Long-run Growth Expectations and "Global Imbalances"*

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Abstract

Discussions of the international dimension of the global economic crisis have frequently focused on the build-up of large current account “imbalances” since the mid-1990s. This paper examines the extent to which the U.S. current account can be understood in a purely real open-economy DSGE model, were agents' perception of long-run growth evolves over time in response to changes in productivity. We first show that long-run growth forecasts based on filtering actual productivity growth comove strongly with survey measures of expectations. Simulating the model, we find that including data on U.S. TFP growth and the world real interest rate can, under standard parametrizations of our model, explain the evolution of the U.S. current account quite closely. With household preference that allow positive labor supply effects after favorable news of future income, we can also generate output movements in line with the data.

JEL Codes: E13, E32, D83, O40.

Keywords: Open economy DSGE models, trend growth, Kalman filter, real-time data.

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Axiom 1 *The fundamental things apply / As time goes by - Casablanca (1942)*

1 Introduction

The global economic crisis of 2008 and 2009 that began with financial market problems in the United States is often seen as related to the global imbalances in the preceding decade. That is, seemingly excessive borrowing by the United States in an environment of low world interest rates is seen as the pathological cause of an ever-widening and unsustainable U.S. current account deficit that was bound to be corrected sooner or later. While an eventual correction of this unsustainability was regarded by many observers as necessarily leading to a large depreciation in the dollar, it turned out to reverse itself in the wake of the global economic crisis, without much exchange rate movement (yet). The end of excesses in financial markets appears to have engendered an end of rising global imbalances, as it stopped excessive lending to U.S. households.

In this paper, we propose an equilibrium explanation of the U.S. current account – and thus also of global imbalances and their reversal – which abstracts from aspects of financial market problems or notions of excessive lending to U.S. households. In particular, we show that the evolution of the U.S. current account deficit from 1995 onward can to a large extent be explained solely by households' and firms' optimal responses to changing long-run U.S. growth expectations and the decline of world real interest rates after 2000. Central to our results is the role of expectations as the driver of the current account. This of course is the implication of the intertemporal approach to the current account, in which savings and investment decisions by forward-looking agents are based on the present value of future income, relative to prevailing borrowing costs determined in world capital markets.

The basis of our explanation of U.S. current account dynamics is a standard open-economy real stochastic growth model with capital accumulation and international trade in real bonds and goods. Since future long-run growth is intrinsically uncertain, we assume that the growth rate of productivity consists of persistent and transitory stochastic components. While changes in the latter have only minor implications for the present value of income, changes in the former cause major revisions of perceived wealth, and thus of the commensurate consumption choices. However, the uncertain nature of future productivity growth also requires that a signal extraction problem must be solved in order to match data that is based on choices made under imperfect information. To this end, we use the Kalman filter to generate long-run productivity growth expectations from actual total factor productivity data and show that the model-based productivity growth expectations are consistent with published growth expectations from surveys.

We find that simulating the calibrated model using only data on world real interest rates and U.S. productivity growth is sufficient to closely match the actual evolution of the U.S. current account since 1995. Given that our benchmark choice of parameter values is quite standard, this result is rather striking. Neither changing productivity growth expectations nor interest rates alone can explain the data. Holding growth expectations fixed, lower world interest rates since the late 1990s can be seen to have played a role, but they can at best explain a fifth of the widening U.S. current account deficit. Furthermore, since world interest rates have stayed low during and after the economic crisis of 2008/2009, they cannot explain the narrowing of the current account by the end of this decade. This instead is accounted for by the drop in perceived U.S. productivity growth since about 2006. Thus we conclude that changing growth expectations are an important driver of the U.S. current account and consequently of global imbalances.

Two important implication of these results stand out. One is that a large part of the evolution of the U.S. current account can be seen as the efficient response to changing information about imperfectly observed fundamentals. In particular, the reversal of the current account since 2006 need not be the consequence of a crisis caused by financial turmoil. Instead, U.S. growth prospects have worsened, which must lead to revisions of consumption and investment plans by firms, manifesting themselves in the current account.[1] From this perspective, global *im*balances should not be judged as some form of pathological disequilibrium, but are an equilibrium phenomenon. However, as we show, even fundamental changes in actual and perceived growth alone have dramatic effects on the asset valuation of the productive capacity of the economy, and, furthermore, can also

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[1] Of course, disappointed growth expectations may be at the core of the collapse of the housing market, which in turn have feedback onto the financial system. But the housing market developments are just one aspect of more fundamental factors at work.

feature concomitant output movements in the direction we observed since 2008.

The second direct implication relates to the idea of a savings glut (Bernanke, 2003), according to which a lack of investment and high savings in the rest of the world caused an excessive supply of funds to the U.S.[2] Related in the theories of Caballero, Fahri, and Gourinchas (2008), a superior quality and depth of the U.S. financial system have led global investors to supply funds cheaply to the U.S., while Mendoza, Quadrini, and Rios-Rull (2009) explain global imbalances as a consequence of asymmetric degree of financial development. The current account reversal in the wake of the crisis would then be explained by the interaction of financial frictions and portfolio rebalancing of international investors. While these factors certainly have played a role, the fact that we control for the associated interest rate movements suggests that they offer only an incomplete account of the global imbalances.

Some aspects of our reasoning are closely related to the analysis of emerging market current account crises of Aguiar and Gopinath (2008), who find that shocks to trend productivity growth are the primary source of fluctuations in emerging markets. The authors use a small open economy model to identify the true growth trends from current account data, by assuming that households perfectly observe changes to the long-run growth trend. The growth trend thus inferred is highly volatile.[3] In contrast, we constrain ourselves to consider changes in productivity growth expectation that are consistent with measured expectations from surveys, such as Consensus Forecasts. We show that changes in perceived long-run productivity growth imply observed current account movements even for a developed economy such as the U.S.

A large literature has explored the intertemporal approach (present value model) to the current account, which is the key driver of our results. The contrast between our ability to match the U.S. current account and the less conclusive findings in previous work lies in our treatment of interest rates and productivity. In their comprehensive survey, Nason and Rogers (200X) report difficulties in matching the data, but notably assume a fixed world interest rate for the country at hand, as well as a productivity process that

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[2] Note that U.S. interest rates have not been systematically lower than in other developed economies. See Gruber and Kamin (2009), and further evidence presented below.

[3] Boz et al. (2010) employ a similar model with learning and show that it matches emerging market dynamics better than under the full information assumption of Aguiar and Gopinath (2008).

leads to stochastic shifts in the level of technology, but not in the growth rate. Thus, neither this shock nor shocks to demography and government spending among others can explain the current account via a present value logic. From the perspective of our approach this is not surprising since the key variable that can have strong present value implications, the long-run growth trend, is assumed to be constant in expectation. In contrast to this literature, we take account of the central role of expectations formation.[4]

One key component of our theory is the incorporation of preferences that allow us to control the wealth effect on labor supply. In models that incorporate news about future productivity levels, standard preference (of the King-Plosser-Rebelo type) induce labor supply movements that cause cyclical downswings after good news, or at least an implausible negative correlation between consumption and investment. The permanent shocks to the growth rate of technology in our model do in fact have a news interpretation, which we explore formally at the end of the paper. They lead us to generalize household preferences along the lines of Jaimovich and Rebelo (2008), who combine KPR with Greenwood Hercovitz Huffmann preferences. They neutralize the wealth effect on labor supply. As in Jaimovich and Rebelo, we find that a mixture of the two preference types leads to the most plausible adjustments.[5]

[NEWS, tbc]

The paper proceed from here as follows. First, in section 2, we show the evolution of global long-run growth expectations, and their link with long-run interest rates. In section 3, we develop our model – a two-country real open economy stochastic growth model – that incorporates changes in long-run trend growth. We also introduce the signal-extraction problem of inferring long-run from short-run productivity movements, and it solution by means of a Kalman filter. Calibration and simulation results are presented in section 4, where we first illustrate the economics of the model using impulse responses. Then we simulate the model using data on world real interest rates, and on productivity

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[4] The literature on the present value model of the current account has thus far worked with much more transient shocks to technology, or outright assumed perfect information and/or foresight of households. E.g. Engel and Rogers, Aguiar and Gopinath, Ferrero, Chen et al.

[5] This is in contrast to findings of Boz, Daude and Durdu (2010), who show that for explaining emerging market economies, the inclusion of standard preference is sufficient to explain trade dynamics in the presence of learning about growth.

growth as the input to the Kalman filter. We show here also under which parameter constellations the results obtain. Before concluding, we discuss formally the nature of information shocks – or, news – in our model, and argue that shocks to long-run growth trends are a plausible and concrete example where news drive behavior.

2 Trend growth expectations: a first look at the data

In this section we present the data on survey expectations of trend growth that motivate our analysis, and take a first look at the relationship between the evolution of these expectations in the United States and the rest of the world.

