Global Imbalances and Structural Change in the United States

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ABSTRACT_____

Since the early 1990s, as the United States has borrowed from the rest of the world, employment in U.S. goods-producing sectors has fallen. Using a dynamic general equilibrium model, we find that rapid productivity growth in goods production, not U.S. borrowing, has been the most important driver of the decline in goods-sector employment. As the United States repays its debt, its trade balance will reverse, but goods-sector employment will continue to fall. A sudden stop in foreign lending in 2015–2016 would cause a sharp trade balance reversal and painful reallocation across sectors, but would not affect long-term structural change.

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1. Introduction

Between 1992 and 2012, households and the government in the United States borrowed heavily from the rest of the world, and the U.S. net international investment position deteriorated by 4.0 trillion dollars. A commonly-held view in policy circles, expressed, for example, by Bivens (2006) and Scott, Jorgensen, and Hall (2013), is that the U.S. trade deficits generated by this heavy borrowing have played an important role in the decline of employment in the U.S. goods sector and that an end to these deficits will reverse a large part of this trend.

We use a dynamic general equilibrium model of the United States and the rest of the world to address the questions: To what extent are trade deficits responsible for the loss of U.S. goods-sector employment? Will employment return to goods-producing sectors when U.S. borrowing ends and trade deficits become trade surpluses? In addition to modeling foreign lending, we incorporate a key feature of the structural change literature: differential productivity growth across sectors. Using the calibrated model, we find that U.S. trade deficits accounted for 16.3 percent of the decline in the goods-producing sector's employment between 1992 and 2012, with most of the remainder attributed to faster productivity growth in the goods sector relative to other sectors. This implies that eliminating the trade deficit will not generate a significant increase in goods-sector employment. We find that, if the trade deficit gradually changes to a surplus, U.S. borrowing in the 1990s and 2000s has been welfare improving. If the trade balance reverses quickly and unexpectedly — a sudden stop, like that in Mexico in 1995–1996 — then welfare would be greater if the United States had not borrowed.

It is easy to see why some view trade deficits as detrimental to goods-sector employment. Figure 1 shows that the share of employment in the goods sector — agriculture, mining, and manufacturing — has fallen dramatically as the trade deficit has grown. Moreover, this idea has a simple intuition: Imported goods are substitutes for domestically produced goods. As the United States trades bonds for foreign goods, labor shifts away from domestically produced goods and is reallocated to producing services and construction, which are less substitutable for foreign goods. When the debt has to be repaid, so the idea goes, labor will flow back into the goods sector to produce the extra goods needed to repay the debt.

In constructing the model, we must take a stand on the driving force behind U.S. borrowing. A common explanation is that foreign demand for saving increased, making foreigners more willing to trade their goods for U.S. bonds. Bernanke (2005) coined the term

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global saving glut to refer to this idea, and we adopt Bernanke's global-saving-glut hypothesis. Several explanations have been proposed for the increased demand for saving in the rest of the world, such as a lack of financial development in the rest of the world (Caballero, Farhi, and Gourinchas, 2008; Mendoza, Quadrini, and Ríos-Rull, 2009), differences in business cycle or structural growth properties (Backus, Henriksen, Lambert, and Telmer, 2006; Perri and Fogli, 2010), and demographic differences (Du and Wei, 2013). We do not take a stand on which of these explanations, if any, are correct. Instead, we take the saving glut as given and study its impact on the U.S. economy by calibrating a process for the preferences of households in the rest of the world over current versus future consumption so that our model matches exactly the path of the U.S. trade balance between 1992 and 2012.

We include four features in the model that make it well suited to address these issues. First, we model an economy with three sectors: goods, services, and construction. Goods and services can be traded, which allows us to capture the fact that the United States consistently runs a substantial trade surplus in services. International macroeconomic models usually treat goods as the only tradable sector, and lump all other sectors into a single nontradable sector. This assumption is at odds with the data: Services are a large component of U.S. exports. Construction is the only nontradable sector and is used almost entirely to produce investment goods, which means that construction is more sensitive than the other sectors to the effects of capital flows and economic fluctuations in general. Second, we build a detailed input-output structure into the production side of the model. This allows us to model the elasticity of substitution between goods, services, and construction in production as well as consumption. Third, we allow the elasticity of substitution between foreign and domestic inputs to differ across sectors. Our calibration assigns 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, as seen in figure 6. Fourth, and perhaps most important, 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.

