Global Imbalances and Structural Change in the United States

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ABSTRACT

The United States has borrowed heavily from the rest of the world since the early 1990s. At the same time, the share of employment in goods-producing sectors has fall dramatically. We build a general equilibrium model of the United States and the rest of the world to assess the quantitative impact of U.S. borrowing on goods-sector employment, both in the past and the future. We find that U.S. borrowing is not an important driver of sectoral employment dynamics between 1992 and 2011 — differences in productivity growth across sectors is the most important factor. When the U.S. begins to repay its debt to the rest of the world, its trade balance will permanently reverse but goods-sector employment will continue to fall.

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1. Introduction

Between 1992 and 2011, households and the government in the United States borrowed heavily from the rest of the world. As U.S. borrowing — measured as the current account deficit — grew, the U.S. net international investment position deteriorated by 3.6 trillion dollars, and, by 2011, the United States owed the rest of the world 4.0 trillion dollars. During the same time period, the share of employment in goods-producing sectors — manufacturing, mining, and agriculture — fell dramatically. Between 1992 and 2011, the fraction of total labor compensation paid in goods-producing sectors fell from 19.7 percent to 12.4 percent. These facts beg an important question: is U.S. borrowing from the rest of the world an important factor in explaining the decline in goods-sector employment? As a corollary, will repayment of this debt — which will require the U.S. to export more than it imports — lead to a resurgence in goods-sector employment?

In this paper, we develop a dynamic, multisector, general equilibrium of the United States and the rest of the world in which U.S. borrowing is driven by increased foreign demand for saving — a *global savings glut*, borrowing terminology from Fed Chairman Ben Bernanke. We calibrate our model to match the U.S. trade balance between 1992 and 2011 and show that it closely matches several other key facts. We use our model to assess the quantitative impact of U.S. borrowing during this period on sectoral employment dynamics by comparing our baseline model's predictions to a counterfactual scenario in which the savings glut never took place. The decline in goods sectors' share of total labor compensation in the no-borrowing counterfactual is only 18.5 percent smaller than the decline in the baseline model. As the U.S. starts to repay its debt the trade balance will rise, reaching a surplus of almost 1 percent of GDP by 2024. Nevertheless, the goods sectors' share of total labor compensation will continue to fall, and will reach almost exactly the same level by 2024 regardless of whether the savings glut happens or not. Our results indicate that borrowing from the rest of the world is not an important driver of structural change in the United States over the past two decades, and repayment of this borrowing is not likely to mitigate a continued decline in goods-sector employment in the future.

Our model has several features that make it uniquely well-suited to address these issues in a rigorous, quantitative fashion. Most multi-sector models in international macroeconomics treat goods — manufacturing, mining, and agriculture — as the only traded sector, and lump all other sectors into a single non-traded sector. Our model has three sectors: goods, services, and construction. Both goods and services can be traded, which allows us to capture the fact that the U.S. consistently runs a substantial trade surplus in services. We choose a higher elasticity of substitution between domestic and foreign inputs in the goods sector to match the fact that the goods trade balance is significantly more volatile than the services trade balance (see figure 3). Construction is the only non-traded sector in our model and is used almost entirely to produce investment goods, which means that construction is more sensitive than other sectors to the effects of capital flows and economic fluctuations in general. We also have an input-output structure in which goods are disproportionately used as intermediate inputs. Perhaps most importantly, we allow labor productivity to grow at different rates across sectors, which allows us to match the fact that labor productivity in the goods sector grew at a faster pace than in other sectors over the past two decades. Our results indicate that this traditional structural change force is the primary driver of reallocation of labor across sectors in the model. While agents have perfect foresight in our baseline model, it is straightforward (albeit technically complex) to extend our model to a stochastic setting, which we do in our sensitivity analysis. We believe our study is the first to implement rational expectations in this kind of non-stationary modeling framework.

Our results also highlight two puzzles related to the price effects of the savings glut. First, why did U.S. borrowing continue to increase once the U.S. real exchange rate began to depreciate? In other words, why did U.S. purchases of foreign goods and services continue to increase once they stopped getting cheaper and started getting more expensive? Figure 1 illustrates this timing disconnect. After appreciating by more than 20 percent, the U.S. real exchange rate began to depreciate in 2002, but the U.S. trade deficit continued to rise until 2006. While out model matches the amount of real exchange rate appreciation between 1992 and 2011, it fails to generate this disconnect — the real exchange rate depreciates more slowly in the model than the data. The second puzzle concerns U.S. real interest rates. Ben Bernanke, among others, has argued that demand for saving in the rest of the world is an important factor in explaining persistently low U.S. real interest rates (Bernanke, 2005). In our model, foreign demand for saving has very little impact on U.S. real interest rates (see figure 5). The intuition for this result is straightforward: U.S. borrowing primarily financed purchases of foreign goods, and the elasticity of substitution between these goods and the U.S. consumption basket is quite low. Our results are in fact consistent with some empirical estimates on the impact of foreign purchases of

U.S. assets on U.S. real interest rates (Warnock and Warnock, 2008; Krishamurthy and Vissing Jorgensen, 2008). This suggests we may need to look towards other factors, like domestic developments in housing and financial markets discussed by Obstfeld and Rogoff (2009) and Bernanke, Bertaut, DeMarco, and Kamin (2011), to explain low U.S. real interest rates.

Our sensitivity analysis demonstrates that our main results about the impact of U.S. borrowing on sectoral employment dynamics are very robust. We have studied the impact of a sudden stop in foreign lending, as in Mexico in 1994—1995, instead of the gradual rebalancing process in our baseline model, labor adjustment frictions, uncertainty over the length of the period of U.S. borrowing, and calibrating our model to match real exchange rate movements instead of the trade balance. None of these extensions change our main employment dynamics results in a quantitatively meaningful way. We do show, however, that both a sudden stop and adjustment frictions affect the welfare impact of U.S. borrowing and the repayment process. A sudden stop will be quite painful compared to a more gradual rebalancing process, and when accompanied by a large negative TFP shock it can wipe out the welfare benefit of U.S. borrowing compared to the no-borrowing counterfactual we document in the baseline model. Adding labor adjustment costs makes sudden stops more painful, but also increases the welfare benefit from U.S. borrowing. With adjustment costs, the long-term decline in goods-sector employment is costly, and borrowing from the rest of the world allows the U.S. to pay for part of these costs using future consumption rather than current consumption.

The rest of the paper proceeds as follows. Section 2 discusses our paper's relation to several strands of literature. In section 3 we describe our model environment. Section 4 provides an outline of our quantitative strategy. Section 5 details our calibration and data sources for exogenous processes like technological and demographic change. Section 6 presents our main results. We conduct a sensitivity analysis in section 7. Section 8 provides concluding remarks.

2. Related literature

Global financial imbalances

Our study provides a quantitative assessment of the historical impact of U.S. borrowing from the rest of the world on the U.S. economy and the impact they will have in the future if and when they begin to unwind. We remain neutral concerning the source of these imbalances, the degree to which they contributed to the financial crisis of 2008, and the likelihood of a gradual versus swift unwinding. The literature proposes a variety of plausible explanations for increased demand for saving in the rest of the world, particularly developing countries like China: financial underdevelopment (Mendoza, Quadrini, and Rios-Rull, 2009; Caballero, Farhi, and Gourinchas, 2008), demographic differences (Du and Wei, 2010), and differences in business cycle or growth properties (Backus, Henricksen, Lamber, and Telmer, 2006; Perri and Fogli, 2010). We take no stand on this issue, modeling foreigners' demand for saving in a simple, reduced-form manner.

Numerous studies argue that these imbalances are not a benign phenomenon; that they unsustainable and likely to result in financial crisis. See, for example, Obstfeld and Rogoff (2009), Krugman (2007), Roubini and Setzer (2005), Summers (2004). We take no stand on the connection between these imbalances and the recent financial crisis, nor do we take a stand on how these imbalances affect the likelihood of a subsequent crisis in the future. We do not model the financial crisis of 2008 at all, in fact, except to the extent that we capture some of its impact by calibrating our model to match the trade deficit. We do, however, provide an assessment of the impact of a future "sudden stop" to the savings glut on the U.S. economy. Our results indicate that such an eventuality would indeed be quite painful economically, resulting in a substantial output contraction and large welfare losses. We also show, however, that a sudden stop is likely to have a negligible impact on the U.S. economy in the medium and long-run; the U.S. economy will be on roughly the same trajectory several years later regardless of whether the sudden stop happens or not.

Structural change

The structural change literature emphasizes asymmetric productivity growth rates as an important driver of long-run reallocation of labor across sectors. Several recent studies embed this mechanism, originally due to Baumol (1967), into growth models that are consistent with aggregate balanced growth (Ngai and Pissarides, 2007; Buera and Kaboski, 2009). We take a similar approach, using data on value added and labor compensation in the goods, services and construction sectors in the United States over the 1987—2011 period to inform our calibration of productivity growth rates in each of these sectors. Labor productivity in the goods sector grew at a substantially higher rate over this period than in the other two sectors, and this plays a large role in causing employment in the goods sector to decline in our model.

Several recent papers incorporate structural change into open-economy models to study the importance of trade for long-run compositional changes (Echevarria, 1995; Matsuyama, 1992 and 2009; Ui, Yi, and Zhang, 2012; Sposi, 2012). With the exception of Sposi (2012), these studies use models of balanced trade, abstracting from international capital flows. We place capital flows at the forefront of our analysis. To our knowledge, our study is the first to perform a quantitative assessment of the relative contributions of traditional structural change forces (asymmetric labor productivity growth) and the savings glut to the decline in goods sector employment in the United States. Our results indicate that the savings glut is responsible for only a small fraction of this decline; traditional structural change mechanisms are the dominant factor.

3. Model

We model an economy with two countries, the United States and the rest of the world (RW). Throughout this section, we use the superscripts *us* and *rw* to denote prices, quantities, and parameters in the United States and the rest of the world, respectively. The length of a period is one year. Each country has a representative household that works, consumes, and saves to maximize utility subject to a sequence of budget constraints. We assume that the only internationally traded assets are one-period bonds denominated in units of the U.S. consumer price index (CPI). Households have perfect foresight over the future trajectory of the world economy — there is no uncertainty. Each country produces several commodities that serve both intermediate and final uses. We model the U.S. production structure in detail, using an input-output structure which we calibrate to a benchmark input-output matrix published by the U.S. Bureau of Economic Analysis (BEA). We model production in the rest of the world in a simpler fashion, abstracting from investment and domestic input-output linkages. We model the U.S. government in a somewhat reduced-form fashion as well. The government's spending and debt as fractions of U.S. GDP are specified exogenously, and the government levies lump-sum taxes on U.S. households to ensure its budget is satisfied.

Production

The United States produces 4 commodities: goods y_{gt}^{us}, services, y_{st}^{us}, construction y_{ct}^{us}, and investment y_{it}^{us}. The rest of the world produces its own goods, y_{gt}^{rw}, and services, y_{st}^{rw}. The superscripts us and rw denote the country. The subscripts *g, s, c,* and *i* denote sectors: goods, services, construction, and investment. The price of each commodity uses similar notation; for example, the price of U.S. investment is p_{it}^{us}. All commodities are sold in perfectly competitive markets, and sectors in the United States are linked together through an input-output structure. Throughout this section we use upper case notation to distinguish composites and investment from intermediates, and we use the subscript $j \in \{g, s, c\}$ to index goods, services and construction sectors. In what follows we provide a detailed description of production of each type of commodity, starting with U.S. production then moving on to the rest of the world.

In the U.S. economy, each commodity $j \in \{g, s\}$ is produced using capital k_{jt}^{us} and labor ℓ_{jt}^{us}, along with intermediate inputs of U.S. goods z_{gjt}^{us}, U.S. services z_{sjt}^{us}, U.S. construction z_{cjt}^{us}, and imported intermediate inputs m_{jt}^{us} purchased from the same sector j in the rest of the world. The production functions take the form

$$(1)\ y_{jt}^{us} = M_j^{us} \left\{ \mu_j^{us} \left(\min \left[\frac{z_{gjt}^{us}}{a_{gj}^{us}}, \frac{z_{sjt}^{us}}{a_{sj}^{us}}, \frac{z_{cjt}^{us}}{a_{cj}^{us}}, A_j^{us} \left(k_{jt}^{us}\right)^{\alpha_j} \left(\gamma_{jt}^{us} \ell_{jt}^{us}\right)^{1-\alpha_j} \right] \right)^{\zeta_j} + (1-\mu_j^{us}) \left(m_{jt}^{us}\right)^{\zeta_j} \right\}^{\frac{1}{\zeta_j}}.$$

This nested production function embeds a Leontief input-output structure in a standard Armington aggregator. The parameters of the production functions are as follows:

- M_j^{us} and A_j^{us}: constant scaling factors used to facilitate calibration.
- μ_j^{us}: governs the share of imports in production.
- ζ_j: governs the elasticity of substitution between domestic and imported inputs.
- $\left(a_{gj}^{us}, a_{sj}^{us}, a_{cj}^{us}\right)$: shares of goods, services, and construction in gross output.
- γ_{jt}^{us}: labor productivity.
- α_j: capital's share in value added.