2.1 The evolution of long-run growth expectations

The main explanation for the emergence of "global imbalances" that we emphasize is the evolution of perceived trend growth rates in the U.S. and the other major economies. To discipline our analysis, we employ actual survey expectations of real GDP growth at long horizons, which we interpret as perceptions of *trend* growth. As discussed further in section 3, we calibrate our technology process and agents' learning about persistent and transitory movements in technology growth such that the agents' real-time estimate of trend growth in our model matches features of private-sector survey expectations compiled by Consensus Economics. Since 1990, Consensus Economics conducts a monthly survey of professional economists. For the major industrialized economies, every six months this survey has included questions about participants' expectations of real GDP growth and other macroeconomic variables at horizons up to ten years. For the major economies of the Asia-Pacific region these long-horizon expectations start in 1995. We focus on real GDP growth expectations at the longest horizon (6 to 10 years ahead) for the U.S. and a set of nine countries that in 2008 jointly accounted for about 2/3 of world GDP, and in 2003 for about 2/3 of U.S. imports and slightly less of U.S. exports.[6]

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[6] The countries included are the U.S., Japan, Germany, France, the U.K., Italy, Canada, China, Korea and Taiwan. The shares in world GDP are taken from www.ers.usda.gov, the shares in U.S. imports and exports from Federal Reserve Board (2005).

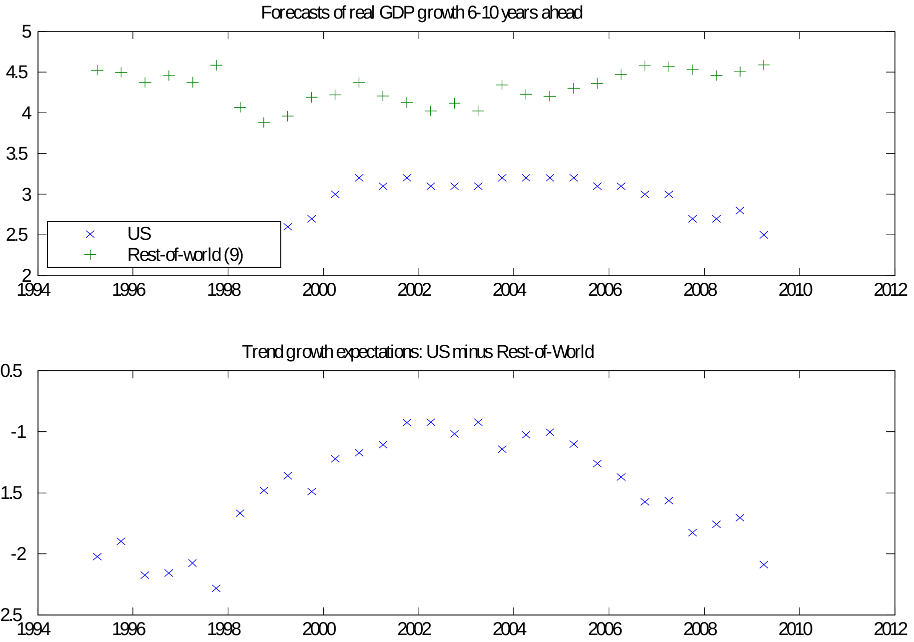

Figure 1: Consensus forecasts of real GDP growth 6-10 years ahead

The top panel of Figure 1 shows these expectations for the U.S. and the GDP-weighted average of the expectations for the other nine countries (henceforth referred to as the "rest of the world").[7] The bottom panel of Figure 1 shows the difference between the trend growth expectations for the US and the weighted average growth expectations for our "rest-of-world" aggregate. As can be seen, participants' perceptions of U.S. trend growth *relative* to the "rest of the world" rose by about 1.5 percentage points between 1998 and 2003, then remained roughly at that level until about 2005, and has since retracted about 1 percentage point. While the initial increase reflected in roughly equal measure an increase in perceived U.S. trend growth and a decline in trend growth elsewhere, the reversal in recent years is mostly due to lower U.S. trend growth expectations.

The upper panel of Figure 2 shows estimates of the *ex-ante* long-term real government bond yields for the U.S. and a subset of six countries of our nine-country "rest-of-world" aggregate.[8] The lower panel plots the real long-term interest rate in the rest of the world

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[7] The long-horizon forecasts are always published in April and October, and are shown in the figure in the first and third quarter of each year.

[8] For each country, long-horizon inflation expectations are proxied by a slow-moving partial-adjustment equation $\bar{\pi}^e_t = \alpha\bar{\pi}^e_{t-1} + (1-\alpha)\pi_t$ using CPI inflation. This type of equation does a good job proxying long-horizon inflation expectations in the U.S. We exclude China and Taiwan from the computation of the "rest-of-world" real interest rate for lack of government bond yield data, and Korea because of the strong effects of the Asian crisis on its yields.

(against the left axis) and the weighted growth expectations in the rest of the world. As can be seen, until about 2003 these two series moved remarkably closely together. Since then, however, there is a widening gap suggesting that other factors than perceived trend growth contributed significantly to the movement of the world real interest rate.

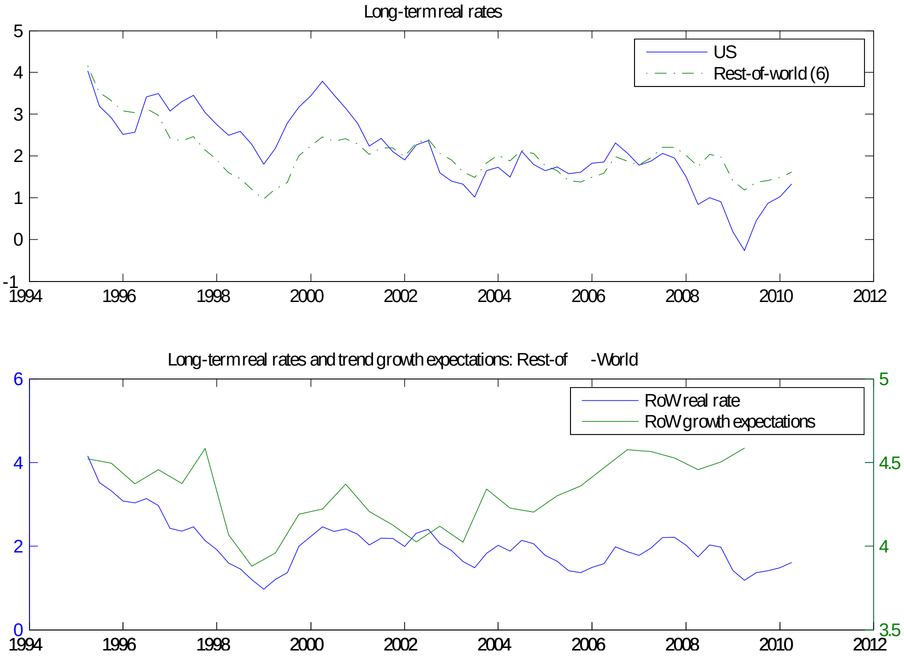

Figure 2: Long-term real rates and growth expectations

Potential explanations for this widening gap have focussed on the relative inability of the rest of the world to create the safe assets they demand (Caballero et al., 2008), or increasing purchases by China of U.S. government issued paper. What matters for U.S. households and firms are financing conditions however, so that our focus is to ensure that our simulations below are consistent with the realized path of the world real interest rate. Thus we avoid taking a stance on which combination of factors explain its evolution.

3 The Model

In this section we develop our real stochastic growth model of open economies. While most elements are standard from the open-economy real business cycle literature, there are two key modifications: learning about productivity growth rates, and preferences which allow to control the wealth effect arising from changing perceptions of productivity growth.

3.1 Setup

The model consists of two countries, home and foreign (the rest of the world), which is denoted by an asterisk $*$. We normalize the population size of the domestic economy to 1 and the relative population size of the foreign economy, i.e., rest of the world, to P^*, so that $1/(1+P^*)$ is the fraction of home population in the world. Each country is inhabited by a large number of infinitely living households and endowed with a constant returns to scale production technology utilized by competitive firms. Firms produce a single good which can be used for consumption and investment in both countries. For ease of exposition, we fully consider only the domestic economy. The foreign country is identical in terms of preferences and technology.

Households in the home economy maximize the present value of their instantaneous utility, discounted with a factor β. Thus a representative households maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\left[\left(C_t - h\bar{C}_{t-1}\right) - \chi\, L_t^{1+\nu} X_t\right]^{1-\sigma} - 1}{1-\sigma},$$

where $X_t = \left(C_t - h\bar{C}_{t-1}\right)^{\gamma} X_{t-1}^{1-\gamma} \left(\frac{Z_t}{Z_{t-1}}\right)^{1-\gamma}$. Utility depends on consumption C_t relative to a weighted habit stock $\bar{C}_{t-1}$, given by past aggregate consumption, and a weighted disutility of labor, L_t. The weighting factor X_t governs the extent of the wealth effect on labor supply, and is inspired by Jaimovich and Rebelo (2009). The parameter γ is between zero and one. When $\gamma = 0$, these simplify to Greenwood, Hercowitz, and Huffmann (1988) preferences, often used in the open economy literature, allowing plausible labor responses to positive wealth innovations. When $\gamma = 1$, the preferences are the growth consistent preferences from King, Plosser, and Rebelo (1988). In contrast to Jaimovich and Rebelo, we include the scale factor $\left(\frac{Z_t}{Z_{t-1}}\right)^{1-\gamma}$, to ensure that the model is consistent with steady state growth in aggregate labor-augmenting technology Z_t, defined below.[9] Note that the expectations operator denotes here the expectation conditional on information available in the current period, which may be imperfect.