The structural change literature emphasizes asymmetric productivity growth as an important driver of long-run reallocation of labor across sectors. Recent studies embed this mechanism, originally due to Baumol (1967), into closed-economy models that are consistent

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with aggregate balanced growth (Ngai and Pissarides, 2007; Buera and Kaboski, 2009). We take a similar approach in an open-economy model. Several other recent papers study structural change in open economies. (Echevarria, 1995; Matsuyama, 1992, 2009; Sposi, 2012; Ui, Yi, and Zhang, 2013). 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, and we perform a quantitative assessment of the relative contributions of traditional structural change forces (asymmetric labor productivity growth) and the saving glut to the decline in goods-sector employment in the United States.

We calibrate our model so that it matches exactly the national accounts and input-output table for the United States in 1992, and the U.S. trade balance during 1992–2012. As figures 5–7 show, our calibrated model endogenously generates outcomes that match several key facts about the U.S. economy during this period: We match the magnitude of the real exchange rate appreciation and subsequent depreciation, the dynamics of the disaggregated goods and services trade balances, and the changes in sectoral employment shares. After demonstrating our model's ability to match historical data, we use it to conduct two kinds of exercises: historical counterfactuals and predictions about the future. In our counterfactual scenario, we turn off the saving glut, which allows us to answer questions about the path the U.S. economy would have taken had the saving glut never occurred. In our model without a saving glut, the goods sector's employment share falls from 19.7 percent in 1992 to 15.3 percent in 2011, compared to 14.2 percent in the model with the saving glut and to 12.4 percent in the data. Looking to the future, our benchmark model with the saving glut predicts that the goods sector's employment share will continue to decline in the long run, and that the trade balance reversal required to repay the debt the United States incurred during the saving glut will have little impact on goods-sector employment. The goods sector's employment share is 13.1 percent in 2024 in our benchmark saving-glut scenario, versus 12.6 percent in the counterfactual scenario in which the saving glut never occurs.

In our baseline model, we assume that the transition from a trade deficit to a surplus will happen gradually. In an extension, we consider the effects of a sharp reversal of the trade balance. The possibility of a U.S. *sudden stop* arises frequently in policy discussions. Bernanke (2005), for example, has argued that, while a gradual rebalancing process is likely, he cannot rule out a sudden stop:

[T]he underlying sources of the U.S. current account deficit appear to be medium-term or even long-term in nature, suggesting that the situation will eventually begin to improve, although a return to approximate balance may take some time. Fundamentally, I see no reason why the whole process should not proceed smoothly. However, the risk of a disorderly adjustment in financial markets always exists.

Sudden stops in the past have often been accompanied by severe economic disruption in the short run: large real exchange rate depreciations, substantial productivity-driven output contractions, and sharp reallocations of factors across sectors (Calvo, Izquierdo, and Mejía, 2004; Calvo and Talvi, 2005; Kehoe and Ruhl, 2009). We use our model to study what a sudden stop in the United States in 2015–2016 would look like and quantify the cost of the disruption in economic activity. Our results indicate that a sudden stop in the United States would look similar to historical episodes in emerging economies. The trade balance, as a share of GDP, would rise by 4.0 percent on impact, the real exchange rate would depreciate by 10.7 percent, and employment would shift away from nontradable sectors (construction) to tradable sectors (goods and services). As in sudden stops of the past, these effects would be short-lived; several years after the sudden stop ends, the U.S. economy would be on almost the same path on which it would have been if the sudden stop had never happened at all.