We allow the Armington elasticities ζ_j to differ across sectors in order to capture the fact that the goods trade balance is considerably more volatile than the services trade balance (see figure 3). We also allow labor productivity γ_{jt}^{us} to grow at different rates across sectors to capture the fact that productivity in the goods sector has grown faster than in other sectors (see figure XX). We discuss these issues in more detail in the calibration section.

Consistent with our input-output table, the construction sector is the only purely nontraded sector. The production function in the construction sector is a special case of (1) where the share of imported inputs in production is set to zero:

$$(2) \qquad y_{ct}^{us} = \min\left[\frac{z_{gct}^{us}}{a_{gc}^{us}}, \frac{z_{sct}^{us}}{a_{sc}^{us}}, \frac{z_{cct}^{us}}{a_{cc}^{us}}, A_c^{us} \left(k_{ct}^{us}\right)^{\alpha_c} \left(\gamma_{ct}^{us} \ell_{ct}^{us}\right)^{1-\alpha_c} \right].$$

U.S. producers in all three sectors $j \in \{g, s, c\}$ choose inputs of intermediates and factors to minimize costs, which implies standard marginal product pricing conditions for capital and labor.

The U.S. investment goods is produced using inputs z_{git}^{us}, z_{sit}^{us}, and z_{cit}^{us} of composite goods, composite services, and construction (all domestic) according to a Cobb-Douglas technology:

$$(3) \qquad y_{it}^{us} = G\left(z_{git}^{us}\right)^{\theta_g} \left(z_{sit}^{us}\right)^{\theta_s} \left(z_{cit}^{us}\right)^{\theta_c}, \quad \theta_g + \theta_s + \theta_c = 1.$$

Our Cobb-Douglas specification is consistent with empirical evidence reported by Bems (2008), who shows that expenditure shares on investment inputs are approximately constant over time across a range of countries.

We model the rest of the world's production structure in less detail, abstracting from investment and input-output linkages. Goods and services in the rest of the world are produced using labor ℓ_{jt}^{rw} and imported intermediate inputs m_{jt}^{rw} from the same sector j in the United States. The production functions are simpler nested Armington aggregators of the form

$$(4) \qquad y_{jt}^{rw} = M_j^{rw} \left(\mu_j^{rw} \left(\gamma_{jt}^{rw} \ell_{jt}^{rw}\right)^{\zeta_j} + (1-\mu_j^{rw})\left(m_{jt}^{rw}\right)^{\zeta_j} \right)^{\frac{1}{\zeta_j}}.$$

The parameters have the same interpretation as described above.

Households

Each country is populated by a continuum of identical households. We draw a distinction between the total and working-age populations as these two groups grow at different rates. We denote the total U.S. population by $\tilde{n}_t^{us}$ and the working-age population by $\overline{\ell}_t^{us}$. We evaluate consumption per capita on an adult-equivalent basis, defining the U.S. adult-equivalent population as

(5) $$n_t^{us} = \bar{\ell}_t^{us} + (\tilde{n}_t^{us} - \bar{\ell}_t^{us})/2$$

The rest of the world's demographic variables are defined similarly. As in the description of the economy's production structure, we begin with the problem of a U.S. household then move on to the rest of the world.

We normalize the amount of time available for work and leisure by a U.S. working-age person to one and denote total U.S. labor supply by ℓ_t^{us}. U.S. households choose labor supply, consumption of composite goods and services, c_{gt}^{ush} and c_{st}^{ush}, investment i_t^{us}, and bond holdings b_t^{us}, to maximize utility

(6) $$\sum_{t=0}^{\infty}\beta^t\left(\left(\varepsilon^{ush}\left(\frac{c_{gt}^{ush}}{n_t^{us}}\right)^{\rho}+(1-\varepsilon^{ush})\left(\frac{c_{st}^{ush}}{n_t^{us}}\right)^{\rho}\right)^{\frac{\eta\psi}{\rho}}\left(\frac{\bar{\ell}_t^{us}-\ell_t^{us}}{\bar{\ell}_t^{us}}\right)^{(1-\eta)\psi}-1\right)/\psi$$

subject to the budget constraints

(7) $$p_{gt}^{us}c_{gt}^{ush}+p_{st}^{us}c_{st}^{ush}+p_{it}^{us}i_t^{us}+q_t b_{t+1}^{ush}=w_t^{us}\ell_t^{us}+p^{us}(p_{gt}^{us},p_{st}^{us})b_t^{ush}+(1-\tau_k^{us})r_{kt}^{us}k_t^{us}-T_t^{us},$$

the law of motion for capital

(8) $$k_{t+1}^{us}=(1-\delta)k_t^{us}+i_t^{us}$$

The appropriate non-negativity constraints, initial conditions for the capital stock and bond holdings $\bar{k}_0^{us}$ and $\bar{b}_0^{us}$, and a constraint on bond holdings that rules out Ponzi schemes but does not otherwise bond in equilibrium. We use the superscript ush for U.S. households' consumption and bond holdings to distinguish them from those of the U.S. government, for which we use the superscript usg. Notice that we also g to distinguish goods from services and construction.

Bonds are denominated in units of the U.S. CPI, which we define as

(9) $$p^{us}(p_{gt}^{us},p_{st}^{us})=\frac{p_{gt}^{us}c_{g1992}^{ush}+p_{st}^{us}c_{s1992}^{ush}}{P_{g1992}^{us}c_{g1992}^{ush}+P_{s1992}^{us}c_{s1992}^{ush}}$$

We use discount bonds, so the price q_t represents the price in period *t* of one unit of the U.S. CPI basket in period *t*+1. The real interest rate in units of the U.S. CPI is given by

(10) $$1+r_{t+1} = p^{us}(p_{gt}^{us}, p_{st}^{us})/q_t$$

Households pay constant proportional taxes τ_k^{us} on capital income and a lump-sum tax or transfer T_t^{us}. We use the capital income tax to obtain a sensible calibration for the initial capital stock and depreciation rate. In our calibration we also allow the tax rate on capital income in 1993 to differ from the constant rate in order to match the level of investment in 1992. The first-order conditions for bonds and investment imply a no-arbitrage condition:

(11) $$p^{us}(p_{gt}^{us}, p_{st}^{us})/q_t = \left((1-\tau^{us})r_{kt+1}^{us} + p_{it+1}^{us}(1-\delta)\right)/p_{it}^{us}$$

which says that the return on bonds must equal the return on investing in an additional unit of capital. During the sudden stop episode that may occur in 2015, bond-holdings are fixed and the internal real interest rate is determined endogenously in each country separately.

The rest of the world's households solve a slightly simpler problem. We abstract from investment dynamics in the rest of the world, so the only way the rest of the world's households can save is by buying bonds. Labor supply is still endogenous, however, and the rest of the world's households have similar preferences:

(12) $$\sum_{t=0}^{\infty}\beta^t\omega_t^{rw}\left(\left(\varepsilon^{rw}\left(\frac{c_{gt}^{rw}}{n_t^{rw}}\right)^{\rho}+(1-\varepsilon^{rw})\left(\frac{c_{st}^{rw}}{n_t^{rw}}\right)^{\rho}\right)^{\frac{\eta\psi}{\rho}}\left(\frac{\bar{\ell}_t^{rw}-\ell_t^{rw}}{\bar{\ell}_t^{rw}}\right)^{(1-\eta)\psi}-1\right)/\psi$$

The only differences are the share parameter ε^{rw} and the parameter ω_t^{rw}. The latter is a "shock" (perhaps this term is not entirely appropriate in a perfect-foresight model) which we calibrate to match the U.S. trade balance during the savings glut period of 1992–2011. During this period ω_t^{rw} falls, reflecting a reduction in utility gained from consumption during this period compared to future consumption. The rest of the world's representative household chooses labor supply ℓ_t^{rw}, consumption of goods and services, c_{gt}^{rw} and c_{st}^{rw}, and bond holdings b_t^{rw} to maximize utility subject to the budget constraints

(13) $$p_{gt}^{rw} c_{gt}^{rw} + p_{st}^{rw} c_{st}^{rw} + q_t b_{t+1}^{rw} = w_t^{rw} \ell_t^{rw} + p^{us}(p_{gt}^{us}, p_{st}^{us}) b_t^{rw}$$

and similar non-negativity and no-Ponzi constraints to those that U.S. households face. The rest of the world's CPI is defined similarly to equation (9). We then define the real exchange rate as

(14) $$rer_t = p^{rw}(p_{gt}^{rw}, p_{st}^{rw}) / p^{us}(p_{gt}^{us}, p_{st}^{us})$$

U.S. government

The government in the United States levies taxes and sells bonds in order to finance exogenously-required expenditures on consumption of composite goods and services. The government's budget constraint is

(15) $$p_{gt}^{us} c_{gt}^{usg} + p_{st}^{us} c_{st}^{usg} + q_t b_{t+1}^{usg} = \tau_k^{us} r_{kt}^{us} K_t^{us} + T_t^{us} + p^{us}(p_{gt}^{us}, p_{st}^{us}) b_t^{usg}$$

As mentioned above, we use the superscript g to distinguish public from private U.S. consumption and bond holdings. We specify time paths for government consumption expenditures and debt as fractions of GDP, using historical data for 1992—2011 and projections for the future. We allow the lump-sum tax T_t^{us} to vary as necessary to ensure that the government's budget constraint is always satisfied. More formally, let ν_t and υ_t denote the fractions of nominal GDP in period *t* that government consumption expenditures and debt must equal respectively. We require that

(16) $$p_{gt}^{us} c_{gt}^{usg} + p_{st}^{us} c_{st}^{usg} = \nu_t GDP_t^{us}$$

and

(17) $$b_t^{usg} = -\upsilon_t GDP_t^{us}$$

In this setup we must specify the degree to which the government can substitute goods for services in consumption. We remain neutral as to whether goods and services are complements or substitutes for the government, setting the elasticity of substitution to one. The government therefore chooses c_{gt}^{usg} and c_{st}^{usg} to maximize

(18) $$\left(c_{gt}^{usg}\right)^{\varepsilon^{usg}} \left(c_{st}^{usg}\right)^{1-\varepsilon^{usg}}$$

subject to (16). We assume that government spending does not enter the household's utility function (or equivalently, enters in a separable fashion), nor does it enter any of the production functions.

It is important to point out that our model exhibits near-Ricardian equivalence. Ricardian equivalence breaks down only when we introduce unexpected events — the savings glut and the sudden stop. Unanticipated changes in the time path of government spending and debt that accompany these events do affect the model's equilibrium dynamics, particularly in the short run.

Market clearing and equilibrium

The market clearing conditions for U.S. composite goods and services are

(19) $$c_{jt}^{ush} + c_{jt}^{usg} + m_{jt}^{rw} + z_{gjt}^{us} + z_{sjt}^{us} + z_{cjt}^{us} + z_{jit}^{us} = y_{jt}^{us}, \quad j \in \{g, s\}$$

Construction is not traded or used for consumption, so the market clearing condition for construction is

(20) $$z_{cgt}^{us} + z_{cst}^{us} + z_{cct}^{us} + z_{cit}^{us} = y_{dt}^{us}.$$

Market clearing for U.S. investment is

(21) $$i_t^{us} = y_{it}^{us}.$$

The market clearing conditions for the rest of the world's composite goods and services are

(22) $$c_{jt}^{rw} + m_{jt}^{us} = y_{tjt}^{rw}, \quad j \in \{g, s\}.$$

Factor markets must also clear:

(23) $$k_{gt}^{us} + k_{st}^{us} + k_{ct}^{us} = k_t^{us}, \quad \ell_{gt}^{us} + \ell_{st}^{us} + \ell_{ct}^{us} = \ell_t^{us}, \quad \ell_{gt}^{rw} + \ell_{st}^{rw} = \ell_t^{rw}.$$

Finally, the bond market must clear:

(24) $$b_t^{ush} + b_t^{usg} + b_t^{rw} = 0.$$

An equilibrium in our model for a given sequence of time series parameters $\{\omega_t^{rw}, \nu_t, \upsilon_t\}_{t=0}^{\infty}$ and initial conditions $(\bar{b}_0^{ush}, \bar{b}_0^{ush}, \bar{k}_0^{us})$ consists of a sequence of all model variables such that households in the U.S. and the rest of the world maximize their utilities subject to their constraint sets, prices and quantities satisfy marginal product pricing conditions for all 10 commodities, all market clearing conditions are satisfied, and the U.S. government solves its consumption spending allocation problem in each period. When we solve the model numerically, we require that equilibria converge to balanced growth paths after 100 years. There are an infinite number of possible balanced growth paths — one for every combination of public and private bond holdings.

