption are considerably smaller than those in the U.S. in absolute value. These results reinforce our evidence for qualitative cross-country differences in responses of foreign assets and consumption to permanent, worldwide productivity shocks, and also suggest that Japan may be an important counterpart to the U.S. case we analyzed (*i.e.*, the more patient country). Our results for Germany, instead, are more mixed. (Results not reported but available from the authors.)

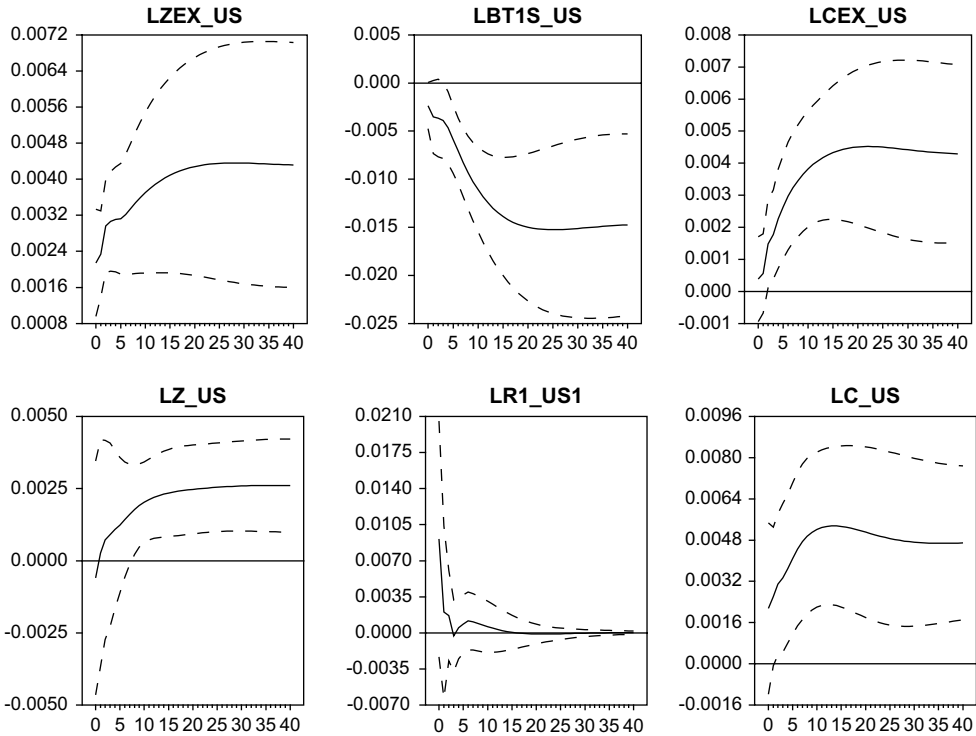


Fig. 3. Estimated responses to a permanent, one-standard deviation, worldwide productivity shock. (LZ_US is U.S. productivity; LZEX_US is rest of the G7 productivity; LBT1S_US is U.S. net foreign assets; LR1_US1 is U.S. real interest rate; LC_US is U.S. consumption; LCEX_US is rest of the G7 consumption.)

Finally, our theoretical model also predicts that net foreign asset and consumption dynamics are largely driven by consumption tilting and variations in relative prices, with no dynamic response from the risk-free real interest rate (LR1_US1 in Fig. 3). Although the point estimates indicate a positive initial interest rate response, the standard errors suggest that this is not statistically different from zero.

Our finding that G7 net foreign assets respond to permanent, worldwide productivity shocks asymmetrically is consistent with other studies, although they use different empirical models. For instance, Nason and Rogers (2002) find that the Canadian current account tends to respond to worldwide shocks. Gregory and Head (1999) find that a highly persistent worldwide productivity shock has an economically significant and asymmetric impact on individual G7 current accounts, including a negative and statistically significant impact on the U.S. current account. Based on this evidence they conclude that “asymmetries across countries that appear in the empirical analysis cannot be replicated in a calibrated version of the artificial economy in which countries are asymmetric only with regard to the parameterization of the technology shock process” (p. 427).

In sum, we find that net foreign assets and consumption do respond to permanent worldwide productivity shocks differently across countries, in a manner that is predicted by our theoretical model of consumption and foreign asset dynamics with different discount factors, but inconsistent with standard, symmetric models with equal discount factors.

6. Conclusion

We proposed a framework to study international consumption and net foreign asset dynamics in a two-country model of macroeconomic interdependence with non-zero long-run net foreign asset

positions. Our model generates such non-zero positions starting from first principles – specifically, differences in discount factors across countries. These differences generate tilts in steady-state consumption profiles of individual households that, in turn, have implications for the dynamics of the economy in response to shocks. Our exercise thus shows that providing a structural interpretation of long-run asset positions – as our model allows us to do – is important also to interpret dynamics outside the steady state. By departing from the symmetry assumption of standard, two-country models, we can account for asymmetric responses of consumption and net foreign assets to worldwide productivity shocks observed in the data. In particular, the responses of U.S. data in our empirical analysis are consistent with those of the less patient economy in our model, with the rest of the G7 as the counterpart of this interpretation. Thus, our framework goes some way toward reconciling the theory of international consumption and asset dynamics with the data.