Our results suggest that the impact of a sudden stop would be temporary, but this does not mean the welfare costs of a sudden stop would be small. We construct a measure of the real income of U.S. households in 1992, and compare the welfare of U.S. households in three scenarios: (1) the baseline, in which the saving glut ends in gradual rebalancing, (2) an alternative in which the saving glut ends in a sudden stop, and (3) a counterfactual in which the saving glut never happened. The saving glut itself improves welfare: The lifetime real income of U.S. households in 1992 would have been almost 700 billion dollars lower (about 11 percent of 1992 GDP) if the saving glut had not happened. A sudden stop in 2015–2016, though, would reduce real income from the perspective of model agents in 1992 by 1 trillion dollars compared to gradual rebalancing, eliminating the welfare gains created by the saving glut. In other words, if the saving glut ends in a sudden stop, U.S. households would prefer that the saving glut had never happened.

In the sensitivity analysis of our model, we find that our main results are robust to a range of modeling choices, such as altering our assumptions about the path of government spending and abandoning perfect foresight in favor of a stochastic model with rational expectations. The

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input-output production structure and the tradability of services, however, play important quantitative roles in our model's predictions for goods-sector employment. Removing the input-output structure raises the elasticity of substitution between goods and services in gross output, which causes our model to capture a significantly smaller fraction of the decline in goods-sector employment we observe in the data during 1992–2011. This change also leads our model to overstate the role of the saving glut in reducing goods-sector employment during this period; making services nontradable has a similar effect.

To justify our assumption that the U.S. trade deficit has been driven by the rest of the world's demand for saving rather than domestic factors, we study a version of our model in which we alter the preferences of U.S. households — rather than those in the rest of the world — to match the U.S. trade balance. This *domestic-saving-drought* experiment does not significantly affect our main results about goods-sector employment and the impact of a sudden stop, but it leads to predictions for investment and construction employment that are sharply at odds with the data: The foreign-saving-glut hypothesis fits the data better.

2. The U.S. economy, 1992–2012

This section presents our approach to analyzing U.S. data over the past two decades. We view the massive foreign borrowing and the differentials in productivity growth across sectors as exogenous driving forces that we hardwire into the model. We present three key facts about U.S. data that we view as tests for our model. It is our model's ability to replicate these three facts in response to the exogenous driving forces that gives us confidence in using the model to make predictions about the future of the U.S. economy.

Exogenous driving force 1: Foreign borrowing increased, then decreased

Figure 3 illustrates just how much borrowing households and the government in the United States have done. The current account balance measures the exact magnitude of capital flows into the United States, but we see that the trade balance tracks the current account balance almost exactly. Since our model is not designed to accurately capture the difference between these two series and the trade balance has an exact model analogue, we use the trade deficit as our measure of U.S. borrowing. Figure 3 shows that between 1992 and 2006, the trade deficit grew steadily, reaching 5.8 percent of GDP, after which it began to shrink. In 2012, the trade

deficit remained at 3.6 percent of GDP. We view the path of the trade balance as what defines the saving glut in our model. Our hypothesis is that the U.S. economy is currently in the process of emerging from the saving glut.

Exogenous driving force 2: Labor productivity grew fastest in the goods sector

During 1992–2011, labor productivity in the goods sector increased by an average of 4.6 percent per year, while it increased by only 1.4 percent per year in the services sector and fell by 1.3 percent per year in construction. What is essential in our model is the differential between productivity growth in the goods sector and that in the services sector. As the data in figure 2 show, this differential has been close to constant since 1980, with average productivity growth of 4.4 percent per year in goods during 1980–2011, compared with 1.1 percent in services. Except for the productivity slowdown of 1970s, the differential has been persistent since 1960. Our hypothesis is that this productivity differential persists until at least 2030.

Fact 1: The real exchange rate appreciated, then depreciated

Figure 3 presents the first key fact that we ask our model to replicate. The figure shows that the U.S. real exchange rate was volatile and tracked the trade balance closely during 1992–2012. We construct our measure of the U.S. real exchange rate by taking a weighted average of bilateral real exchange rates with the United States' 20 largest trading partners, with weights given by these countries' shares of U.S. imports in 1992. (Other weighting schemes do not significantly affect our results.) This approach forms the basis of our concept of the *rest of the world* in our model. The real exchange rate appreciated by 27.9 ($=100 \times (100/78.2 - 1)$) percent between 1992 and 2002, after which it depreciated by 22.1 percent between 2002 and 2012. The intuition for why the real exchange rate and trade balance should move closely is straightforward: As foreign goods and services become cheaper, U.S. households buy more of them. Notice, however, that the timing is off: The maximum appreciation of the real exchange rate occurred in 2002, while the largest trade deficit occurred in 2006.