4. Outline of our quantitative strategy

Before we proceed with our calibration and quantitative exercises, we pause for a moment to briefly describe our overall quantitative strategy. Our first step is to calibrate the model's parameters and initial conditions so that the equilibrium in which neither the sudden stop nor savings glut occur replicates the benchmark input-output matrix and national account figures published by the BEA for 1992. We calibrate the rest of the world's preference shock ω_{1992}^{rw} to match the U.S. trade balance in 1992, and assume that it converges quickly to a constant value of one thereafter. In other words, we do not calibrate our model to match any time series at all. We treat the model's equilibrium dynamics in this scenario as a counterfactual exercise, allowing us to ask the question: what would have happened over the past two decades and in the future had the savings glut not happened at all?

Our second step is to solve for the model's dynamics in the scenario where the savings glut actually happens. Here, we hold fixed all parameters calibrated during the first step, and calibrate the values of ω_t^{rw} for 1993–2011 so that the equilibrium replicates exactly the aggregate U.S. trade balance during this period. As in the first step of our exercise, we assume that ω_t^{rw} gradually converges to one once this period ends. We use the equilibrium values of capital and bond holdings in 1993 from the no-savings glut first step as initial conditions in this second step. The savings glut, which manifests in our model as temporarily reduced utility from consumption and leisure in the rest of the world, is an unanticipated event. Model agents in 1992 do not expect it to occur -- its sudden onset is a completely unexpected — but they have perfect foresight thereafter. We refer to the model's post-2011 dynamics in this scenario as a "gradual rebalancing," representing the outcome of a slow, orderly end to the forces driving the savings glut.

5. Calibration

In the spirit of multisector, static applied general equilibrium models like Kehoe and Kehoe (1994), we calibrate many of the model's parameters so that the equilibrium in 1992 of the model in which the savings glut does not occur replicates the input-output matrix for that same year published by the BEA. There are several discrepancies between the NIPA tables and the input-output matrix, so we let the NIPA tables take precedence and perform several adjustments using the RAS algorithm to the input-output matrix so that it matches the relevant NIPA data exactly. Our adjusted input-output matrix is listed in table 1. The dynamic, open-economy nature of the model introduces several other elements to the model's calibration. We set the time series for sector-level productivity growth, demographics, and government exogenously.

U.S. production parameters

We normalize quantity units so that U.S. GDP is equal to 100 and all prices are equal to one in 1992 — all quantities are expressed as percentages of 1992 GDP. We compute all parameters for the Leontief portion of the U.S. production functions in equation (1) directly from the input-output matrix. For example, to compute a_{gc}^{us}, the amount of goods needed to produce one unit of gross output in the construction sector, we divide the value in the goods row and construction column (3.79) by gross output in the construction column (10.71). We use a similar procedure to calculate factor shares in value added for each sector. For the Armington aggregators in (1) we first specify values for the elasticities of substitution between domestic and imported inputs. There is some debate over this elasticity as business cycle models tend to imply low elasticities while analysis of trade policy changes often suggest much higher elasticities (see Ruhl (2008) for a detailed discussion). In order to match sector-level trade balance dynamics closely, we set the goods Armington elasticity to 3 and the services elasticity to 1. We then use equilibrium conditions (marginal product pricing and zero profits) to μ_j^{us} from the input-output matrix. The scale factors M_j^{us} follow immediately. We use equilibrium conditions in a similar procedure to calibrate the investment sector's parameters.

Household and government parameters

We set the elasticity of intertemporal substitution $1/(1-\psi)$ to 0.5. We set the long-run interest rate to 3 percent. We set the discount factor β so that this interest rate is consistent with balanced growth. We set the elasticity of substitution between goods and services in consumption, $1/(1-\rho)$, to 0.5. The household's first-order conditions imply

$$(25) \qquad \frac{\varepsilon^{ush}}{1-\varepsilon^{ush}} = \frac{p^{us}_{g1992}}{p^{usS}_{s1992}} \left(\frac{c^{ush}_{g1992}}{c^{ush}_{c1992}} \right)^{1-\rho}$$

which we use to calibrate the share parameter ε^{ush}. We then use data on hours worked to calibrate η. A similar procedure yields the government's share parameter ε^{usg}.

U.S. initial conditions

To calculate the initial capital stock we set the 1992 real interest rate to 4 percent. The real interest rate in 1992 is not an equilibrium object in our model; it would be determined in 1991 and 1992 is our initial year. The real interest rate on 10-year U.S. treasury bonds is approximately 4 percent in 1992. Our results are not sensitive to alternative approaches to calibrating the initial capital stock. Depreciation was 11.7 percent of GDP in 1992, so given a tax rate on capital income τ^{us}_k we can then calibrate the initial capital stock as

$$(26) \qquad k^{us}_{1992} = \frac{(1-\tau^{us}_k) r^{us}_{k1992} k^{us}_{1992} - \delta k^{us}_{1992}}{r_{1992}}.$$

and the depreciation rate as

$$(27) \qquad \delta = \frac{11.7}{k^{us}_{1992}}.$$

We choose $\tau^{us}_k = 0.415$, which implies a value of $\delta = 0.062$, well within the standard range of annual depreciation rates used in the literature. U.S. government debt was 42.8 percent of GDP in 1992. We use this figure to set the government's bonds in 1992, $\bar{b}^{usg}_{1992}$, then set private bond holdings, $\bar{b}^{ush}_{1992}$, so that total net foreign assets $\bar{b}^{ush}_{1992} + \bar{b}^{usg}_{1992}$ equals negative 6 percent of GDP (this value comes from Lane and Milesi-Feretti, 2007).

Constructing the rest of the world

To calibrate the remaining parameters we need to specify what the "rest of the world" is in the data. We calculate the United States' top 20 trading partners, ranked by average annual bilateral trade (exports plus imports) between 1992 and 2011, and weight them by their average share of U.S. total annual trade (again, exports plus imports) during this period. We use these countries weights to construct a composite trading partner, thinking of the rest of the world as being composed of 20 identical countries that all look like this composite. See Appendix A for more detail.

To calculate the rest of the world's gross output of goods and services, we take a weighted average of goods and services output of these 20 countries and multiply these figures by 20 to get total output of goods and services in the rest of the world. We use equilibrium conditions in a similar manner as before to calibrate the rest of the world's Armington aggregators and preference parameters.

Exogenous processes

We use historical data and future projections from the United Nations World Population Prospects 2010 Revision to construct time series for the demographic parameters for both the United States and the rest of the world (using the same 20 countries and weights as before). We use the "medium" scenario for the future projections. The United States and the rest of the world are projected to grow at different rates well past the 100-year cutoff, so to ensure balanced growth in our computation we assume that populations in both countries begin to converge to constant levels after 2050. Our model's equilibrium dynamics between 1992 and 2030, the period on which we focus, are not sensitive to this assumption.

We calculate sector-level productivity growth rates using data on value added and labor compensation by sector from the BEA for the period 1987–2011. We use this data to perform growth accounting by sector, and find that the average growth rates of labor productivity over this period are 4.3 percent in goods, 1.3 percent in services, and -0.04 percent in construction. We use these values in the model between 1992 and 2030, then assume that all sector-level growth rates converge to 2 percent per year slowly over time, again to allow the equilibrium converges to a balanced growth path.

We construct several time series for government consumption expenditure and debt. We use historical data from the NIPA tables for government consumption expenditures and from the U.S. Congressional Budget Office (CBO) for government debt. We use CBO projections as a starting point for our own projections, but make adjustments to allow for balanced growth in the long run. The CBO's long-run projections for government debt as a fraction of GDP vary greatly from year to year and are, quite frankly, implausible. The 2012 Long Term Budget Outlook provides two possible scenarios for government debt as a fraction of GDP in the long run, neither of which are remotely stationary. The first, the "extended baseline" scenario, has debt as a fraction of GDP falling below zero in the long run. The other, the "extended alternative fiscal scenario," has government debt reaching more than 250 percent of GDP by 2045. These two scenarios differ substantially from the 2011 projections.

In the no-savings glut counterfactual scenario, we assume that government spending as a fraction of GDP remains constant, and that government debt gradually rises to 60 percent of GDP over time. In modeling the savings glut, we use the actual data for 1992–2011. In the gradual rebalancing scenario, consumption spending as a fraction of GDP rises gradually to approximately 23 percent in the long run, while debt/GDP converges to 74 percent. In the sudden stop scenario, we use the same spending series but assume that debt/GDP falls to 60 percent once the savings glut ends, reflecting a permanent change in U.S. government policy that coincides with the sudden stop.

6. Quantitative results

We begin this section by discussing our baseline model's historical performance in matching the U.S. trade balance (aggregate and disaggregated), real exchange rate, and sectoral labor dynamics between 1992 and 2011. We then compare these results to the counterfactual scenario in which the savings glut never took place. We finish by discussing our baseline model's predictions for these key variables in the future.

Dynamics of the trade balance and real exchange rate

Figures 2 and 3 plots the model's results for the aggregate trade balance and real exchange rate over the period 1992–2024. In the data, the U.S. trade balance falls from -0.52 percent of GDP in 1992 to -5.75 percent in 2006, then rises back up to -3.09 percent by 2011. By construction, our model matches this series exactly. In the absence of a sudden stop, our model predicts that the trade balance will turn positive in 2017, and rise gradually to 0.82 percent of GDP by 2024. Beyond this point, the trade balance continues to rise, reaching a maximum of 1.17 percent of GDP in 2052, and remaining above 0.5 percent of GDP in perpetuity. This is the primary consequence of the savings glut — the United States has to pay back the debt it has incurred over the past two decades.

In the data, the real exchange rate appreciates by 21.8 percent between 1992 and 2002, then depreciates by 27.9 percent between 2002 and 2011. Our model matches almost exactly the maximum amount of depreciation (21.6 percent in the model versus 21.8 percent in the data). This maximum occurs, however, in 2006 in the model, the same year in which the trade deficit peaks. More broadly, looking at the model's results for the trade balance and the real exchange rate we see that they always move simultaneously — an increase in the trade deficit is always accompanied by a real exchange rate appreciation. The reason for this tight link is obvious. An increase in the trade deficit implies an increase in foreign goods (and a small increase in foreign services) shipped to the United States. In equilibrium, this increase in supply generates a reduction in the price of foreign output relative to its U.S. counterpart. We view the fact that the U.S. continued to borrow heavily after the real exchange rate began to depreciate in 2003 as a puzzle — why would U.S. demand for foreign goods not wane in the face of an increase in price? We discuss this in more detail below. After 2011, our model predicts that the U.S. real exchange rate will continue to depreciate, flattening out near its 1992 value by the end of the observation period. This reflects a gradual reduction in the supply of foreign goods and services in the United States — once the trade balance begins to level off, this supply levels off as well, and so does the price.

Figure 4 plots disaggregated trade balances for goods and services separately. During the 1992—2011 period, the model matches the data almost exactly for both sectors. Standard international macro models that treat goods — agriculture, mining, and manufacturing — as the only traded sector and ignore services trade cannot match this fact. Also note how our calibration of the Armington elasticities (3 for goods, 1 for services) allows us to capture the fact that the goods trade balance is much more volatile than the services trade balance. After 2011, the model predicts that the goods trade balance will rise, reaching -0.21 percent of GDP by 2024. The services trade balance rises slightly, to 1.03 percent of GDP by 2024. In other words, the entire

U.S. trade surplus in 2024 will be composed of services; the United States will still import more goods than it exports.

Labor reallocation across sectors

Figures 5 and 6 plot our model's results for the goods and construction sectors' share of total labor compensation. This is the natural data analogue with which to compare our model's results. Hourly wages differ across sectors; an hour of labor in the goods sector is not equivalent to an hour of labor in services. In our model, one unit of labor supply is interchangeable with another, and all three sectors pay the same wages. Loosely, we aim to compare each sector's share of total effective labor supply in the model and the data.

In the data, the goods sector's share falls from 19.69 percent in 1992 to 12.39 percent in 2011, a drop of 7.30 percent. In the model, the goods labor compensation share falls to 14.5 percent by 2011, a drop of 5.15 percent. Thus our model captures 71 percent of the decline in the goods sector's share of total labor compensation during the period. This share continues to fall in the model once the rebalancing process begins after 2011, reaching 13.6 percent in 2024 and eventually reaching close to 12 percent by 2050. So even when the United States stops borrowing and begins to reduce its consumption of imported goods, employment in the goods sector continues to fall. This result is driven by the fact that labor productivity grows faster in goods than in the other sectors. Combined with the low elasticity of substitution between goods and services in consumption, this is a standard result in the structural change literature (see, e.g. Ngai and Pissarides, 2007).