The household faces, two constraints, the budget constraint and the capital accumu-

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[9] Jaimovich and Rebelo (1998) impose that $\gamma > 0$, so that preferences are growth consistent, by the weight on the King-Plosser-Rebelo part of preference. Very low values of γ imply however in the limit highly persistent deviations from the steady state growth part.

lation equation. The former is given by

$$W_t L_t + r_t^k K_{t-1} + r_{t-1} B_{t-1} = C_t + I_t + B_t - B_{t-1}.$$

Income consists of real labor income $W_t L_t$, as well as return on capital determined in the previous period, $r_t^k K_{t-1}$, and the net return on a single non-contingent real bonds, $r_{t-1} B_{t-1}$, respectively. The income is used to finance consumption C_t, investment I_t, and to accumulate net foreign assets, B_t. When agents borrow from the rest of the world it follows that $B_t < 0$. Financial markets are incomplete in that households cannot insure against all possible contingencies. The capital accumulation constraint equals

$$K_t = (1-\delta) K_{t-1} + I_t \left[1 - \frac{\phi}{2} \left(\frac{I_t}{I_{t-1}} - \exp(g) \right)^2 \right].$$

Investment is subject to quadratic adjustment costs, with $\phi(1) = 0$, $\phi'(1) = 0$, and $\phi''(1) > 0$ at the stationary steady state and g the long-run mean growth rate. When agents take net positions in international bond markets, a financial intermediation premium must be paid, which relates the domestic interest rate r_t and the rest of the world's real interest rate r_t^* by the following function:

$$r_t = r_t^* - \varphi \left[\exp\left(\frac{B_t}{Y_t} - \frac{B}{Y} \right) - 1 \right], \tag{1}$$

where B/Y reflects the steady-state ratio of the country's net foreign assets to GDP.[10] Thus, both the actual net foreign asset position relative to GDP, B_t/Y_t, and movements of the real interest rate r_t^* in the rest of the world will affect the borrowing conditions of the domestic economy.

A competitive representative firm in the domestic economy produces a single good according to the technology

$$Y_t = \widetilde{K}_t^{\alpha} \left(Z_t L_t \right)^{1-\alpha},$$

where $0 < \alpha < 1$, and $\widetilde{K}_t$ is the capital stock used by the firm. In equilibrium it will have to equal the capital K_{t-1} supplied by households. Aggregate technology evolves according to

$$\ln Z_t - \ln Z_{t-1} = g_t + \omega_t, \tag{2}$$

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[10] The financial intermediation premium ensures that the net foreign asset position becomes stationary in the linearized version of the model (see Schmitt-Grohe and Uribe, 2003).

with

$$g_t = \left(1 - \rho_g\right) g + \rho_g g_{t-1} + \nu_t. \tag{3}$$

Both ω_t and υ_t are i.i.d. distributed as $\nu_t \sim N\left(0, \sigma_\upsilon^2\right)$ and $\omega_t \sim N\left(0, \sigma_\omega^2\right)$. The growth in technology thus has two components. An innovation ω_t leads to a permanent shift in the *level* of technology Z_t, but has no persistent effects on the *growth rate* of technology, $\ln\left(Z_t/Z_{t-1}\right)$. An innovation υ_t, by contrast, leads to a sequence of changes in Z_t in the same direction because it raises its growth rate temporarily above its steady-state growth rate g.

The foreign economy (i.e., the rest of the world) is identically specified. In particular, we assume that it faces the same steady-state growth rate. Nonetheless, both regions can grow at different rates for a substantial amount of time, depending on the realizations of the domestic and foreign technology shocks. Since the model is expressed in per capita terms, the global goods market clearing condition takes account of the relative sizes of the two regions:

$$\frac{C_t^* P^*}{1+P^*} + \frac{C_t}{1+P^*} + \frac{I_t^* P^*}{1+P^*} + \frac{I_t}{1+P^*} = \frac{Y_t^* P^*}{1+P^*} + \frac{Y_t}{1+P^*}. \tag{4}$$

For later expositional purposes, the world real interest rate can also be written as the average of the foreign and domestic interest rates.

$$r_t^w = r_t^* \frac{P^*}{1+P^*} + r_t \frac{1}{1+P^*}. \tag{5}$$

Finally, bond market clearing requires that

$$\frac{B_t^* P^*}{1+P^*} + \frac{B_t}{1+P^*} = 0, \tag{6}$$

since bonds are in zero net supply in the world economy.

3.2 Filtering long-run domestic productivity growth

The key addition to the standard real open economy is the presence of imperfect information about future growth rates. Therefore, agents must solve an inference problem about the expected productivity growth, which we assume to be the result of linear filtering via the Kalman filter. Intuitively, agents take the current period realization of aggregate technology and use their knowledge of the relative persistencies and volatilities of the two components to infer the level of the persistent growth component. Given this level, agents can extrapolate the evolution of technology into the future and make their optimal current, but forward-looking choices.

What we mean here by "trend growth" is the (actual or perceived) value of g_t at a given point in time, under the assumption that g_t is a persistent process (say, $\rho_g = 0.99$). The signal-to-noise ratio $\eta \equiv \sigma_\nu^2/\sigma_\omega^2$ measures the importance of innovations to trend growth relative to permanent one-off changes to the level of technology. As persistent changes in growth rates appear to be infrequent, it is natural to think of η as a small number.[11]

A key assumption in our analysis below, as in Edge, Laubach, and Williams (2007) and Gilchrist and Saito (2008), is that agents only observe the current level of technology Z_t, but are unable to disentangle changes in $\ln Z_t$ from $\ln Z_{t-1}$ into one-off level shifts ω_t and persistent growth rate changes due to innovations ν_t, in the notation introduced above. They therefore form at each point in time a best estimate $g_{t|t}$ of the current level of trend growth. Given the linearity of our setup, this best estimate is obtained by the Kalman filter according to the recursion

$$g_{t|t} = (1-\kappa)\rho_g g_{t-1|t-1} + \kappa \ln dz_t,$$

where $dz_t = Z_t/Z_{t-1}$. The Kalman gain κ is given by

$$\kappa = \frac{\eta - (1-\rho_g^2) + \eta\sqrt{((1-\rho_g^2)/\eta)^2 + 1 + 2(1+\rho_g^2)/\eta}}{2 + \eta - (1-\rho_g^2) + \eta\sqrt{((1-\rho_g^2)/\eta)^2 + 1 + 2(1+\rho_g^2)/\eta}}.$$

The implication of such inference problem is a deviation from the rational expectations assumption in the strict sense, which implies equality between the actual and subjective probability distribution. All agents, domestic and foreign, share the same signal extraction problem for both the domestic and foreign productivity process. In other words,

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[11] Using the median-unbiased estimator of Stock and Watson (1998), Laubach and Williams (2003) estimate a ratio of *standard deviations* of permanent to transitory changes in quarterly postwar U.S. real GDP growth of 0.042. Edge et al. (2007) apply this methodology to annual U.S. labor productivity growth and obtain an estimate of 0.12, which applied to quarterly frequency would be close to 0.03. We discuss the calibration of this parameter further below.

there is symmetric information about each others permanent and transitory changes in productivity.

3.3 Stationary equilibrium conditions

Households in both regions solve optimization problems of choosing capital, investment, consumption, labor input, and international bonds, taking the choices of agents as given. Furthermore, while habits are external (in the sense that households take $\bar{C}_t$ to be exogenous), the scale factor X_t of labor disutility is taken as internal. This means that households take into account the effect of consumption choices on the future evolution of X_t and thus the effect this has on the future disutility of labor. Firms have the sole task of hiring capital and labor in a competitive market, and produce output using the available technology. Optimization of agents and aggregate constraints result in optimality conditions for all relevant variables, depending on expectations about the future.

The economy of the model is growing at a stochastic growth rate. Therefore, to find the solution for the equilibrium dynamics, the system must be made stationary for standard solution methods to be applicable. Thus we divide all variables that grow in steady state with the same growth rate as technology by Z_t, denoting the rescaled variables by lower case letters: $k_{t-1} = K_{t-1}/Z_{t-1,}$ $c_t = C_t/Z_t$, $\lambda_t = \Lambda_t Z_t^{\sigma}$, $dz_{t+1} = Z_{t+1}/Z_t$ and similarly for the other non stationary variables. After the rational expectations solution has been found, the levels of the variables can be found by appropriate rescaling.