Fact 2: The goods sector drove aggregate trade balance dynamics

Figure 6 presents our second key fact. Here we disaggregate the trade balance, plotting the trade balances for goods and services separately. We see that the goods trade balance

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generates most of the fluctuations in the aggregate trade balance, while the services trade balance fluctuates in a band between 0.5 and 1.2 percent of GDP. That the United States has consistently run a trade surplus in services motivates one of the key features of our modeling framework. Standard modeling conventions in international macroeconomics lump services together with construction into a nontradable sector, treating goods as the only sector that produces output that can be traded internationally. By contrast, we allow both goods and services to be traded in our model, and we calibrate home bias parameters for each sector separately to capture the fact that the United States consistently runs a surplus in services and a deficit in goods.

Fact 3: Employment in goods declined steadily; construction employment rose, then fell

Figure 7 presents our third fact: Between 1992 and 2011, the fraction of total labor compensation paid to the goods sector fell from 19.7 percent to 12.4 percent. The fraction of total labor compensation is our preferred measure of the goods sector's employment share because it maps directly into our model, where we measure labor inputs in terms of effective hours worked, rather than raw hours worked. As figure 1 shows, this measure moves closely with more common measures like the share of employees in the goods sector; the same is true for the construction sector. The construction sector's share of labor compensation rose from 4.4 percent in 1992 to 5.7 percent in 2006, as construction boomed prior to the financial crisis in 2008–2009. Employment in construction then started to fall, and by 2012 the construction sector's share of labor compensation was 4.4 percent.

3. Model

We model an economy with two countries, the United States and the rest of the world (RW). We use the superscripts *us* and *rw* to denote prices, quantities, and parameters in the United States and the rest of the world. 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). In the baseline model, households have perfect foresight over the future trajectory of the world economy — there is no uncertainty. Each country produces 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 reduced-form fashion as well. The government's spending and debt are specified exogenously as fractions of U.S. GDP, and the government levies lump-sum taxes on U.S. households to ensure that its budget constraints are satisfied.

Production

The United States produces four 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}. Prices are denoted similarly. All commodities are sold in perfectly competitive markets. Each U.S. commodity $j = g, s$ 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 imports m_{jt}^{us} purchased from the same sector j in the rest of the world:

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

This nested production function embeds a Leontief input-output structure in an Armington aggregator. The parameters of the production functions are: M_j^{us} and A_j^{us}, the constant scaling factors used to facilitate calibration; μ_j^{us}, which governs the share of imports in production; ζ_j, which governs the elasticity of substitution between domestic and imported inputs; $\left(a_{gj}^{us}, a_{sj}^{us}, a_{cj}^{us} \right)$, which govern the shares of goods, services, and construction in gross output; γ_{jt}^{us}, the sector-specific labor productivity; and α_j, capital's share of value added. Our assumption of zero substitutability between intermediate inputs is standard in the input-output literature, consistent with empirical findings that direct requirement coefficients vary little over time (Sevaldson, 1970; Miller and Blair, 2009). This assumption implies that the elasticity of substitution between goods and services in gross output is lower than the same elasticity in consumption. In section 7,

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we show that this plays an important role in our model's ability to capture the bulk of the reallocation of labor across sectors in the data.

We allow the Armington elasticities $1/(1-\zeta_j)$ to differ across sectors to capture the fact that the goods trade balance is considerably more volatile than the services trade balance (see figure 6). 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.