In the data, the construction sector's share of total labor rises from 4.37 percent in 1992 to 5.69 percent in 2006, then falls to 4.38 percent in 2011. This reflects the construction boom and subsequent bust following the financial crisis. Construction's share of labor compensation peaks in 2006 in the model as well, reaching 6.3 percent. In other words, our model actually over-predicts the increase in construction employment during the period. Because we do not model the financial crisis at all (except to the extent that trade balance dynamics during 2008—2011 were driven in part by the crisis), our model does not generate a large decline in construction's employment share after 2006. It falls to 6.12 percent by 2011, then rises slightly to 6.35 percent by 2024, again driven by structural change.

A natural question arises in light of these results: what is the contribution of the savings glut (and the subsequent rebalancing process) to reallocation of labor across sectors? In other words, how much of these results is driven purely by standard structural change forces? Figure 4 also plots our model's results for labor compensation shares in the counterfactual scenario in which the savings glut does not occur. Table 3 lists the goods and services sectors' shares of total labor compensation in the data, the gradual rebalancing scenario, and the no-savings glut counterfactual for each year between 1992 and 2024. For the goods sector, it is clear that the bulk of employment share dynamics in the model are driven by that sector's faster productivity growth, i.e., standard structural change forces. While the good's sectors share of employment compensation initially falls faster with the savings glut than without, by 2011 this share has fallen to 15.49 percent in the counterfactual scenario, as compared to 12.39 percent in the data and 14.54 percent in the model with the savings glut. This means that in the counterfactual, the model still captures 58 percent of the drop in the goods employment share — 82 percent of what the model with the savings glut captures. In other words, only 18 percent of the drop in the goods employment share between 1992 and 2011 is driven by the savings glut, the rest is driven by structural change. By 2024, the goods sector's share of labor compensation falls to 13.62 in the rebalancing scenario and 13.04 percent in the counterfactual. So the fact that the U.S. goods trade balance rises somewhat after the savings glut occurs does put some upward pressure on goods sector employment, but not much.

The impact of the savings glut on employment is larger for the construction sector. By 2006 (the year in which construction's share of labor compensation peaks in the data and the model with the savings glut), construction's employment share rises from 4.37 percent to 6.30 percent in the model with the savings glut and only 5.37 percent in the no-savings glut counterfactual. In other words, construction's employment share rises by less than half as much between 1993 and 2006 in the model without the savings glut — the savings glut is responsible for more than half of the boom in construction employment during this period. By 2024, however, the effects of the savings glut on construction employment have essentially vanished; construction's share of labor compensation is 6.36 percent in the model with the savings glut and 6.30 percent in the counterfactual.

Put simply, our model's results indicate that while the savings glut was an important force in driving the construction boom, it has played little role in causing the decline in goods sector employment. Moreover, the long-run trade surplus that will follow the end of the savings glut is not likely to mitigate the continued effects of structural change on goods sector employment in any substantial manner.

Puzzle: Timing of the real exchange rate and trade balance

As we point out above, in our model the trade balance and real exchange rate move simultaneously; an increase in the trade deficit is always accompanied by a real exchange rate appreciation (and the reverse for a decrease in the deficit). In the data, real exchange rate appreciation peaks in 2002, 4 years before the trade deficit peaks. This timing disconnect presents a puzzle — why would the U.S. continue to borrow while foreign goods and services are becoming more expensive relative to their domestic counterparts? One potential solution lies in domestic factors our model ignores: policies that promote homebuying, financial innovation, and other forces described in studies like Obstfeld and Rogoff (2009). Disaggregating the U.S. real exchange rate suggests a simpler solution. Figure 7 plots the U.S. real exchange rate with China and the U.S. real exchange rate with the other 19 of its top 20 trading partners separately. Notice that after around 2001, as China became more important in U.S. trade, our model's real exchange rate looks more like the U.S.-China real exchange rate; the peak appreciation with China (after China's nominal devaluation of 1994) occurs around 2006, right alongside the peak trade deficit. This suggests that we may need to model U.S. trade with countries like China, Korea, and Japan — the principal lenders to the United States, and other major trading partners like Canada and Mexico separately. A multi-country model in our non-stationary dynamic framework would introduce significant complications, so we leave this for future work.

Puzzle: U.S. real interest rates

There is a commonly-held belief that the savings glut has played a large role in driving the low real interest rates in the United States during the past decade. Ben Bernanke has advocated for this position on several occasions. In our model, the savings glut has a negligible impact on the U.S. real interest rate. Figure 5 plots the U.S. real interest rate in the rebalancing scenario and the no-savings glut counterfactual against the data, which we take as the ex-post real interest rate on 10-year treasury bonds. All other methods of calculating the U.S. real interest rate exhibit a similar decline during the period under observation. In the data, the real interest rate falls steadily starting in 1993, with the exception of a large, temporary increase during the financial crisis driven by deflation in 2009. In both versions of the model, however, the interest rate gradually converges to the long-run value of 3 percent and there is little difference between the model with the savings glut and the no-savings glut counterfactual. The maximum difference between the two model series is 46 basis points in 2010 (3.70 percent in the counterfactual versus 3.24 percent in the model with the savings glut).

Our results indicate that the savings glut is not responsible for low U.S. real interest rates during this period. They are, however, similar to empirical estimates on the impact of foreign purchases of U.S. assets on U.S. real interest rates. For example, Warnock and Warnock (2008) estimate that foreign lending has lowered U.S. real interest rates by 80 basis points. Krishnamurthy and Vissing-Jorgensen (2008) report similar findings. While this figure is larger than our model's prediction, it is only a small fraction of the observed decline in U.S. real interest rates during between 1992 and 2011. It is also worth noting that Bernanke's successor, Alan Greenspan, espoused a view consistent with our results. In his statement before the U.S. Senate Committee on Banking, Housing, and Urban Affairs on February 16, 2005, he argued that foreign lending had lowered the U.S. real interest rate by less than 50 basis points. By this time, the U.S. real interest rate was already well below 2 percent, compared to values closer to 4 percent in the early 1990s.

The implication of our results concerning the effects of the savings glut on U.S. real interest rates is that we probably need to look elsewhere to find the forces that are primarily responsible for the low real interest rates we have observed over the last decade, perhaps to domestic developments in housing and financial markets discussed by Obstfeld and Rogoff (2009) and Bernanke, Bertaut, DeMarco, and Kamin. Chinn and Ito (2005) argue that such domestic factors may also be responsible for U.S. borrowing from abroad; that the U.S. current account deficit has been driven primarily by a domestic "savings draught" than a global savings glut. In a related paper, we show that a reduction in the domestic discount factor is likely to generate larger domestic real interest rate movements than a reduction in the foreign discount factor. We have conducted numerical exercises using our model in the present paper in which we calibrate discount factor shocks in the United States to match the trade balance rather than foreign discount facto shocks. While we find that this exercise does in fact generate larger U.S.

real interest rate movements, it also generates movements in other relative prices that are much more volatile than we see in the data.

Welfare implications of the savings glut

To assess the welfare implications of the savings glut, we calculate real income in 1992 dollars in each of the scenarios studied so far: the benchmark gradual rebalancing scenario in which the savings glut occurs but a sudden stop does not, the counterfactual in which the savings glut does not occur at all, and the scenario in which both savings glut and sudden stop occur.

In our baseline model we assume that in 1992, model agents expect government consumption expenditures to remain fixed at the 1992 level of 16.6 percent of GDP, but when the savings glut begins an unforeseen change in government spending policy occurs: government spending as a fraction of GDP tracks the data between 1993 and 2011, then rises to 22.9 percent over time. This reflects policy changes that have occurred over the past two decades, e.g. increased healthcare and defense spending, that people likely did not anticipate in the early 1990s. This increase in government consumption gives U.S. households an incentive to save for the future.

Here we explore what happens under the alternative assumption that which 1992 agents expect government consumption as a fraction of GDP to follow the path it actually took between 1992 and 2011, and then follow the same trajectory to 22.9 percent over time that we used in the savings glut scenario in our main exercise. In the savings glut and sudden stop, we require that government consumption, in terms of actual quantities of goods and services, stay constant in all three stages of the exercise, the no savings glut counterfactual, the savings glut with gradual rebalancing, and the sudden stop. This allows for direct welfare comparisons across the three scenarios even if government spending enters the utility function — as long as it enters in an additively separable fashion — allowing us to ask whether the savings glut is good or bad, and just how costly a sudden stop would be.

Figure 12 presents the model's equilibrium dynamics in the baseline model and the model with constant government spending described above. We plot the rebalancing series only once because these results are virtually unchanged, and we omit the sudden stop series entirely for the same reason. The only observable difference is the no-savings glut counterfactual. In this alternative exercise, households now have an increased incentive to save in 1992 before the savings glut begins because they believe government consumption expenditures as a fraction of GDP will rise over time. This bears out in the figure: the trade balance in the no-savings glut counterfactual is substantially higher in this alternative specification with constant government consumption than in the baseline model. This translates into a higher trajectory for the real exchange rate — fewer imported goods means the price of imported goods compared to their U.S. equivalents is higher.

Our real income index is based on an alternative — but equivalent — specification of the representative household's preferences that is homogeneous of degree one:

(28) $$\left(\sum_{t=1992}^{\infty} \beta^t \left(\varepsilon^{us} \left(\frac{c_{gt}^{ush}}{n_t^{us}} \right)^{\rho} + (1-\varepsilon^{us}) \left(\frac{c_{st}^{ush}}{n_t^{us}} \right)^{\rho} \right)^{\frac{\eta\psi}{\rho}} \left(\frac{\bar{\ell}_t^{us} - \ell_t^{us}}{\bar{\ell}_t^{us}} \right)^{(1-\eta)\psi} \right)^{\frac{1}{\psi}}$$

The cost of achieving this utility in units of the U.S. CPI in 1992 is

(29) $$\sum_{t=1992}^{\infty} \left(\prod_{s=1992}^{t-1} q_s \right) \left(p_{gt}^{us} c_{gt}^{ush} + p_{st}^{us} c_{st}^{ush} + w_t^{us} (\bar{\ell}_t^{us} - \ell_t^{us}) \right)$$

We can also write this as

(30) $$\sum_{t=1992}^{\infty} \left(\prod_{s=1992}^{t-1} q_s \right) w_t^{us} \bar{\ell}_t^{us} + r_{k1992}^{us} \bar{k}_{1992}^{us} + p(p_{g1992}^{us}, p_{s1992}^{us})(\bar{b}_{1992}^{ush} + \bar{b}_{1992}^{usg})$$

Notice that U.S. households are ultimately responsible for their government's debt. The prices and quantities above represent equilibrium objects in our benchmark gradual rebalancing scenario, the one in which the savings glut occurs but a sudden stop does not. To convert this object to 1992 dollars, we scale so that consumption expenditures in the model are equal to 1992 private consumption in the NIPA tables (call this number C_{1992}^{ush}). The scaling factor

(31) $$C = \frac{C_{1992}^{ush}}{p_{g1992}^{us} c_{g1992}^{ush} + p_{s1992}^{us} c_{s1992}^{ush}}$$

Converts consumption expenditures in the model into 1992 dollars, and

$$(32) \qquad P = \frac{\sum_{t=1992}^{\infty}\left(\prod_{s=1992}^{t-1} q_s\right) w_t^{us}\bar{\ell}_t^{us} + r_{k1992}^{us}\bar{k}_{1992}^{us} + p(p_{g1992}^{us}, p_{s1992}^{us})(\bar{b}_{1992}^{ush} + \bar{b}_{1992}^{usg})}{\left(\sum_{t=1992}^{\infty}\beta^t\left(\varepsilon^{us}\left(\frac{c_{gt}^{ush}}{n_t^{us}}\right)^{\rho} + (1-\varepsilon^{us})\left(\frac{c_{st}^{ush}}{n_t^{us}}\right)^{\rho}\right)^{\frac{\eta\psi}{\rho}}\left(\frac{\bar{\ell}_t^{us} - \ell_t^{us}}{\bar{\ell}_t^{us}}\right)^{(1-\eta)\psi}\right)^{\frac{1}{\psi}}}$$

converts utility into expenditures — P is the price of utility. The real income of U.S. households in1992 dollars in our benchmark scenario is then

$$(33) \qquad PC\left(\sum_{t=1992}^{\infty}\beta^t\left(\varepsilon^{us}\left(\frac{c_{gt}^{ush}}{n_t^{us}}\right)^{\rho} + (1-\varepsilon^{us})\left(\frac{c_{st}^{ush}}{n_t^{us}}\right)^{\rho}\right)^{\frac{\eta\psi}{\rho}}\left(\frac{\bar{\ell}_t^{us} - \ell_t^{us}}{\bar{\ell}_t^{us}}\right)^{(1-\eta)\psi}\right)^{\frac{1}{\psi}}$$

To calculate real income in alternative scenarios, like the counterfactual in which the savings glut does not occur or the scenario in which both the savings glut and sudden stop occur, we simply multiply lifetime utility by the scaling factors obtained from the benchmark scenario:

$$(34) \qquad PC\left(\sum_{t=1992}^{\infty}\beta^t\left(\varepsilon^{us}\left(\frac{\tilde{c}_{gt}^{ush}}{n_t^{us}}\right)^{\rho} + (1-\varepsilon^{us})\left(\frac{\tilde{c}_{st}^{ush}}{n_t^{us}}\right)^{\rho}\right)^{\frac{\eta\psi}{\rho}}\left(\frac{\bar{\ell}_t^{us} - \tilde{\ell}_t^{us}}{\bar{\ell}_t^{us}}\right)^{(1-\eta)\psi}\right)^{\frac{1}{\psi}}$$

We use tildes to denote equilibrium objects in the alternative scenario being studied.