Several issues for future research remain. Our theoretical framework is admittedly stylized. Given the difficulty of allowing for *any* cross-country heterogeneity in a general equilibrium model, we confined our analysis to differences in patience as the fundamental source of asymmetry. Clearly, other sources of structural heterogeneity may account for the consumption and net foreign asset dynamics found in the data. For instance, it would be useful to incorporate asymmetries in demographics. We also see extending the model to include investment in physical capital and allow for richer asymmetry in production structures across countries as particularly promising.

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Appendix. Data

A.1. Sources and coverage

We use quarterly data for the G7 countries. We primarily use three data sources: (i) The OECD *Analytical Database* (AD, retrieved on 18 February 2002), which provides quarterly data on *business sector* output, consumption, and employment⁴¹; (ii) Quarterly net foreign assets (NFA) data graciously provided by Christopher Baum, who builds on the annual series constructed by Lane and Milesi-Ferretti (2001); and (iii) the IMF *International Financial Statistics* (IFS).

While some series go back to 1960, available OECD data for the business sector are mostly limited to the period from 1970:Q1 to 1999:Q4. The sample period for NFA is from 1977:Q1 to the last year for which we have NFA data for Japan, 1997:Q4. So this is the main series which constrains our analysis. We re-scaled these net foreign assets series by adding a positive constant to ensure strictly positive series before taking logs.

⁴¹ The OECD defines the business sector as “the institutional sector whose primary role is the production and sale of goods and services. This sector consequently corresponds to the aggregation of the corporate, quasi-corporate and unincorporated enterprises *including* public enterprises.” We should note that the OECD created this business sector database with “the specific purpose of comparing [...] economic performance in the OECD member countries. By focusing only on market agents and sectors [the business sector data] facilitate and enhance data comparability across countries” (Meyer zu Schlochtern and Meyer zu Schlochtern, 1994).

A.2. Variables

Output—Gross domestic product (GDP), business sector, volume, factor cost, in millions of local currency units. For Canada and the U.S., the base year is 1997 and 1996, respectively. For the rest of the G7, the base year is 1995. We re-based the Canadian and U.S. business sector GDP so that 1995 is the common base year. We used the GDP business sector deflator for this purpose.

Employment—Employment of the business sector, millions of persons.

Hours worked—Actual hours worked per employee in the business sector. The U.S. series is an index. We back-casted it starting from 1989 by using the annual average hours actually worked obtained from the OECD, *Employment Outlook*, 2001 Edition, Table F.

Exchange rate—Purchasing power parity (PPP), local currency per U.S. dollar, from the AD; annual series interpolated to quarterly by means of a cubic spline.

Consumption—Business sector private final consumption deflated by the (business sector) GDP deflator, except in the case of the UK, for which we lacked the GDP deflator series and used the private final consumption deflator.

Population—Annual series from AD interpolated by using a cubic spline.

NFA—Deflated with the CPI from the IFS and expressed in per capita terms. These series are then converted into current U.S. dollars by using market exchange rates (from the IFS) and deflated by the U.S. GDP business sector deflator (from the AD).

Real interest rate (r)—Nominal interest rate (i) adjusted for annualized quarterly inflation in the average CPI:

$$1 + r_t = \log \frac{1 + i_t/100}{(CPI_t/CPI_{t-1})^4}.$$

The nominal interest rate is a quarterly average of 3-month T-bill rates on an annual basis, except for Japan. For Japan, we used the call money market rate because we lacked comparable data.

Labor productivity—To obtain “per unit of labor service,” we first calculated business sector GDP per hour worked in local currency units (*gdp*) as GDP per employee hour worked:

$$gdp = \text{GDP}/(\text{employment} \times \text{hours worked}).$$

We then converted this variable to a common currency.

To do this, we deflated *gdp* for each country by its national business sector GDP deflator (P),

$$rgdp_t = gdp_t/P_t,$$

and then divided *rgdp* by the 1995 PPP exchange rate (PPP_{1995}):

$$Z_t = rgdp_t/PPP_{1995}.$$

This is the labor productivity measure we use in the empirical analysis.

Rest of the G7 labor productivity—We constructed rest-of-the-world labor productivity by computing *rgdp*, then converting this variable for those countries that make up the rest of the G7 into U.S. dollars by using PPP_{1995} . Finally, we added over these countries and divided this sum by the rest of the G7 total employee hours.

Per capita consumption—Per capita consumption is private final consumption expenditure divided by population. Our measure of consumption is real per capita consumption in PPP U.S. dollars. We computed rest-of-the-G7 per capita consumption data using the same methodology discussed above for labor productivity.

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