Consistent with our input-output table (table 1), the construction sector is the only purely nontradable sector. The production function in the construction sector is a special case of (1):

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

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 good is produced using inputs z_{git}^{us}, z_{sit}^{us}, and z_{cit}^{us} of goods, services, and construction according to a Cobb-Douglas technology:

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

This specification is consistent with evidence reported by Bems (2008) 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

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

Households

Each country is populated by a continuum of identical households. We draw a distinction between the total and working-age populations so that our model can capture the impact of demographic changes. 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 $n_t^{us} = \overline{\ell}_t^{us} + (\tilde{n}_t^{us} - \overline{\ell}_t^{us})/2$. The rest of the world's demographic variables are defined analogously.

We normalize the amount of time available for work and leisure by a U.S. working-age person to 1 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^{ush} to maximize utility

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

subject to the budget constraints

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

the law of motion for capital

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

appropriate non-negativity constraints, initial conditions for the capital stock and bond holdings $\overline{k}_0^{us}$ and $\overline{b}_0^{ush}$, and a constraint on bond holdings that rules out Ponzi schemes but does not otherwise bind 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*.

Bonds are denominated in units of the U.S. CPI, defined as

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

We model 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

$$
(9) \qquad\qquad\qquad 1 + r_{t+1} = p^{us}(p_{gt}^{us}, p_{st}^{us}) / q_t.
$$

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. 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. During the sudden stop episode that can 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 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 U.S. bonds. We can easily allow for rest-of-the-world bonds as well without changing the equilibrium of the model. Labor supply is again endogenous and the rest of the world's households have a utility function similar to that of U.S. households:

$$(10) \qquad \sum_{t=0}^{\infty} \beta^t \omega_t^{rw} \left(\left[\varepsilon^{rw} \left(\frac{c_{gt}^{rw}}{n_t^{rw}} \right)^{\rho} + (1-\varepsilon^{rw}) \left(\frac{c_{st}^{rw}}{n_t^{rw}} \right)^{\rho} \right]^{\frac{\eta\psi}{\rho}} \left(\frac{\overline{\ell}_t^{rw} - \ell_t^{rw}}{\overline{\ell}_t^{rw}} \right)^{(1-\eta)\psi} - 1 \right) / \psi \,.$$

The only differences from the U.S. household's utility function are the share parameter ε^{rw} and the utility weight ω_t^{rw}. The latter is an intertemporal demand shifter, which we calibrate to match the U.S. trade balance during 1992–2012. During this period ω_t^{rw} falls, reflecting a reduction in utility gained from consumption at t compared with future consumption. This is the driving force behind the saving glut. 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,

$$(11) \qquad p_{gt}^{rw} c_{gt}^{rw} + p_{st}^{rw} c_{st}^{rw} + q_t b_{t+1}^{rw} = w_t^{rw} \ell_t^{rw} + p^{us}(p_{gt}^{us}, p_{st}^{us}) b_t^{rw} \,,$$

and non-negativity and no-Ponzi constraints similar to those that U.S. households face. The rest of the world's CPI is defined analogously to the U.S. CPI in (8). We then define the real exchange rate as

$$(12) \qquad rer_t = p^{rw}(p_{gt}^{rw}, p_{st}^{rw}) / p^{us}(p_{gt}^{us}, p_{st}^{us}) \,.$$

U.S. government

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

$$(13) \qquad p_{gt}^{us} c_{gt}^{usg} + p_{st}^{us} c_{st}^{usg} + q_t b_{t+1}^{usg} = \tau_k^{us} r_{kt}^{us} K_t^{us} + T_t^{us} + p^{us}(p_{gt}^{us}, p_{st}^{us}) b_t^{usg} .$$

We specify exogenous time paths for government consumption expenditures and debt as fractions of GDP, using historical data for 1992–2012 and Congressional Budget Office (CBO) projections for the future. We use v_t and υ_t to denote these time-series. We allow the lump-sum tax T_t^{us} to vary as necessary to ensure that the government's budget constraint is satisfied.

We specify the elasticity of substitution between goods and services in the government's spending rule to be 1, so that the government chooses c_{gt}^{usg} and c_{st}^{usg} to maximize a Cobb-Douglas aggregator with goods-share parameter ε^{usg} subject to the constraint that the government makes its required total expenditures. 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.