The first column of panel (a) in table 4 contains our welfare results for the baseline model. When government spending is held constant across scenarios, the savings glut clearly improves welfare — 1992 real income is $660 billion lower in the counterfactual in which the savings glut does not happen at all. In other words, the fact that the savings glut happened improved welfare in our model — the influx of cheap foreign goods allowed U.S. households to increase their consumption. It is important to point out that our welfare results are based on the assumption of a representative household. We have abstracted from differences across households in income, wealth, and age. It is likely that the welfare implications for individual households' of the savings glut and a future sudden stop depend on these households' characteristics — some households may gain while others lose. The savings glut in particular is likely to affect young and old households quite differently. Addressing these issues is outside the scope of this study, but they are promising subjects of future work.

7. Sensitivity analysis

In this section we study how our results change when we alter some of our key assumptions. First, we study the impact of adding labor adjustment frictions. Next, we explore how our results change when the savings glut ends in a sudden stop like Mexico experienced in 1994—1995 rather than our baseline gradual rebalancing process. Third, we study how adding uncertainty over the length of the savings glut affects our results. As we will see, our main results about the impact of the savings glut and the repayment process on sectoral employment dynamics are very robust to all of these extensions, but our welfare results do change in the first two extensions (the sudden stop and labor adjustment frictions).

Labor adjustment costs

In our baseline model, labor can be costlessly reallocated across sectors. Here we study the impact of adding adjustment costs, with a particular focus on employment share dynamics during the savings glut and sudden stop. To model labor adjustment costs, we assume that firms lose some output if their change their employment levels. We employ the quadratic specification used by Sargent (1978) and Kehoe and Ruhl (2009). The Leontief portions of the U.S. production functions are now .

(35) $$\min\left[\frac{z_{gjt}^{us}}{a_{gj}^{us}},\frac{z_{sjt}^{us}}{a_{sj}^{us}},\frac{z_{cjt}^{us}}{a_{cj}^{us}},A_j^{us}\left(k_{jt}^{us}\right)^{\alpha_j}\left(\gamma_{jt}^{us}\ell_{jt}^{us}\right)^{1-\alpha_j}\right]-\gamma_{jt}^{us}\phi\left(\frac{\ell_{jt}^{us}}{\ell_{jt-1}^{us}}-1\right)\ell_{jt-1}^{us}$$

We assume that the adjustment cost grows at the same rate as productivity to ensure that it plays an equally important role every period. We set $\phi = 2$. Note that this value is much smaller than that used in Kehoe and Ruhl (2009). We choose this value to show that even a small adjustment cost can have a large impact on employment share dynamics during a sudden stop.

Figure 10 shows that adding labor adjustment costs has almost no impact on the dynamics of the aggregate trade balance and the real exchange rate. We plot only the series for the model with a sudden stop, since this is the only scenario in which there is any observable difference. In the model with adjustment costs, the real exchange rate rises by 14.5 percent as compared to 9.9 percent in the baseline model. This larger depreciation is the only quantitatively large impact that labor adjustment costs have on the aggregate dynamics of the economy. Figure 11 shows that while adjustment costs have very little impact on the longer-term reallocation caused by structural change (and the savings glut, to a small extent), adjustment costs almost entirely smooth out the sharp reallocations that the sudden strop triggers. This translates into an additional drop in GDP (7.3 percent versus 4.8 percent in the baseline model). In other words, while many of the variables we have focused on in our analysis are not sensitive to adding adjustment costs, the aggregate impact of a sudden stop is very sensitive — a sudden stop will lead to a much larger drop in output if reallocation is costly.

To assess the sensitivity of our welfare analysis, we conduct the same real income calculations as described above in the model with labor adjustment costs. In table 4, we see that adding labor adjustment costs increases the welfare gains from the savings glut compared to the no-savings glut counterfactual. Here's why: our model still exhibits long-run structural change in the presence of adjustment costs — goods-sector employment still declines — and this process is now costly. By increasing U.S. borrowing from the rest of the world, the savings glut allows the U.S. to finance some of these costs using future consumption instead of current consumption. From the perspective of model agents living in 1992, this reduces the welfare impact of the adjustment costs associated with long-run structural change.

Sudden stop in 2015

Thus far we have confined our analysis of the model's projections for the future to the scenario in which the savings glut gradually rebalances, reflecting a slow, orderly reduction in demand for saving in the rest of the world. Here we ask: what would happen if foreign demand for saving stopped abruptly in a "sudden stop" of the kind that Mexico and several Southeast Asian countries experienced in the 1990s?

We follow Kehoe and Ruhl (2009) and model a sudden stop as an unanticipated event that begins in 2015 and lasts for two years. During this time, the rest of the world stops accumulating assets; public and private bond holdings in the United States are fixed. Once this period ends, the rest of the world's preference for current consumption and leisure, reflected by the preference shock ω_t^{rw}, converges to its long-run value much more quickly than agents anticipate during the rebalancing scenario (see figure 9), and the U.S. government's debt as a fraction of U.S. GDP begins to fall to a lower long-run value (see figure 8). This adds a third stage to our solution method in which we solve for an equilibrium from 2015 onwards using the state variables from the baseline model in that year as the initial conditions. We perform this exercise a second time in which we add a 10 percent drop in labor productivity in all sectors in 2015, which decays to 5 percent in 2016 and 0 percent by 2017. We do this to capture the fact that historical sudden stop episodes have been characterized by large declines in output driven in large part by falling TFP (see, for example, Calvo, Izquierdo, and Talvi, 2006). Standard models in international macro have trouble generating this pattern (Chari, Kehoe, and McGrattan, 2005). Our model, despite its departures from the standard framework, still suffers from this problem.

Figure 3 illustrates that a sudden stop would have large impacts on the trade balance and the real exchange rate. The trade balance would rise by 3.6 percent on impact, to 2.59 percent, and would remain positive thereafter. The real exchange rate would increase by 9.8 percent on impact. These sharp changes are short-lived, however. By 2024, the trade balance and real exchange rate are on almost exactly the same trajectory regardless of whether or not the sudden stop occurs. Figure 2 shows that the large trade balance reversal occurs primarily in the goods sector. This is driven by the fact that foreign asset purchases are financed almost primarily by sales of foreign goods to the United States, and when these purchases suddenly stop, U.S. goods imports fall sharply. Again, the disaggregated trade balances are on the same trajectory by 2024 , however; once the sudden stop ends, the United States goes back to importing more goods than it exports.

Figure 4 shows that a sudden stop will be very disruptive for labor markets, with particularly pronounced effects in the construction sector. The goods sector's share of total labor compensation rises by from 14.9 percent to 15.4 percent, while construction's share falls from 6.05 percent to 4.14 percent. This represents approximately a 30 percent drop in construction employment. The modest increase in the goods sector's share of employment despite the large increase in the goods trade balance is driven by our model's input-output production structure. Goods are used more as intermediate inputs than services or construction, so the drop in demand for intermediate inputs triggered by the economy-wide drop in productivity affects the goods sector the most. The large drop in construction employment is driven by two factors. First, construction is the only purely nontraded sector. Second, construction makes up the largest share of investment production, and the sudden stop causes a large increase in the U.S. real interest rate as seen in figure 5 that leads to a large decline in investment. Just as before, however, these changes are short-lived; the effects of the sudden stop on sectoral employment shares dissipate almost entirely by 2024.

To assess the welfare impact of a sudden stop, we re-do our welfare calculations from two perspectives. First, just as we did for the baseline model, we calculate real income in 1992 in the scenario in which a sudden stop occurs. The sudden stop does not occur until 2015, discounting reduces the impact of a sudden stop on welfare from the perspective of model agents in 1992. Panel (a) of table 4 contains these results. A sudden stop reduces welfare relative to the baseline gradual rebalancing scenario, but only if that sudden stop is accompanied by a TFP shock does welfare fall more than it would if the savings glut had never happened at all. Our second set of welfare calculations for the sudden stop scenarios takes the perspective of model agents in 2015, the year the sudden stop happens. Panel (b) of table 4 contains these results. Discounting between 1992 and 2015 no longer reduces the sudden stop's welfare impact; a sudden stop is quite painful for model agents in 2015. Without a TFP shock, a sudden stop will reduce 2015 real income by more than $1 trillion, and a TFP will reduce 2015 welfare by an additional $2 trillion. Not surprisingly, adding labor adjustment costs increases welfare losses; a sudden stop triggers large (albeit temporary) labor reallocations across sectors.

To sum up, our analysis of a hypothetical sudden stop in foreign lending indicates that such a sudden stop would be very disruptive to the U.S. economy, triggering sharp changes in trade balances, and relative prices, large reallocations of labor across sectors, and large welfare losses from the perspective of model agents living in 2015. Our results also indicate, however, that these effects are likely to be short-lived. The long-run trajectory of the U.S. economy that follows the end of the savings glut does not depend on whether a sudden stop occurs or whether the rebalancing process is orderly and gradual. In particular, a sudden stop has no discernible quantitative impact on long-run sectoral labor dynamics.

Uncertainty

In our baseline model, agents in both the United States and the rest of the world have perfect foresight once the savings glut begins; they know exactly when it will end and the rate at which it will rebalance. We have studied a version of our model with uncertainty about the length of the savings glut. In this version of the model, once the savings glut begins there is a 10 percent chance in each year between 1993 and 2011 that the savings glut will end in the following period, and the rest of the world's demand for saving will begin to increase again. The other 90 percent of the time, the savings glut will continue for at least one additional period. The realized path the economy takes is the one in which the savings glut persists through 2011, and while this is the unconditionally most likely path the economy can take, it is not very likely from the perspective of model agents in 1992. Our results with this version of the model indicate that this kind of uncertainty has no discernible impact on our results. We do not plot time series of our results with this addition due to the fact that one cannot visually distinguish them from our baseline results.

This addition to our model represents a substantial technical contribution. Due to the presence of asymmetric, time-varying growth rates in productivity, demographics and other variables, our modeling framework does not admit a stationary dynamic program. In the model with uncertainty, the current value of the stochastic savings glut process is not a sufficient statistic for the exogenous state of the economy — the entire history of shocks matters. As a consequence, we must solve for the growth paths of the world economy along all possible sequences of shocks simultaneously. The number of possible sequences increases proportionally with the number of periods with uncertainty, so the dimensionality of the problem increases rapidly. To our knowledge, no other studies have attempted to solve this kind of model. We believe this framework was a wide variety of applications.

Conclusion

This paper studies the impact of the global savings glut — an increased willingness on the part of economic agents in the rest of the world to trade their own goods and services in the present for claims on U.S. goods and services in the future — on the U.S. economy over the past two decades as well as the next one. We build a model of the U.S. and the rest of the world that incorporates a number of unique features in the international macroeconomics literature and show that it accounts for four key facts about the U.S. economy during the 1992—2011 period. First, the trade deficit increased then decreased. Second, the real exchange rate appreciated then depreciated roughly at the same time. Third, the trade balance dynamics are driven almost entirely by the goods trade balance. Finally, labor shifted away from the goods sector towards services and construction. We use our model to show that while faster productivity growth compared to other sectors is responsible for the bulk of the shift in employment away from the goods sector, the savings glut is in fact responsible for a large fraction of the boom in construction employment during this period.

We then use our model to ask what will happen in the future when the forces driving the savings glut begin to taper off, causing the United States to begin to pay back the debt it has incurred. We show that the United States will run a perpetual trade surplus, but will nevertheless continue to import more goods than it exports — this trade surplus will originate entirely in the services sector. The real exchange rate will continue to depreciate in the long run as the supply of foreign goods and services in the United States falls, and traditional structural change forces will continue to drive a decline in goods sector employment despite the fact that the United States will produce more of the goods it consumes at home. We also use our model to ask what will happen if the savings glut ends swiftly and unexpectedly, in a sudden stop episode like those that hit Mexico and Southeast Asian in the 1990s. We show that this scenario will trigger sharp increases in the trade balance and the real exchange rate and potentially painful reallocations of labor across sectors, but it will have little lasting impact — the long run trajectory of the U.S. economy will be approximately the same by 2024 regardless of whether a sudden stop occurs.