The households' optimal choice of consumption is given by the equality of the marginal utilities of wealth and of consumption, and by the Euler equation. In stationary form, the first condition is

$$\lambda_t = \left(c_t - \frac{h}{dz_t}c_{t-1} - \chi L_t^{1+\nu} x_t\right)^{-\sigma} + \mu_t \gamma \left(c_t - \frac{h}{dz_t}c_{t-1}\right)^{-(1-\gamma)}. \tag{7}$$

The marginal utility of wealth is given by the Lagrange multiplier on the budget constraint. It equals the marginal utility of consumption which here depends on the term arising for non-separable utility plus a term due to the interaction between consumption and the marginal disutility of labor, which follows from the presence of $x_{t.}$ The latter in turn evolves as

$$x_t = \left(c_t - \frac{h}{dz_t}c_{t-1}\right)^{\gamma} x_{t-1}^{1-\gamma}. \tag{8}$$

and is associated with a multiplier μ_t. This evolves somewhat involved according to

$$\mu_t = \beta E_t dz_{t+1}^{1-\sigma} (1-\gamma) \frac{x_{t+1}}{x_t} \mu_{t+1} - \chi L_t^{1+\nu} \left(c_t - \frac{h}{dz_t} c_{t-1} - \chi L_t^{1+\nu} x_t \right)^{-\sigma} . \tag{9}$$

For the special case of $\gamma = 1$ and $h = 0$ the condition reduces to the more familiar equation

$$\lambda_t = c_t^{-\sigma} \left(1 - \chi L_t^{1+v}\right)^{1-\sigma} ,$$

as the multiplier μ_t drop out. Equation (7) has the same intuition, except that it adds the effect of habits in consumption ($h > 0$) and the strength of the wealth effect, as given by $\gamma < 1$. The intertemporal Euler equations derived from the holdings of real bonds is

$$\lambda_t = \beta (1 + r_t) E_t \lambda_{t+1} (dz_{t+1})^{-\sigma} , \tag{10}$$

which balances current and future marginal utilities. The only difference with a standard Euler equation is the presence of the scale factor resulting from defining λ_t as a stationary variable.

Factor supplies are determined by an intra-temporal condition for labor supply and intertemporal conditions for investment and capital. Labor supply is chosen to meet

$$\lambda_t w_t = (1+\nu) \chi x_t L_t^{\nu} \left(c_t - \frac{h}{dz_t} c_{t-1} - \chi L_t^{1+\nu} x_t \right)^{-\sigma} , \tag{11}$$

which equalizes the utility value of the real wage with the disutility of labor. Capital is chosen such that the marginal value of a unit of installed capital is equal to its discounted expected value, which is the sum of the marginal product of capital and the expected value of capital, net of depreciation. Thus capital adjusts to meet the Euler equation

$$Q_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} dz_{t+1}^{-\sigma} \left[r_{t+1}^k + Q_{t+1} (1-\delta) \right] , \tag{12}$$

with r_t^k reflecting the rental rate of capital and Q_t the marginal value of a unit of installed capital. In the presence of adjustment costs investments follows

$$\begin{aligned} 1 \;&=\; Q_t \left(1 - \frac{\phi}{2} \left(\frac{i_t}{i_{t-1}} dz_t - \exp(g) \right)^2 - \frac{i_t}{i_{t-1}} dz_t \phi \left(\frac{i_t}{i_{t-1}} dz_t - \exp(g) \right) \right) \\ &\quad + \phi E_t \beta \frac{\lambda_{t+1}}{\lambda_t} dz_{t+1}^{-\sigma} Q_{t+1} \left(\frac{i_{t+1}}{i_t} dz_{t+1} - \exp(g) \right) \left(dz_{t+1} \frac{i_{t+1}}{i_t} \right)^2 , \end{aligned} \tag{13}$$

and the stationary capital stock evolves according to

$$k_t = (1-\delta)\frac{k_{t-1}}{dz_t} + i_t\left[1 - \frac{\phi}{2}\left(\frac{i_t}{i_{t-1}}dz_t - \exp(g)\right)^2\right]. \tag{14}$$

Aggregate output of firms in the domestic economy equals

$$y_t = \left(\frac{k_{t-1}}{dz_t}\right)^{\alpha} L_t^{1-\alpha}. \tag{15}$$

The optimal choices of k_{t-1} and L_t are governed by the equality of marginal products to factor prices:

$$w_t = (1-\alpha)\left(\frac{k_{t-1}}{dz_t}\right)^{\alpha} L_t^{-\alpha}, \tag{16}$$

$$r_t^k = \alpha\left(\frac{k_{t-1}}{dz_t}\right)^{-(1-\alpha)} L_t^{1-\alpha}. \tag{17}$$

Finally, from the budget constraint it follows that output equals spending plus net foreign asset accumulation:

$$y_t = c_t + i_t + b_t - b_{t-1} + \frac{dz_t - (1+r_{t-1})}{dz_t}b_{t-1}. \tag{18}$$

These stationary conditions together with (1)-(6) and their foreign counterparts determine the equilibrium of the system, along with the corresponding transversality conditions. A rational expectations equilibrium of the model is a set of sequences $\{c_t$, c_t^*, y_t, y_t^*, L_t, L_t^*, i_t, i_t^*, λ_t, λ_t^*, μ_t, μ_t^*, Q_t, Q_t^* b_t, k_t, k_t^*, r_t, r_t^*, r_t^k, $r_t^{k^*}$, w_t, w_t^*, x_t, x_t^*, dz_t, dz_t^*, g_t, $g_t^*\}$ for $t \geq 0$ given the sequences of shocks $\{\varepsilon_t$, ν_t, ε_t^*, $\nu_t^*\}_{t=0}^{\infty}$. The model is solved by log-linearizing the stationary equilibrium equations around the stationary steady state, and applying familiar methods for the solution of rational expectations models (e.g., Sims, 2002). Recall that while we maintain rationality agents given their information set, we depart from the standard rational expectations assumption in that information on the economy (productivity growth) is imperfectly observed. Technically speaking, to simulate the model, we feed the state of the technology as inferred by the Kalman filter into the state-space representation of the rational expectations equilibrium.

4 Analysis

4.1 Calibration

In our calibration, we assign values to the deep parameters using guidance from the literature and a priori reasoning. Their values are displayed in Table 1:

Table 1: Parameters of the model

Parameters		Values
φ	International risk premium	0.0002
σ	Coefficient of relative risk aversion	2
ν	Labor supply parameter	1
L	Steady state hours worked	0.2
γ	Wealth elasticity of labor supply	0.0075
h	Habit formation in consumption	0.85
β	Discount factor	0.9975
α	Capital share	0.3
δ	Depreciation rate	0.025
ϕ	Investment adjustment costs	5
ρ_g	Persistence of growth rate of technology	0.99
η	Signal to noise ratio	0.0064
$\mathcal{P}^*$	Size of the foreign economy	3

International capital mobility is high, in that we set the international risk premium parameter to a value of $\varphi = 0.0002$, since we consider a long-run horizon, and a period where financial market appear highly integrated. For simplicity we assume that in the steady state $B = B^* = 0$. The size of the domestic economy in the world economy is assumed to be 25% so that $\mathcal{P}^*$ equals 3.

Household preferences are calibrated based on values from Schmitt-Grohe and Uribe (2008), who estimate the Jaimovich-Rebelo (2008) model of news shocks. They find a value for the coefficient of relative risk aversion of $\sigma = 2$ and a labor supply parameter $\nu = 1$, which implies a Frisch labor supply elasticity of 1. In line with Schmitt-Grohe and Uribe we set the steady state hours worked $L = 0.2$. Most crucially, the parameter determining the response of labor supply to changes in consumption, is set based on the estimation of Schmitt-Grohe and Uribe, at $\gamma = 0.0075$. This is somewhat higher than the value of Jaimovich and Rebelo, who set $\gamma = 0.0001$. Both values imply that the positive effect of increased consumption on labor supply only slowly fades away. For $\gamma < 1$, the marginal disutility of labor will rise as much with consumption, since X_t will grow slower than the stock of consumption, $C_t - h\mathcal{C}_{t-1}$, so that $X_t / (C_t - h\mathcal{C}_{t-1})$ initially falls. The implication of this is that current labor supply may rise after increased perceived wealth. Thus, as γ falls the wealth elasticity of labor supply declines. We also follow Schmitt-Grohe and Uribe estimates and set the habit formation in consumption $h = 0.85$. This value is in line with other estimates of habit formation in the literature, e.g. Smets and Wouters (2007). The discount factor β is set at a quarterly value of 0.9975.

In terms of technology, the parameter of the production function is set at $\alpha = 1/3$. Capital depreciates at quarterly rate $\delta = 0.025$. The investment adjustment costs are calibrated at $\phi = 5$, which is in line with the literature (e.g., Smets and Wouters, 2003). The persistent component of technology is set at $\rho_g = 0.99$. This is within the range of values used by other authors, e.g. Edge such as (2007) and Erceg et al. (2006). The volatilities, i.e. the transitory and the persistent component of productivity growth are set to $\sigma_\nu^2 = 0.004^2$ and $\sigma_\omega^2 = 0.05^2$, respectively. Hence, the signal-to-noise ratio is $\eta \equiv \sigma_\nu^2 / \sigma_\omega^2 = 0.0064$, which is line with other work in the literature, e.g. Tambalotti (2003). The foreign country has identical preferences and technologies. All these parameter values determine the steady state of the stationary version of the model. For the simulations, we rescale the endogenous variables either to actual levels or to growth rates, to match them with actual data.

4.2 Impulse responses

The main element of the model is imperfect information about the persistent component of changes in labor productivity. In this section, we illustrate the impulse responses of key variables to both transitory and persistent productivity shocks, under full and imperfect information.