Because of the lump sum tax T_t^{us}, our model exhibits near-Ricardian equivalence. That is, the timing of taxes and government borrowing is almost irrelevant. Ricardian equivalence breaks down only when we introduce unexpected events — the saving glut and the sudden stop. Unanticipated changes in the time path of government debt that accompanies these events do affect the model's equilibrium dynamics, particularly in the short run.

Equilibrium

An equilibrium in our model for a given sequence of time-series parameters $\{\omega_t^{rw}, v_t, \upsilon_t\}_{t=0}^{\infty}$ and initial conditions $(\bar{b}_0^{ush}, \bar{b}_0^{usg}, \bar{k}_0^{us})$ consists of a sequence of all model variables such that households in the United States and the rest of the world maximize their utilities subject to their constraint sets, prices and quantities satisfy marginal product pricing conditions for all commodities, prices and quantities are such that all production activities earn zero profits, all commodity, factor and bond 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. Calibration

As in 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 saving glut does not occur replicates the input-output matrix. There are several discrepancies between the national income and product accounts and the input-output matrix, so we let the NIPA tables take precedence and perform several adjustments using the RAS algorithm (Stone, 1961) to the input-output matrix so that it matches the relevant NIPA data exactly. Details are provided in the online data appendix at http://www.econ.umn.edu/~tkehoe. Our adjusted input-output matrix is shown in table 1. Table 2 lists our calibrated parameter values.

U.S. production parameters

We choose units so that U.S. GDP is equal to 100 and all prices are equal to 1 in 1992 — all quantities are expressed as percentages of 1992 GDP. We compute the parameters in the Leontief portion of the U.S. production functions in (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 (3.7) by gross output in construction (10.7). 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 because business cycle models tend to imply low elasticities while analysis of trade policy changes often suggests much higher elasticities; see Ruhl (2008) for a detailed discussion. Because the services trade balance is less volatile than the goods trade balance, we choose a lower elasticity of substitution between domestic and foreign inputs in the services sector. We set the elasticity in goods $1/(1-\zeta_g)$ to 3 and that in services $1/(1-\zeta_s)$ to 1. We then use equilibrium conditions (marginal product pricing and zero profits) to calibrate 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 (U.S. Congress, Congressional Budget Office, 2012). 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, similar to the value in Stockman and Tesar (1995). We calibrate the parameters ε^{ush} and η of the household's preferences using private consumption data from our input-output table and data in hours worked in the household's first-order conditions. 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 have been determined in 1991, but 1992 is our initial model year. The real interest rate on 10-year U.S. Treasury bonds was approximately 4 percent in 1992. Our results are not sensitive to alternative approaches to calibrating the initial capital stock. Given a tax rate on capital income τ_k^{us}, we can compute our initial capital stock using data on depreciation from the 1992 national income accounts and data on payments to capital in our input-output table. We choose $\tau_k^{us} = 0.4$, which implies a depreciation rate of 6.6 percent per year, well within the standard range of annual depreciation rates used in the literature. U.S. government debt was 48.1 percent of GDP in 1992, and we use this value directly to set the government's bonds in 1992, $\bar{b}_{1992}^{usg}$. We then set private bond holdings, $\bar{b}_{1992}^{ush}$, so that total net foreign assets $\bar{b}_{1992}^{ush} + \bar{b}_{1992}^{usg}$ are -7.8 percent of GDP as reported in Lane and Milesi-Feretti (2007).

Calibrating 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 select the United States' top 20 trading partners, ranked by average annual bilateral

trade (exports plus imports) between 1992 and 2012, and weight them by their average share of U.S. total annual trade 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. To calculate the size of the rest of the world relative to the United States, we take a weighted average of goods and services consumption of these 20 countries and multiply these figures by 20 to get total consumption 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 *World Population Prospects: 2010 Revision* (United Nations, 2011) 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). The United States and the rest of the world are projected to grow at different rates well past the 100-year terminal date in our model, so to ensure balanced growth in our computation, we assume that the populations in both countries begin to converge to constant levels after 2050. Our model's equilibrium dynamics between 1992 and 2024, 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 1992–2011. We use these data to perform growth accounting by sector and find that the average growth rates of labor productivity over this period are 4.6 percent in goods, 1.4 percent in services, and −1.3 percent in construction. We use these values in the model between 1992 and 2030, and in the years following we assume that all of the sector-level growth rates converge slowly to 2 percent per year, to ensure that 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 BEA for government consumption expenditures and from the CBO for government debt. We use CBO projections for government expenditures and debt as fractions of GDP as a starting point, but we make adjustments to retain consistency with the national income accounts and to allow for balanced growth in the long run. We use the most recent projections when possible. More details are available in the data appendix.