Our study identifies several puzzles. In our model, the trade balance and real exchange rate move simultaneously; an increase in the trade deficit is always accompanied by a real exchange rate appreciation (and the reverse for a decrease in the deficit). In the data, real exchange rate appreciation peaks in 2002, 4 years before the trade deficit peaks. We believe that modeling several of the United States' trade partners separately (China in particular) may help resolve this issue. Another puzzle our study identifies concerns the relationship between foreign lending and U.S. real interest rates. Contrary to popular wisdom, our results suggest that the savings glut is not an important factor in driving the low U.S. real interest rates of the past decade. Our results are not far off from empirical estimates on the effect of foreign lending on U.S. real interest rates (see, for example, Warnock and Warnock, 2008), indicating that researchers may need to look elsewhere. Nevertheless, we cannot rule out the possibility that the savings glut contributed to low U.S. real interest rates by interacting with domestic factors like those discussed by Bernanke, Bertaut, DeMarco, and Kamin (2011).

One of our main results is that the manner in which the savings glut ends — gradual rebalancing or sudden stop — will not have much impact on the long-run trajectory of the U.S.

economy. We wish to leave the reader with one final point: the fact that the savings glut happened *does* have large implications for the future of the U.S. economy. The U.S. economy's current long-run trajectory is very different than the one it would have taken had the savings glut not taken place at all. Figure 14 illustrates this point by plotting the aggregate trade balance and real exchange rate in our gradual rebalancing scenario against the counterfactual in which the savings glut never happened. In the counterfactual, U.S. trade is approximately balanced in the long run since the United States has little debt to repay. Because the savings glut did happen, however, our mode predicts that the U.S. will run a trade surplus of around one percent of GDP in perpetuity. This means that the supply of foreign goods in the United States will be lower than it would otherwise, implying a larger long-run real exchange rate depreciation. So while the manner in which the savings glut ends is not likely to affect the U.S. economy in the long run, the fact that the savings glut occurred will have long-lasting effects.

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Table 1: 1992 Input-Output Matrix (Billions of 1992 Dollars)

	Inputs			Final demand					
Industry	**Goods**	**Services**	**Construction**	**Private consumption**	**Government consumption**	**Investment**	**Exports**	**-Imports**	**Total demand**
Goods	1,345	424	240	891	196	345	448	-545	**3,346**
Services	638	1,488	179	3,346	854	228	187	-123	**6,798**
Construction	26	139	1	-	-	514	-	-	**679**
Labor compensation	849	3,273	188	-	-	-	-	-	**4,310**
Returns to capital	488	1,474	71	-	-	-	-	-	**2,033**
Total gross output	**3,346**	**6,798**	**679**	**4,237**	**1,050**	**1,088**	**635**	**-668**	

Table 2: Calibration

Parameter	Value	Statistic	Target
Producer parameters			
A_g, A_s, A_c	(2.59,1.56,2.95)	Domestic gross output in 1992	(52.8,107,10.7)
a_{gg}, a_{sg}, a_{cg}	(0.41,0.19,0.01)	Share of intermediates in domestic goods in 1992	(0.41,0.19,0.01)
a_{gs}, a_{ss}, a_{cs}	(0.07,0.22,0.02)	Share of intermediates in domestic services in 1992	(0.07,0.22,0.02)
a_{gc}, a_{sc}, a_{cc}	(0.35,0.26,0.001)	Share of intermediates in construction in 1992	(0.35,0.26,0.001)
$\alpha_g, \alpha_s, \alpha_c$	(0.37,0.31,0.27)	Capital's share of domestic value added in goods/svcs/constr. in 1992	(0.37,0.31,0.27)
$\theta_g, \theta_s, \theta_c$	(0.32,0.21,0.47)	Share of intermediates in investment good production in 1992	(0.32,0.21,0.47)
G	2.85	Investment in 1992	17.2
Household parameters and initial conditions			
$\bar{b}_{1992}^{ush}$	36.8	Capital account balance in 1992, in percent of GDP	0.08
$\bar{k}_{1992}^{us}$	176.25	Real interest rate in 1992, in percent	4.00
β^{us}, β^{rw}	(0.996,0.996)	Long-term real interest rate, in percent	3.00
$\varepsilon^{ush}, \varepsilon^{rw}$	(0.07,0.19)	Goods share of private consumption in 1992	21.0
ρ	-1.00	Elasticity of substitution, traded to nontraded	0.50
η	0.29	Ratio of hours worked to available hours in 1992	0.29
ψ	-1.00	Intertemporal elasticity of substitution	0.50
δ	0.066	Depreciation to GDP in 1992, in percent	11.7
Trade parameters			
M_g^{us}, M_s^{us}	(1.78,1.08)	Gross composite output in goods/services in 1992	(61.3,109.1)
μ_g^{us}, μ_s^{us}	(0.65,0.98)	U.S. imports in 1992	(8.59,1.94)
M_g^{rw}, M_s^{rw}	(0.71,0.95)	Implied R.W. traded goods/services output	(86.9,161.7)
μ_g^{rw}, μ_s^{rw}	(0.71,0.98)	U.S. exports in 1992 in 1992	(7.06,2.95)
ζ_g, ζ_s	(0.67,0.00)	Elasticity of substitution, domestic traded to imports	(3.00, 1.00)
Government parameters and initial conditions			
$\bar{b}_{1992}^{usg}$	-42.8	U.S. government debt in 1992	42.8
τ_k^{us}	0.415	Depreciation rate	0.066
τ_{k1993}^{us}	0.397	Investment in 1992	17.2
ε^{usg}	0.179	Goods share of government consumption, in percent	0.19
Time series parameters			
$\{\tilde{n}_t^{us}, \tilde{n}_t^{rw}, \bar{\ell}_t^{us}, \bar{\ell}_t^{rw}\}_{t=0}^{\infty}$		U.N. Population Prospects: 2010 Revision	
$\{\omega_t^{rw}\}_{t=0}^{\infty}$		U.S. trade balance, 1992–2011	
$\{\gamma_{jt}^{us}\gamma_{jt}^{rw}\}_{t=0}^{\infty}$		Labor productivity growth in goods/svs/constr. 1987—2011	
$\{\nu_t, \upsilon_t\}_{t=0}^{\infty}$		CBO historical data and projections; authors' projections	

Table 3: Goods and services labor compensation shares

	Goods			Construction		
Year	**Data**	**Rebalancing**	**No savings glut**	**Data**	**Rebalancing**	**No savings glut**
1992	19.69	19.69	19.69	4.37	4.37	4.37
1993	19.45	18.70	19.36	4.36	3.92	4.27
1994	19.33	18.48	19.07	4.52	4.06	4.34
1995	18.88	18.26	18.79	4.58	4.07	4.41
1996	18.27	18.06	18.54	4.74	4.14	4.51
1997	17.88	17.86	18.32	4.87	4.20	4.60
1998	17.59	17.49	18.11	5.01	4.44	4.69
1999	17.14	17.01	17.91	5.19	4.74	4.78
2000	16.72	16.54	17.70	5.30	5.13	4.86
2001	15.77	16.36	17.50	5.44	5.07	4.94
2002	15.13	15.99	17.31	5.36	5.17	5.03
2003	14.86	15.63	17.11	5.32	5.36	5.11
2004	14.33	15.29	16.91	5.33	5.73	5.21
2005	13.91	15.03	16.71	5.52	6.09	5.31
2006	13.67	14.90	16.51	5.69	6.30	5.37
2007	13.27	14.94	16.30	5.62	6.26	5.43
2008	13.09	14.76	16.09	5.45	6.26	5.51
2009	12.26	15.08	15.89	4.79	5.51	5.59
2010	12.17	14.72	15.69	4.42	5.87	5.69
2011	12.39	14.54	15.49	4.38	6.18	5.72
2012	-	14.78	15.29	-	6.12	5.76
2013	-	14.88	15.10	-	6.05	5.80
2014	-	14.93	14.90	-	6.05	5.85
2015	-	14.90	14.71	-	6.05	5.91
2016	-	14.83	14.52	-	6.01	5.95
2017	-	14.75	14.34	-	6.06	5.99
2018	-	14.64	14.15	-	6.13	6.04
2019	-	14.50	13.97	-	6.15	6.09
2020	-	14.34	13.79	-	6.19	6.14
2021	-	14.18	13.60	-	6.24	6.18
2022	-	14.00	13.41	-	6.28	6.22
2023	-	13.81	13.23	-	6.32	6.26
2024	-	13.62	13.04	-	6.36	6.30

Table 4: Welfare impact of savings glut and sudden stop

Change in real income (billions of dollars)	No adjustment costs	Adjustment costs
(a) In 1992 compared to rebalancing scenario		
No savings glut counterfactual	-660	-802
Sudden stop (no TFP shock)	-347	-397
Sudden stop (TFP shock)	-989	-1,070
(b) In 2015 compared to rebalancing scenario		
Sudden stop (no TFP shock)	-1,202	-1,379
Sudden stop (TFP shock)	-3,423	-3,721