Figure 3 illustrates the agents inference problem to a persistent productivity growth shock. The domestic economy is hit by a growth rate shock to technology. However, agents consider innovations to permanent one-off changes to the level of technology to be more likely then trend growth innovations. Consequently, they will initially assume that the innovation to technology growth is mostly due to a level shock to technology. This is illustrated by the initial mitigated increase in the perceived growth rate, the dashed red line in Figure 3.

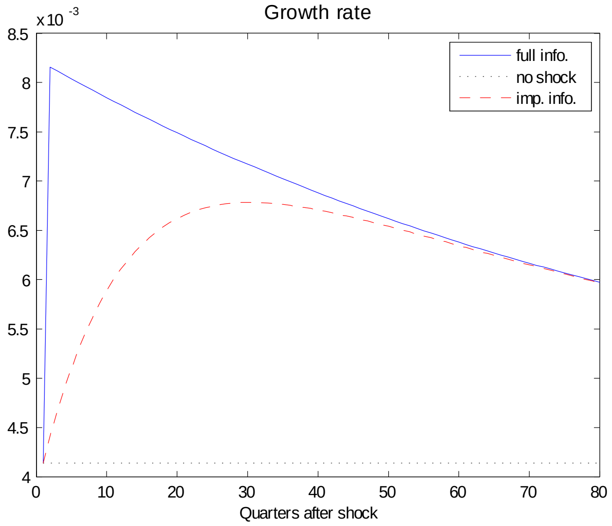

Figure 3: Growth rate shock to technology

Only as agents observe the realized technology over time they are able to extract the true growth process from the data. Figure 4 illustrates that a growth rate shock leads to delayed responses of output, consumption and investment under imperfect information.

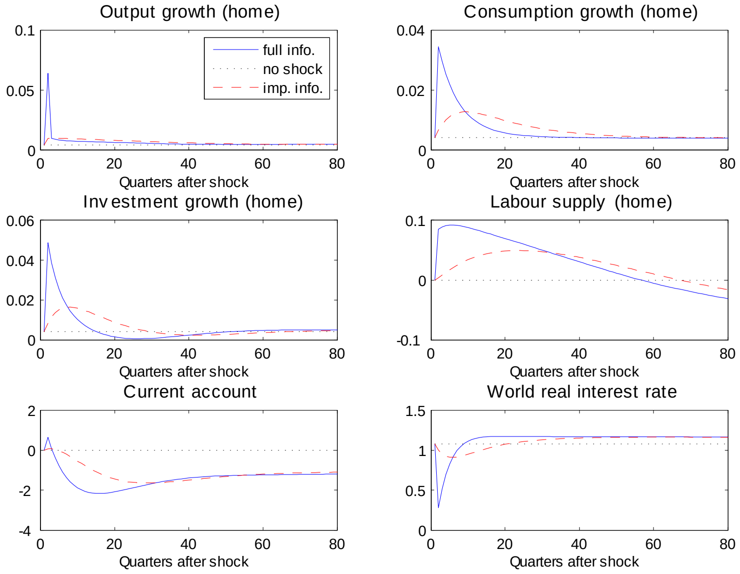

Figure 4: Impulse responses the model's endogenous variables to a growth rate shock

Since agents only realize over time that the level of technology is growing they only start slowly to consume and invest more. Thus, in contrast to the full information case, the current account only slowly moves into deficit. The current account deficit occurs since households present value of future income, relative to prevailing borrowing costs has increased due to a higher growth rate in technology.

Figure 5 shows the inference problem to a level shock to technology in the domestic economy.

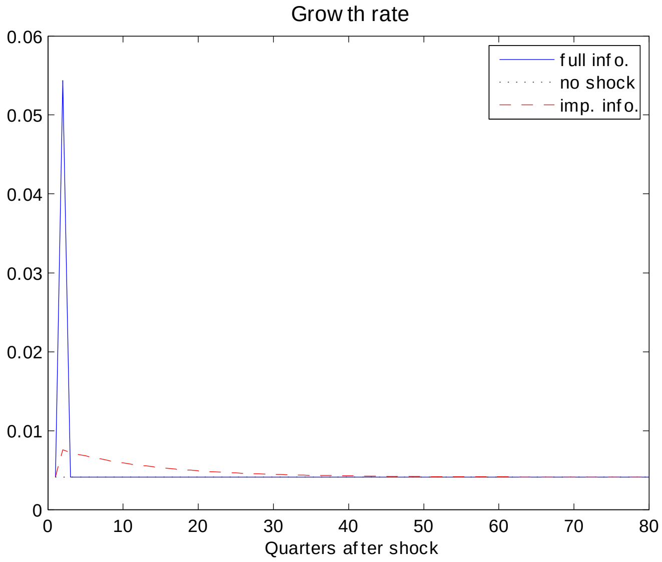

Figure 5: Level shock to technology

In the initial period households assume under imperfect information that a fraction κ of the innovation in technology is due to a growth rate shock to technology. Only over time they learn about the true nature of the technology innovation and slowly revise technology growth downwards. This downward revision has also strong implications for the endogenous variables of the model.

Figure 6 shows that the downward revision of technology growth leads to a higher volatility in output, consumption, investment and the current account under imperfect information. It follows from the permanent income hypothesis that under full information the current account only responds mildly to a level shock to technology while, as shown in Figure 4, households want to smooth consumption when the economy is hit by a growth rate shock. Consequently, in the case of full information a growth rate shock leads to an amplified response of the current account.

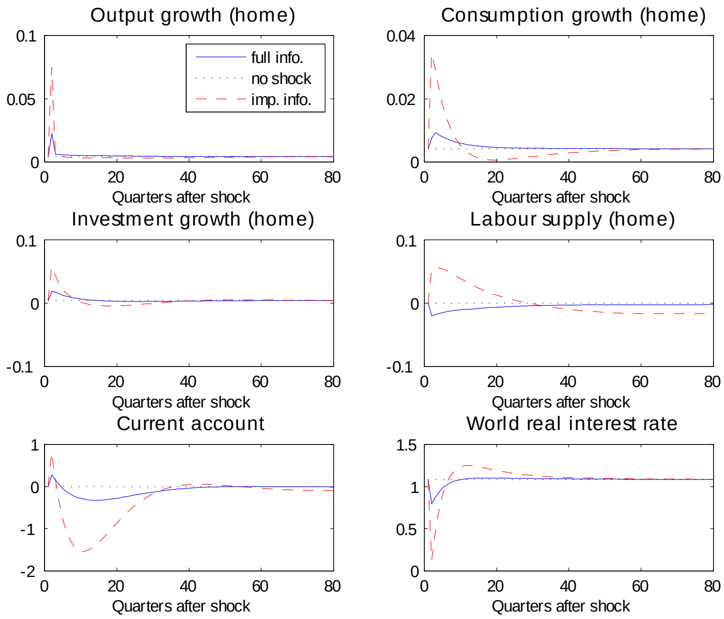

Figure 6: Impulse responses the model's endogenous variables to a level shock

In contrast, if agents do not have full information about the true nature of technology and have to form expectations about future long-run growth, it follows that they need to revise their perceived wealth as well as consumption and investment choices. This has strong implications for the adjustment of the current account, as shown in figures 4 and 6. Thus, the revision of trend growth perceptions might be central to the understanding of the evolution of the current account, as we will show in the following section.

4.3 Trend growth perceptions and the U.S. current account

In this section we use our model to examine the implications of changes in perceived trend growth on the domestic and foreign economies. Following the evidence from the Consensus survey expectations of long-run real GDP growth presented in section 2, we here first document the close relationship between these survey-based expectations and the expectations on productivity long-run growth. These we extract from the technology estimates of Basu, Fernald and Kimball (2006) using the Kalman Filter specified above. Then we use the model to show how those perceived future growth rates determine the U.S. current account. We arrive at two main results: The estimated changes in perceived trend productivity growth match both in terms of magnitude and timing the survey estimates of long-run U.S. real GDP growth. This provides evidence for the plausibility of our Kalman filter specification. Furthermore, the simulated U.S. current account matches the data very closely. Thus we conclude that the "global imbalances" can be also be understood as the optimal outcome of a world in which perceptions of trend growth undergo substantial fluctuations.

4.3.1 Survey expectations of trend growth and Kalman-filtered trend growth

We now show the extent to which Kalman-filtered trend growth rates match the survey expectations on long-run growth. The solid blue line in Figure 7 shows the evolution of long-run growth expectations as introduced in section 2.

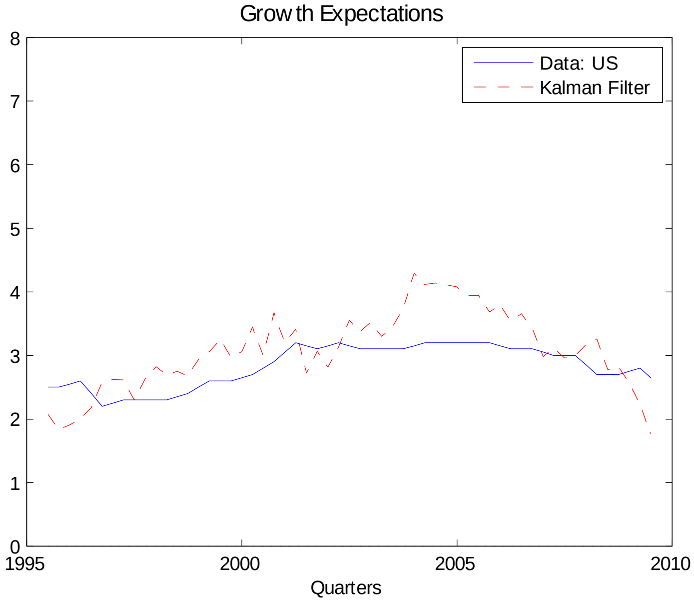

Figure 7: US Consensus growth forecasts and estimated trend growth rates

The dashed red line shows the perceived trend growth rate $g_{t|t}$ based on the Kalman filter when we feed into the model the technology growth estimate of Basu et al. (2006) as the observable change in technology $\ln dz_t$. As shown in the figure, the resulting model-implied perception of trend growth matches closely the survey expectations.

4.3.2 Some considerations regarding the world real interest rate

It is important to capture the external financing conditions for U.S. households and firms. Therefore, Our aim is to ensure that our simulations are consistent with the realized path of the world real interest rate. The evolution of the world real interest rate is mainly captured by changes in output, consumption and investment in the rest of the world. It would be possible to subsume a set of shocks in the rest of the world which are able to replicate the evolution of the world real interest rate as shown in Figure 2. However, as has been pointed out by Caballero et al.(2008) and others, there exists a wide set of factors which contributed to explaining the world real interest rate. We avoid taking a stance on which combination of factors explain its evolution. We therefore take the world real interest rate as the mirror image of the evolution of the rest of the world. Thus, instead of modelling the foreign economy directly, we utilise the evolution of the world real interest rate to capture the behavior of the rest of world in our simulation exercise.

4.3.3 The US current account and wealth

We use the estimated, model-implied perception of trend growth to simulate the model. That is, while aggregate productivity follows the above TFP process by Basu, Fernald and Kimball (2006), the perceived permanent and transitory components of productivity growth are those extracted via the Kalman filter. Agents in the model use the perception of the permanent component to calculate their current wealth, based on which they optimally choose their consumption and investment path. Depending on whether the perceived growth trend is high or low relative to the prevailing world interest rate, agents will be borrowers or lenders in world capital markets.

The resulting evolution of the U.S. current account is shown in Figure 8. The solid blue line represents data, the dashed red line the model-implied evolution. The simulated series matches the data quite closely, despite the very simple structure of our model. Thus, the evolution of the U.S. current account seems to be explained simply by changes in perceptions of trend growth as well as by the evolution of the world real interest rate.

Thus, the build-up of “global imbalances” can to a substantial degree be explained without resorting to any type of financial market innovations or imperfections, but simply as the optimizing outcome of basic international consumption smoothing in response to changing income prospects.

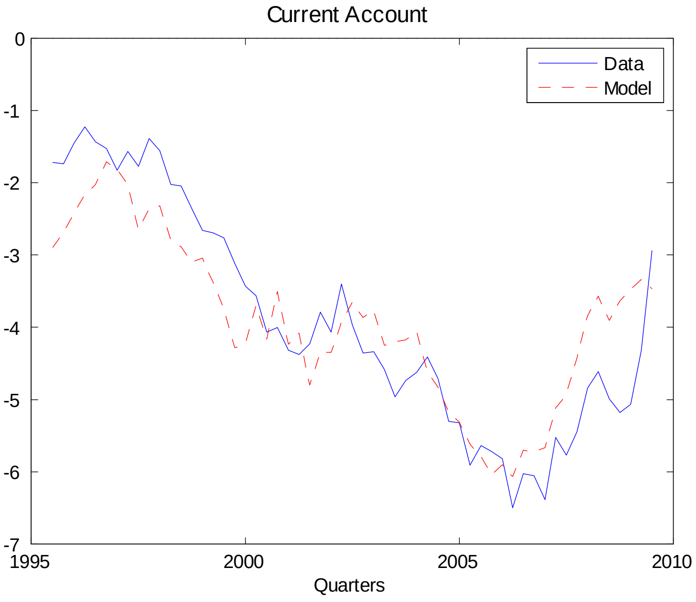

Figure 8: Actual and simulated evolution of the US current account

To see this more clearly consider the model implied evolution of the present value of income, illustrated in Figure 9.

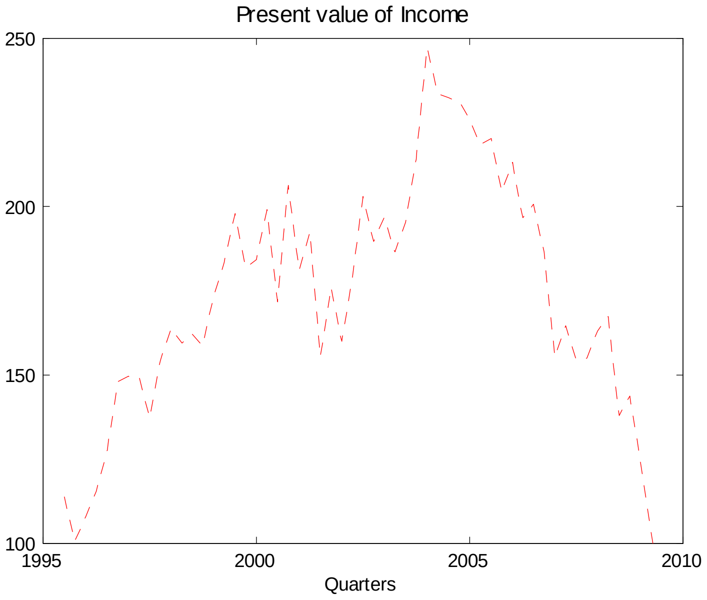

Figure 9: Simulated present value of income

Figure 9 shows clearly the large changes in wealth that go along with changes in perceived income growth. Since the mid-1990s, wealth has been growing. Interestingly, we observe a downward revision of wealth after 2000, the bursting of the dotcom bubble, followed, however, by a rather accelerated increase in 2003 to 2004. From 2004 up until 2006 wealth perceptions stagnated at a high level, until falling slightly in 2007. Most striking is the large drop in wealth towards the end of the sample. The revision in wealth must, by the logic of our model, lead to adjustments in agents consumption and investment plans and should manifest itself also in output movements.

4.3.4 The adjustment of output, consumption and investment

In our model, the adjustment to changing growth trends is efficient ex ante, since agents react in the best possible manner to the best possible information available. However, ex-post, growth expectations might turn out to be wrong, and behavior will appear suboptimal. Assuming that an optimal filtering process gives the best possible estimate of the long-run growth trend, outcomes cannot be improved upon. We stress that even in the absence of seemingly obvious deviations from fundamentals, such as bubbles, the adjustment to fundamental changes can induce substantial strain on an economy. In spite of the absence of financial or nominal frictions the model is able to generate a behavior of output that is in some respects closely matching actual data. We can generate a sizable downturn in output – an actual recession in terms of negative growth rates.

Figure 10 shows U.S. output growth rates since 1995 along with output growth as predicted by the model.

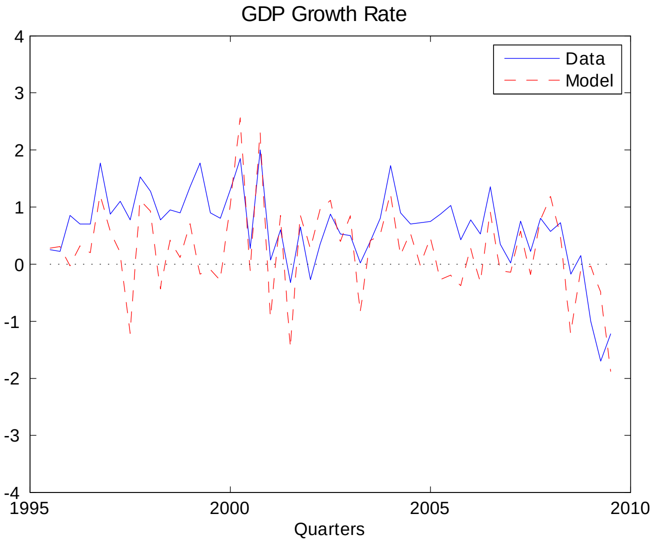

Figure 10: Simulated and actual U.S. output growth

The correlation between model and data growth rates is quite striking, and we do see a downturn at the end of the sample. The dynamics of output are governed by three forces. First, there is the direct impact of aggregate productivity on output. Second, there is the direct impact of labor supply, and third, the more long-run adjustment arising from investment that raises the capital stock in response to rising productivity (actual and projected). Most important is the behavior of labor supply. As mentioned earlier, household preferences allow labor supply to respond positively to favorable growth expectations. Under standard preferences, labor supply would decline in times of faster consumption growth, and thereby mitigating the output response to perceived higher income growth.