Figure 1: U.S. trade balance, current account balance, and real exchange rate

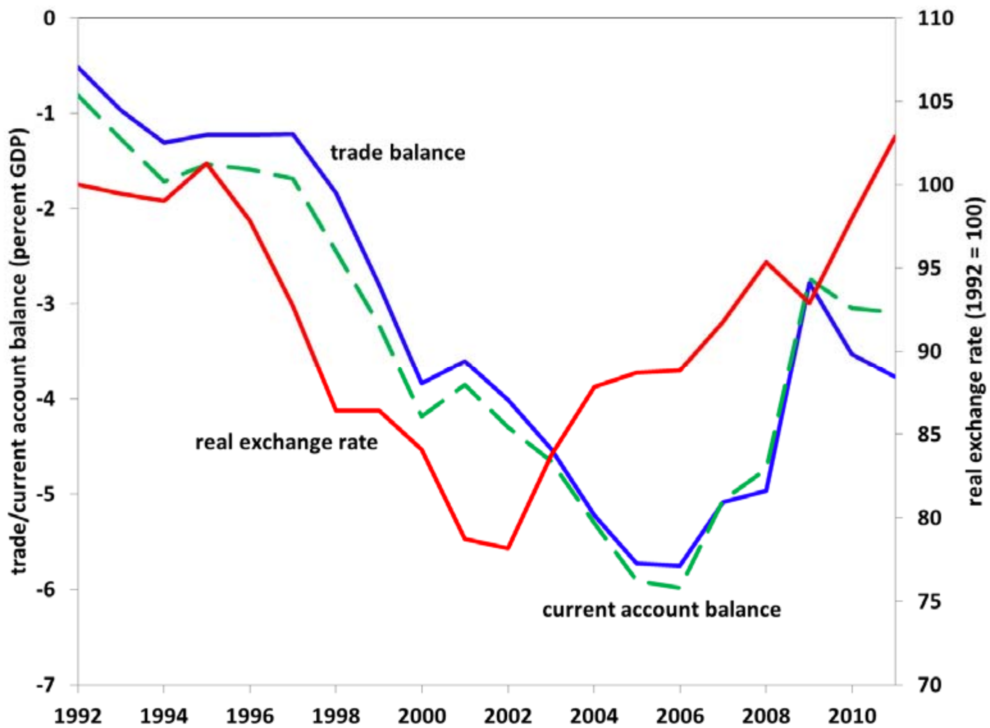

Figure 2: Trade balance in the model and the data

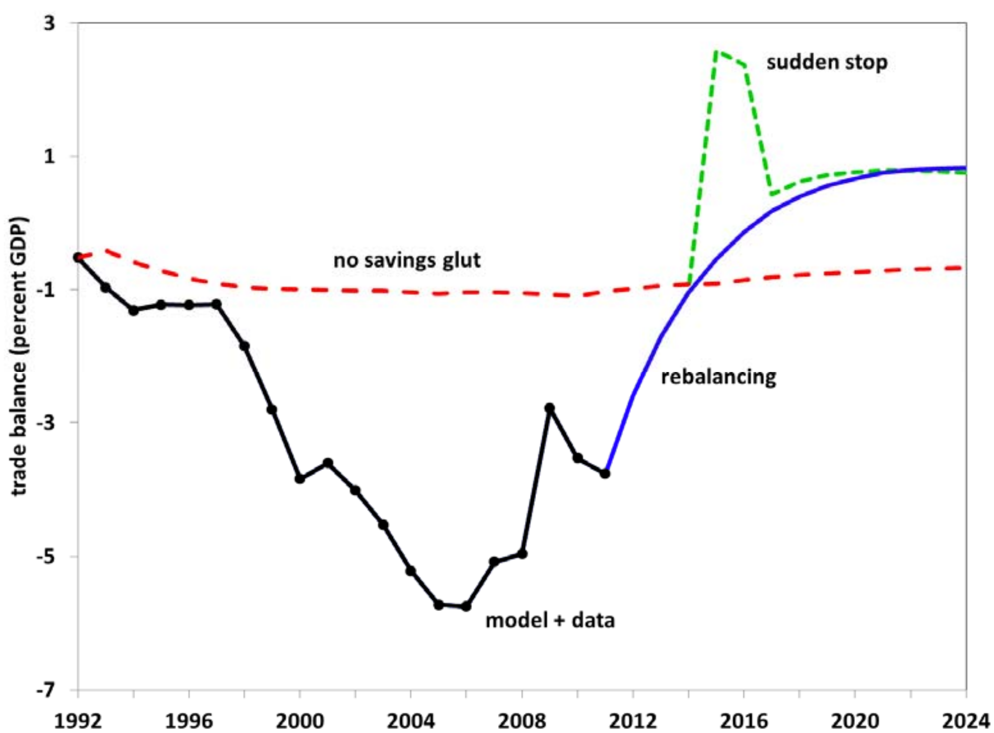

Figure 3: Real exchange rate in the model and the data

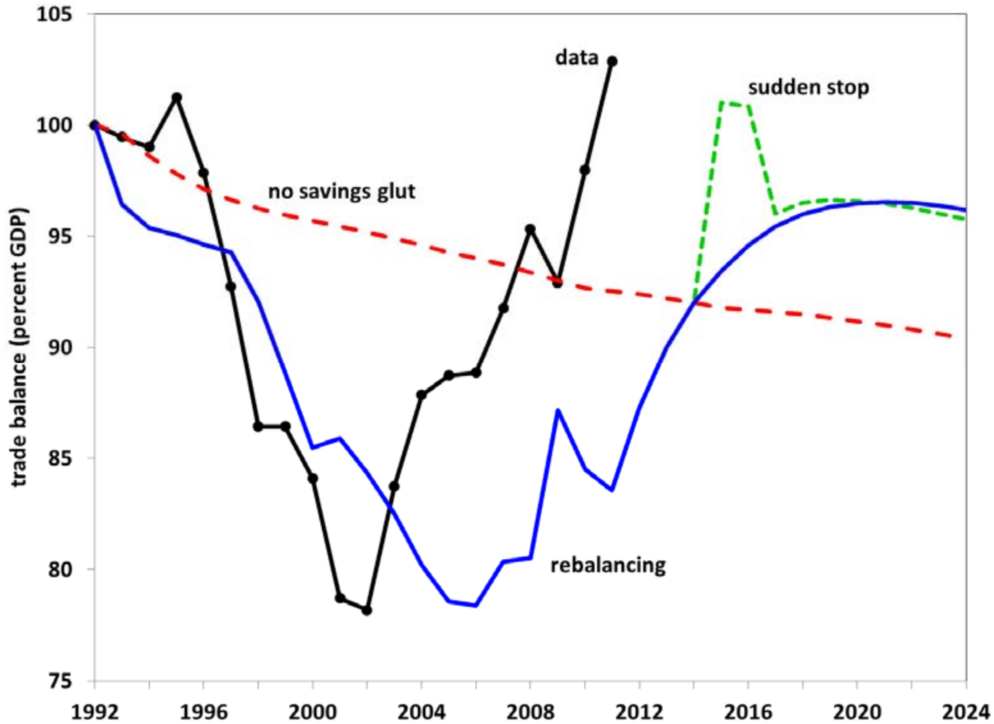

Figure 4: Goods and services trade balances in the model and the data

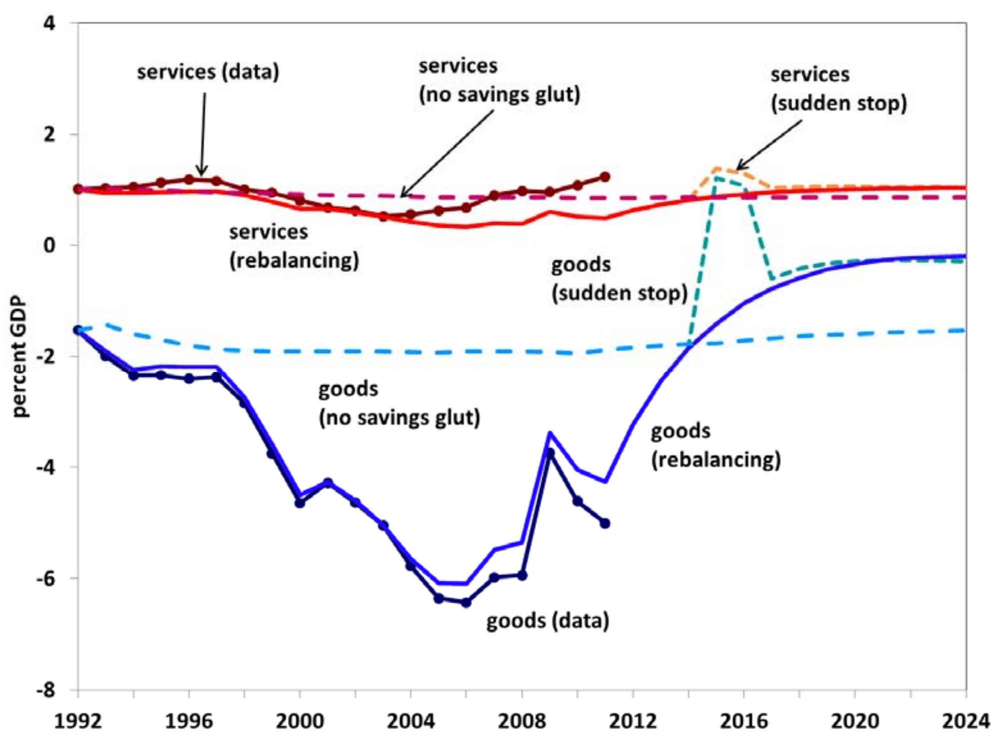

Figure 5: Goods labor compensation in the model and the data

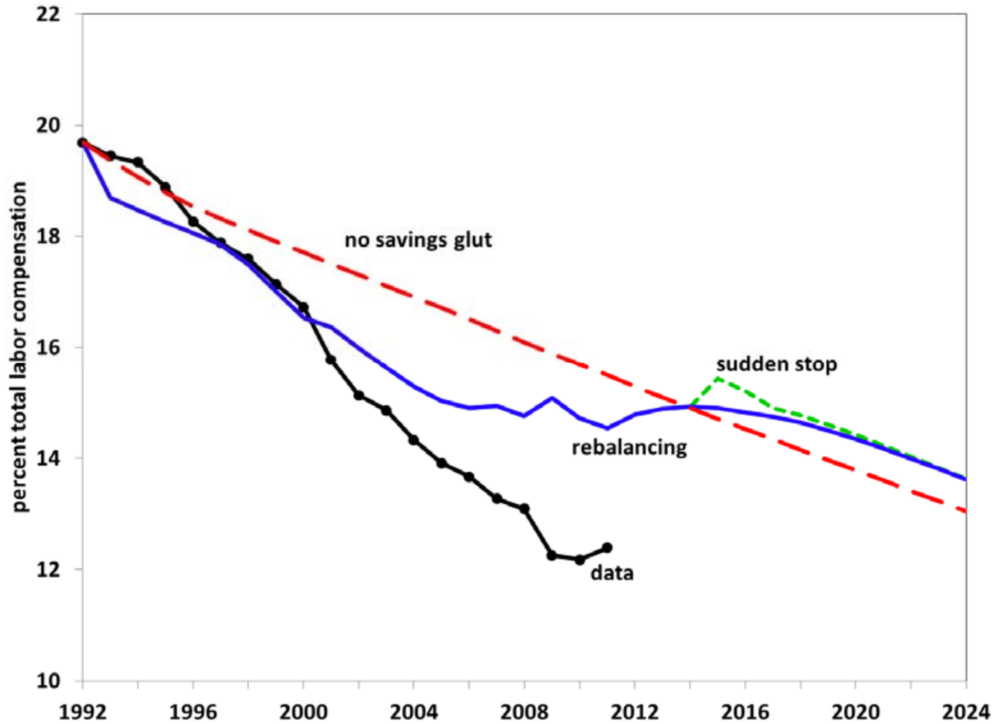

Figure 6: Construction labor compensation in the model and the data

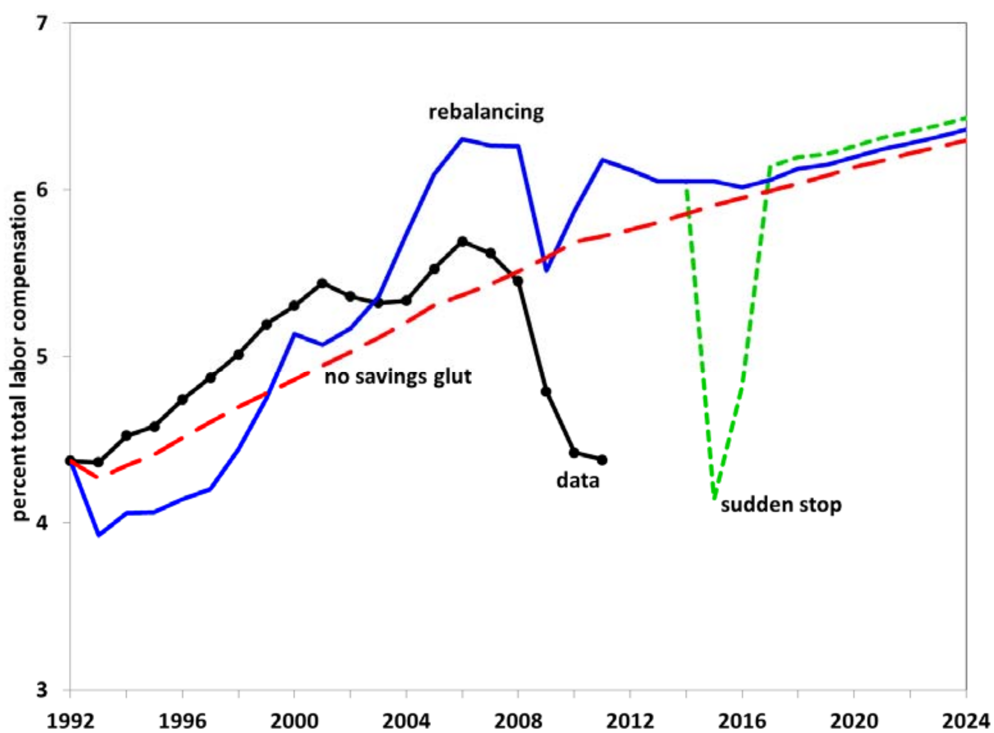