The movements in consumption associated with the revisions of wealth are depicted in Figure 11. Towards the end of the sample, consumption growth falls. We can also see the drop in consumption growth after the dotcom bubble and in 2007, corresponding to our calculation of wealth. This reflects the importance of expectations for the determination of consumption growth relative to income growth, which in turn determines the evolution of the current account. Naturally, part of consumption growth is also driven by the contemporaneous actual changes in aggregate technology.

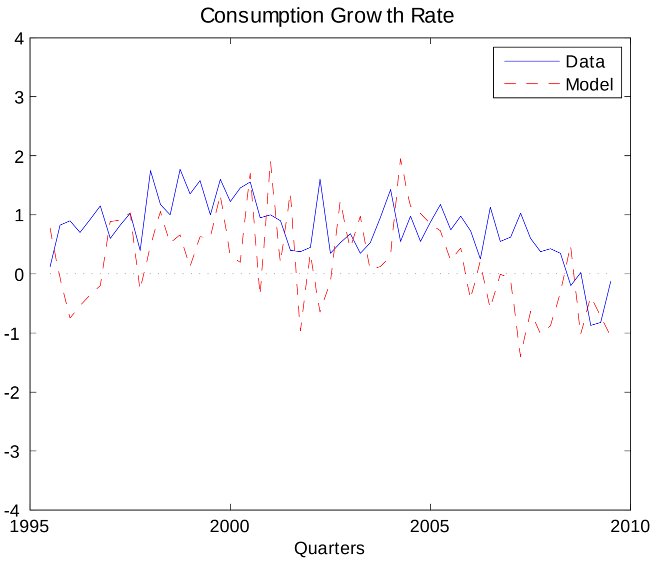

Figure 11: Simulated and actual U.S. consumption growth

Naturally, part of consumption growth is also driven by the contemporaneous actual changes in aggregate technology. What becomes obvious from Figure 11 is that simulated and actual Us consumption growth does not move that closely in the beginning of the 2000s and between 2006 and 2007. However, this gap closes towards the end of the sample.

Figure 12 illustrates the evolution of investment between 1995 and 2009. The simulated series matches the actual investment growth data qualitatively. Both time series point towards a down turn in investment after the dot com bubble after 2000. The accelerated increase in investment between 2003 to 2005 and down swing in investment from 2007 onwards is also captured by the simulated time series.

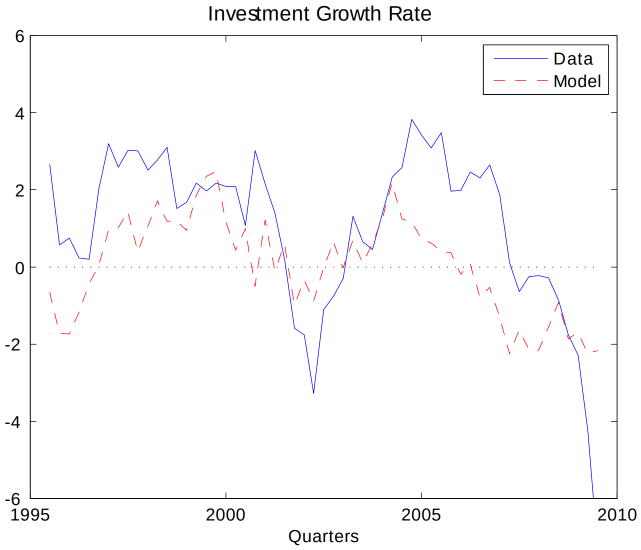

Figure 12: Simulated and actual U.S. investment growth

4.3.5 The importance of trend growth expectations and the world real interest rate for the US current account

In the following we outline the relevance of trend growth expectations and the world real interest rate in explaining the evolution of the US current account. To do so, we make use of a counter factual exercise. Figures 13 shows the evolution of the simulated US current account letting the world real interest rate vary while holding growth expectations constant. Figure 14 illustrates the importance of trend growth expectations for the simulated evolution of the US current account, holding the world real interest rate constant. The two figures illustrate that neither changing productivity growth expectations nor interest rates alone can explain the US current account data.

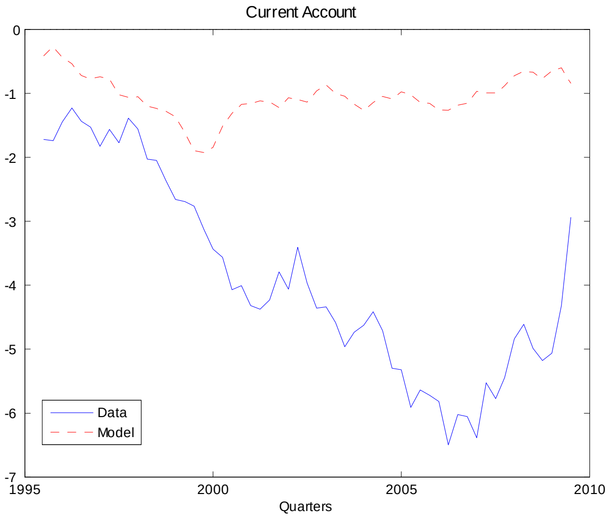

Figure 13: Actual and simulated evolution of the US current account (world real interest rate only)

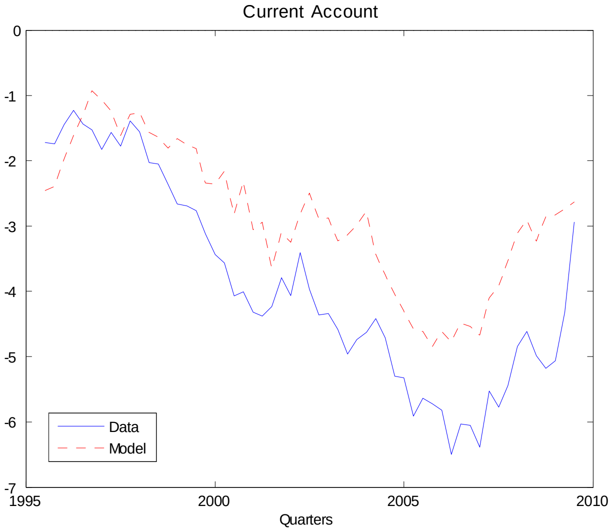

Figure 14: Actual and simulated evolution of the US current account (Growth perceptions only)

Figure 13 shows that holding growth expectations fixed, lower world interest rates since the late 1990s can be seen to have played a role, but they can at best explain a fifth of the widening U.S. current account deficit. Furthermore, since world interest rates have stayed low during and after the economic crisis of 2008/2009, they cannot explain the narrowing of the current account by the end of this decade. This instead is accounted for by the drop in perceived U.S. productivity growth since about 2006, as shown in Figure

14. Thus we conclude that changing growth expectations are an important driver of the U.S. current account and consequently of global imbalances.

4.4 Robustness

[TBC]

5 News and growth expectations

In this section we aim to clarify the relation between the central role in our analysis of learning about the persistence of a technology shock and the rapidly developing literature on the role of news about future technology as source of business fluctuations. In so doing, we also examine the role of our use of GHH preferences for the dynamic responses of the key variables in our economy. An important role of these preferences is suggested by the seminal paper of Jaimovich and Rebelo (2009), who explore the importance of preferences for the comovement of output, hours and consumption in response to news about future technology shocks.

The experiment considered in much of the news literature – information arriving at date t about a technology improvement at date $t + k$ that is found at that time to be either happening or not – looks at first quite distinct from our signal extraction problem. However, a technology shock occurring in our model sets in motion not only a change in the level of technology today, but also revisions to expectations about future technology levels. Moreover, in *every* period after a shock occurring, there will be further revisions to expectations of technology in *all* future periods (although vanishing asymptotically). These revisions are illustrated in Figures 15 and 16.

Figure 15 considers the case of a shock ν to the growth rate of technology occurring at date 1. At date 1, the log level of technology rises by 1. Because the signal-to-noise ratio in our calibration is small, this shock is mostly seen as a permanent shift in the level to technology, with very little consequences for future growth. As time goes by and agents update their beliefs $g_{t|t}$, not only are expectations of future levels of technology being revised upwards, the slope of the expected trajectory of technology becomes more closely aligned to the actual slope (the solid blue line) of the evolution of technology.

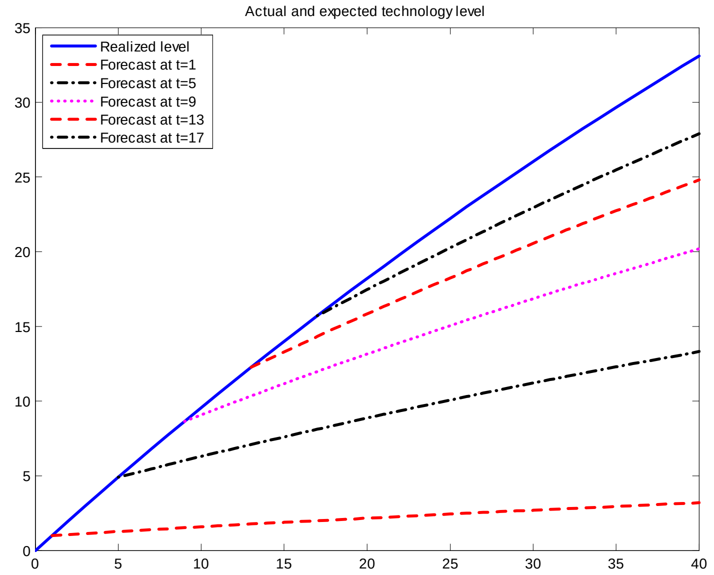

Figure 15: Revisions to expected log technology (Growth rate shock)

Thus, in the spirit of the news literature, in each period there are expectations of future, as yet unrealized, technology increases that are being revised up from the previously held beliefs, and in each period agents are surprised by the actual increase in the level of technology.

As shown in Figure 16, apart from the increase in the level of technology in the impact period, the logic of revisions of beliefs works in reverse when the source of the technology improvement is a one-off increase ω in the level of technology.

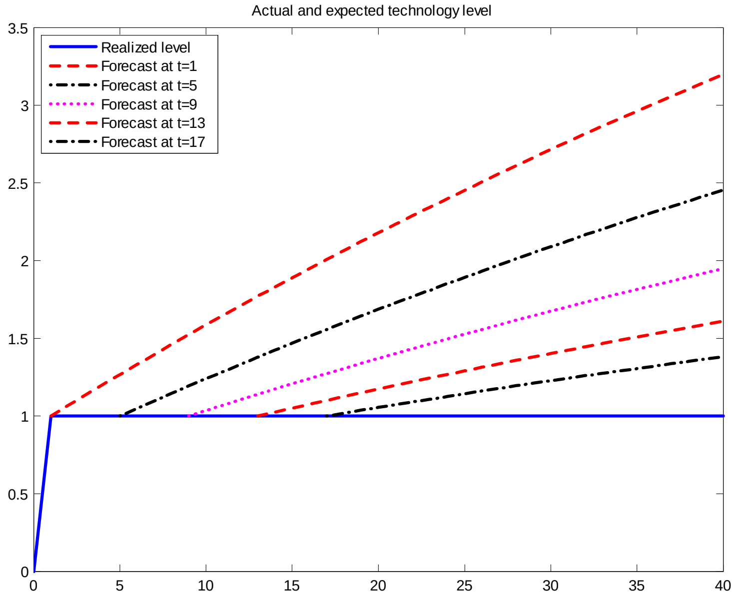

Figure 16: Revisions to expected log technology (Level shock)

The initial small revision in the estimate of $g_{t|t}$ caused by the shock leads to expectations of (albeit small) future technology improvements that fail to materialize. The news process in our model is thus a case of what Walker and Leeper (2010) call “correlated news,” except that each shock in our model triggers an infinite *sequence* of such correlated news shocks, a new one in each period due to the revision of $g_{t|t}$. The impulse responses presented in Figures 4 and 6 can thus be viewed as the sum of IRFs to a traditional technology shock and IRFs to a sequence of subsequent news arrivals.

Given the close relation between technology shocks, be they level or growth rate shocks, and perceived news about future technology, in Figure 17 we explore the role of information and of our preference specification for the response of hours to technology shocks.

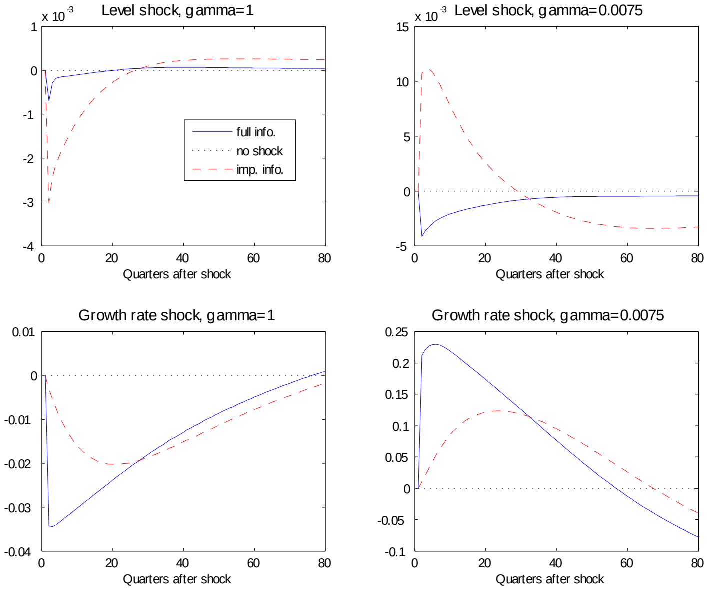

Figure 17: IRFs of hours worked (Preferences and learning)

As highlighted by Jaimovich and Rebelo (2009), the class of preferences considered by King et al. (1988) induces in response to expected future technology increases a decline in hours today due to the wealth effect on labor. This effect is not present with the preferences considered by Greenwood et al. (1988). In the class of preferences proposed by Jaimovich and Rebelo that we use here, the parameter γ measures the strength of this wealth effect, with $\gamma = 1$ corresponding to the King et al. preferences and $\gamma = 0$ to the preferences of Greenwood et al. The responses shown in the left panels of Figure 17 are derived using $\gamma = 1$, those in the left panels using a value of γ very close to 0.

Consider first the solid blue lines, which are the impulse responses derived under perfect information about the nature of the shock. The upper two panels show that qualitatively the hours responses to a one-off permanent increase in the level of technology are quite similar under the two preference specifications: Because consumption is permanently higher, temporarily labor input falls, with this effect being larger in the case of γ close to 0. The lower two panels, by contrast, illustrate the effect of the "news component" in a growth rate shock on hours: With $\gamma = 1$ hours sharply decline due to the wealth effect of expected future productivity gains whereas with $\gamma = 0$ the opposite is the case.

In the case of learning – the dashed red lines – the responses to a growth rate shock (the lower two panels) are qualitatively similar to those under perfect information, due to the constant arrival of positive news about future technology implied by the updating of beliefs $g_{t|t}$. The interesting case is that of a level shock. In the case of $\gamma = 1$ (the upper left panel) the initial expectation of future technology increases (as shown by the forecast of technology in the impact period, the first red dashed line in Figure 16) reinforces the negative impact response under perfect information. By contrast, under GHH preferences (the upper right panel) the expectation of future technology increases leads to an increase in hours that more than offsets the negative effect of the increase in technology upon impact. Over time, as the expected technology increases fail to materialize, the response of hours turns negative.

6 Conclusions

We have presented a way to think of aggregate adjustments as being driven by changes in (relative) expectations about productivity growth. ...In a time of a financial and economic crisis, it may appear inappropriate to present a purely real international business cycle model, with a minimal number of adjustment frictions and learning. We show, first, that growth expectations are crucial for the evolution of the current account, as discussed before by Engel and Rogers (2007) and others. Using both U.S. and international

Consensus Forecast data on expected long-run growth rates, we find that the change in relative growth expectations since the late 90s is highly correlated with the buildup of the U.S. current account deficit.

Secondly, within a two-region DSGE model, we show that optimizing agent's responses to changes in growth expectations lead to sizable current account deficits and strong output reactions. Especially, when we use derived expectations from Kalman-filtered productivity growth data, we obtain realistic current account movements, as well as output swings for the end of the last decade. We also find indications that the past 5 years of the current account deficit were not justified by fundamentals.

The key mechanism is the response of consumption and labor supply to changed perception of future income growth. With our assumptions on preferences and our calibration, labor supply adjusts to positive shocks in a manner that supports our aim: it rises when prospects improve. We face the same fundamental challenge as the news shock literature: how to generate positive comovement when perceived wealth increases, and resolve it in a way taken by that literature.

We emphasize that these results obtain without any recourse to financial frictions – our financial markets are frictionless – nor consideration of housing or other durable asset markets. Furthermore, bubbles are absent. We do not claim that these factors do not matter in the global economy. In fact, they may be crucial in translating beliefs of agents into actual investments and inflows of capital. Beliefs in the unfailing growth of the U.S. housing markets led investors to buy securities backed by mortgages. Implicitly they were sharing house buyers beliefs in future house price appreciations. Fundamentally these could only have been justified by beliefs in future income growth. Conceivably, if the financial sector had not validated these beliefs by triple-A rating the assets drawn on these bonds, then the vast amounts of funds would not have been channeled into the U.S. Even though we do not address problems of financial market turmoil, we believe to add a useful perspective on the crisis: that adjustments to changed perceptions, which may or may not be irrationally exuberant, can lead to sharp adjustments in real variables. This has also been shown for the housing market in a paper by Kahn (2009).

We documented the sizable movements in wealth that the model generates depending on changed beliefs about the future. In a monetary economy, these beliefs must be embedded in financial assets, or find themselves on the balance sheets of financial institutions. How can a bank survive a revision of wealth of 20 percent or more? Apparently an adjustment that would be smooth in a real economy with perfect capital market, can lead to serious disruptions in institutions that carry the nominal representations of real assets (i.e., promises of the future). Our tacit conclusion concerning macroprudential regulation is that authorities should define a probability distribution of possible revisions in wealth, calculate the tensions it would cause on financial institutions, and force the system to hold enough reserves to survive such revisions, and in the worst case step in itself. Nonwithstanding moral hazard problems, a sense of the degree of possible disruptions is what is needed for macroprudential supervision. A model such as ours may be the starting point of a framework that may provide guidance in this direction.

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