Figure 7: U.S. real exchange rates with China and other trade partners

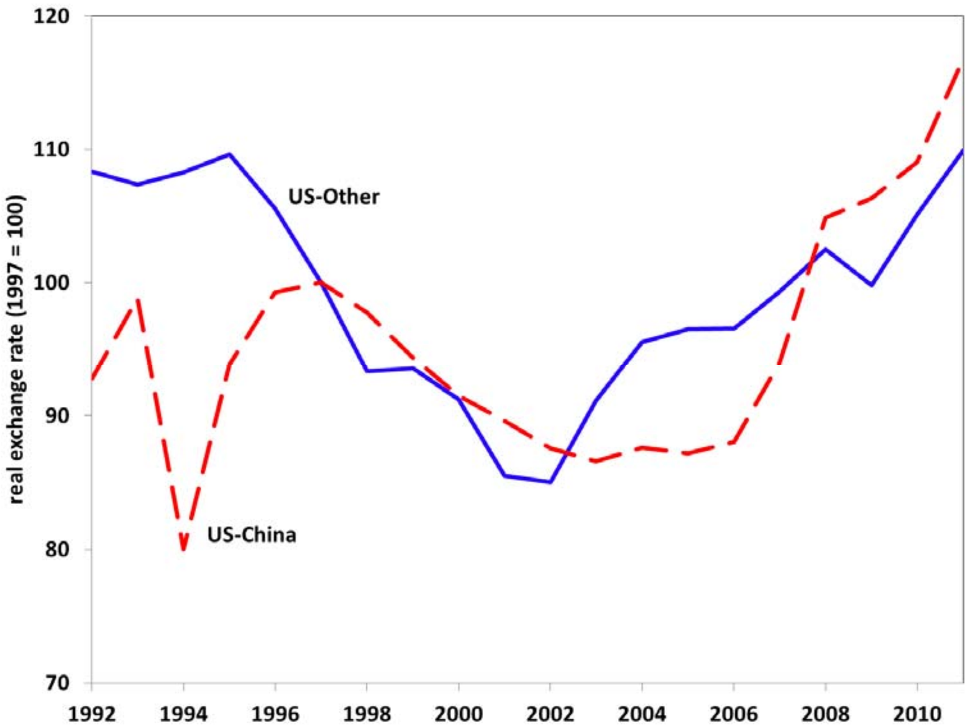

Figure 8: U.S. real interest rate in the model and the data

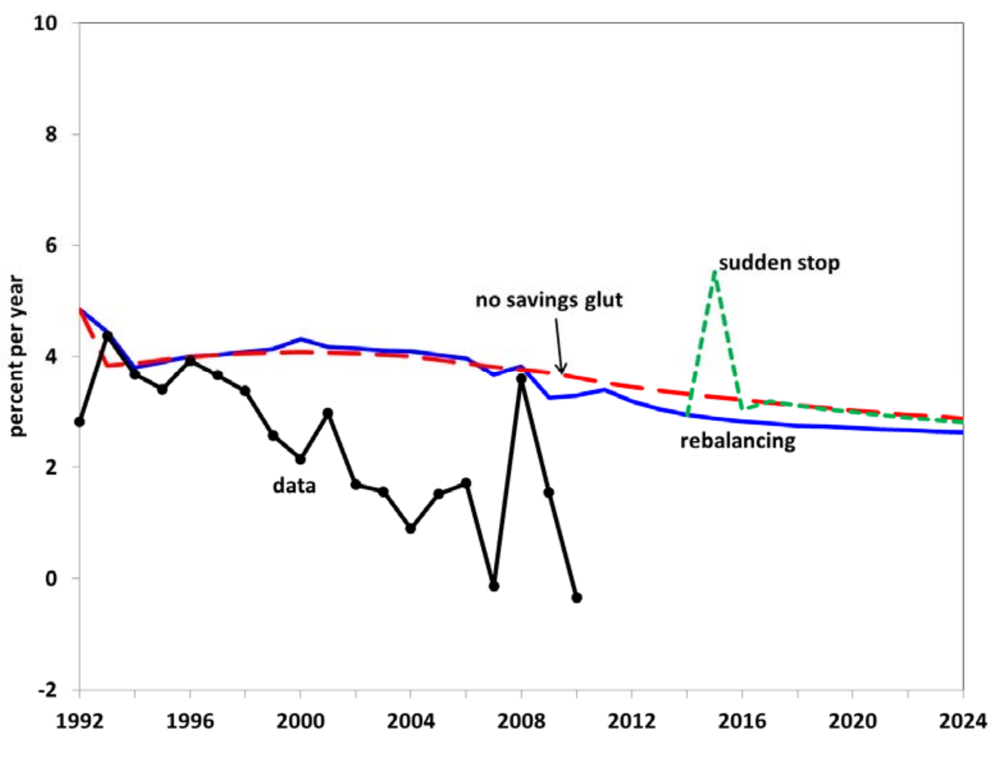

Figure 9: Trade balance and real exchange rate with labor adjustment costs

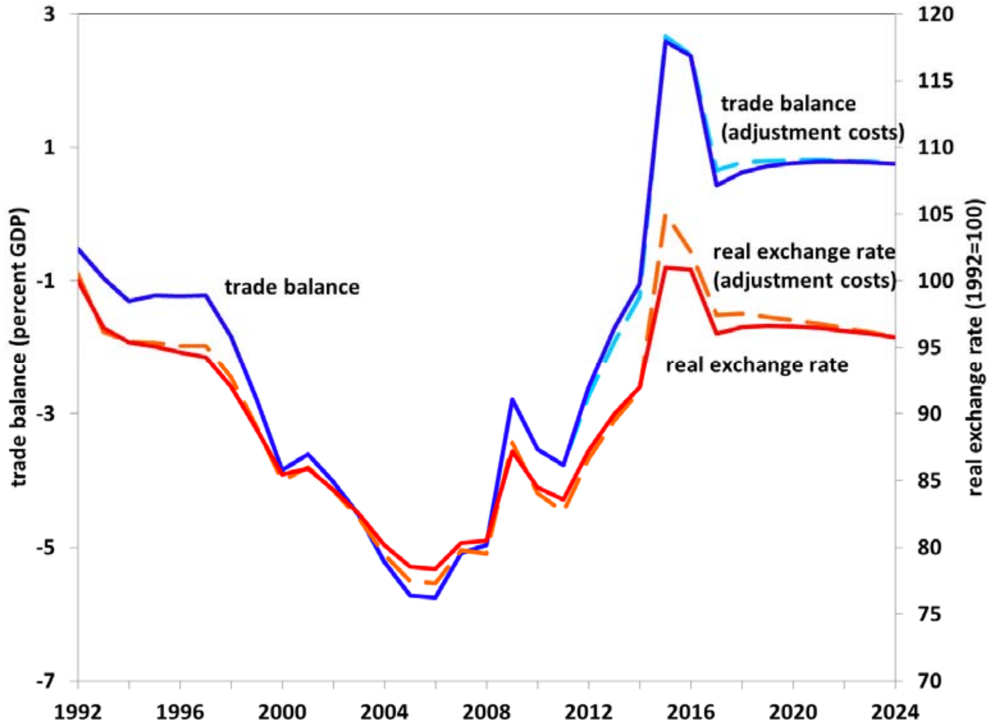

Figure 10: Labor compensation in goods and construction with adjustment costs

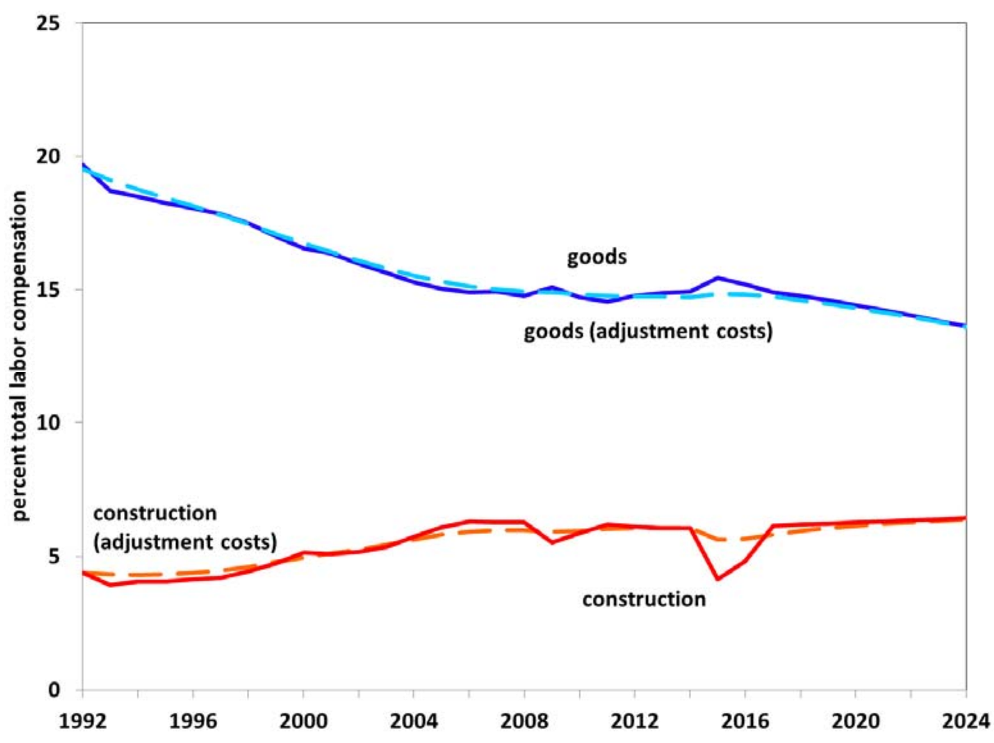

Figure 11: U.S. real interest rates with labor adjustment costs

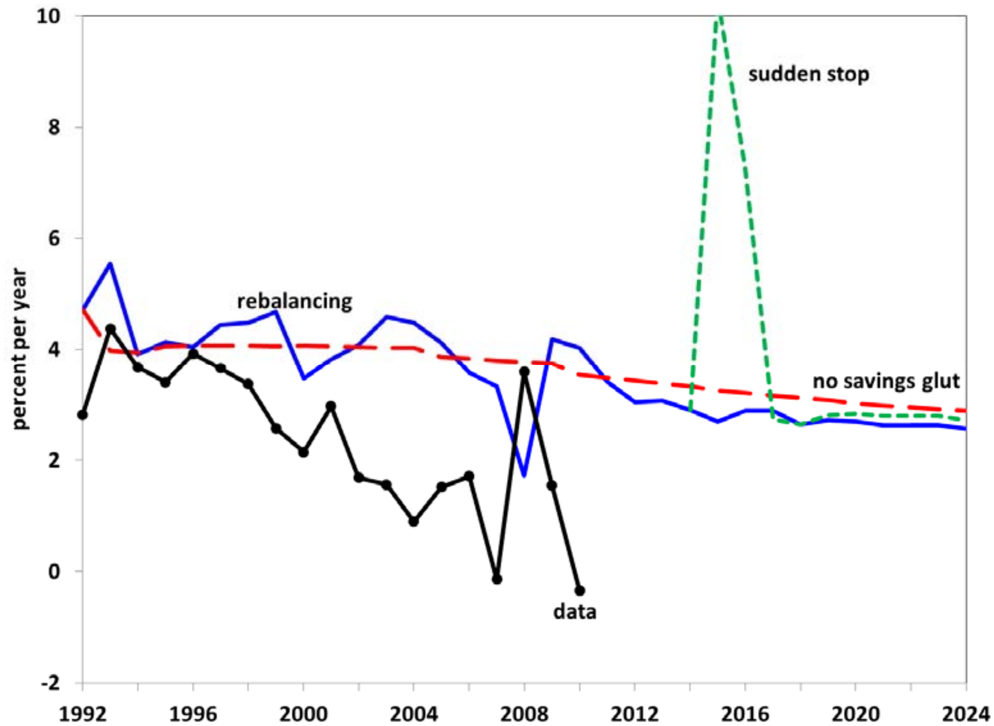

Figure 12: U.S. government debt time paths

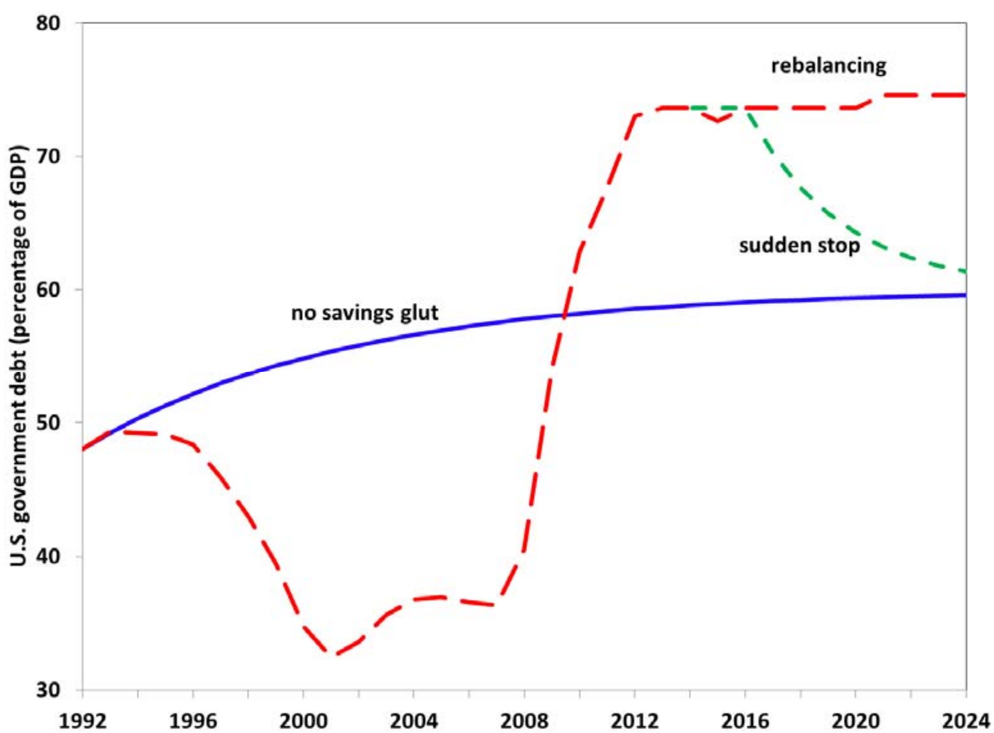

Figure 13: Rest of the world's preference shock