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In the no-saving-glut counterfactual, we assume that government spending as a fraction of GDP remains constant at its 1992 value and that government debt gradually rises to 60 percent of GDP over time. In modeling the rebalancing scenario, we use historical data for 1992–2012 and the CBO projections thereafter. Some of the projections the CBO has made for the paths of government debt are implausible, however; the *extended baseline* scenario predicts that government debt will drop below zero by 2070 and the *extended alternative* scenario predicts that debt will surpass 250 percent of GDP by 2045. We therefore assume that government debt as a fraction of GDP will remain constant at the 2023 value of 77.0 percent of GDP in 2024 and beyond. Finally, in the sudden stop scenario, we use the same expenditure series but assume that the debt-GDP ratio falls to 60 percent once the saving glut ends, reflecting a permanent change in U.S. government policy that coincides with the sudden stop.

5. Quantitative results

This section presents the baseline quantitative results and contrasts the results between the model in which the saving glut occurs and one in which it does not occur, to show how the model is able to replicate our three key facts. We then study the model's predictions for the future and how a sudden stop in foreign lending in 2015–2016 would play out. We finish with an analysis of the welfare consequences of the saving glut and a sudden stop.

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 the saving glut occurs 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 parameter ω_{1992}^{rw} to match the U.S. trade balance in 1992 and assume that it converges quickly to a constant value of 1 thereafter. In this step, agents in our model do not expect the saving glut to occur. We do not calibrate our model to match any time series at all in this step. 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 saving glut not happened? We could skip this step and go right to the next one without changing our main results significantly, but we view this as the most natural way to think about the agents' expectations in the early 1990s: We do not think

that U.S. households in 1992 foresaw the kind of borrowing the United States would do over the subsequent two decades.

Our second step is to solve for the model's dynamics in the scenario in which the saving glut actually happens. Here, we hold fixed all of the parameters calibrated during the first step and calibrate the values of ω_t^{rw} for 1993–2012 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 1 after 2012. We use the equilibrium values of capital and bond holdings in 1993 from the no-saving-glut first step as initial conditions in this second step. The saving 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, but they have perfect foresight thereafter. We refer to the model's post-2012 dynamics in this scenario as a *gradual rebalancing*, representing the outcome of a slow, orderly end to the forces driving the saving glut. In our sensitivity analysis, we relax the perfect foresight assumption and allow for agents to be uncertain about the length of the saving glut.

Our third, and final, step is to solve for the model's dynamics from 2015 onward when a sudden stop occurs. We treat a sudden stop as another unforeseen event and treat the equilibrium state variables from the second step (gradual rebalancing) in 2015 as the initial conditions. As before, once the sudden stop occurs, model agents have perfect foresight thereafter. We model a sudden stop as a two-year period in which the United States is restricted from borrowing further from the rest of the world, after which foreigners are again willing to purchase U.S. bonds. We assume that the rest of the world's preference parameter ω_t^{rw} converges to its long-run value of 1 more quickly than in the previous scenario, which we intend to capture the idea that a sudden stop is associated with a faster end to the forces that drove the saving glut in the first place. Furthermore, we assume that a sudden stop generates a *disorderly* adjustment in financial markets that causes total factor productivity (TFP) in all three production sectors to fall by 10 percent in 2015, to recover half of this drop in 2016, and to fully recover in 2017. This TFP drop captures the sort of disruption and rapid recovery that occurred in sudden stop episodes like that in Mexico in 1995–1996 (Kehoe and Ruhl, 2009). We also assume that the U.S. government's debt as a fraction of GDP falls to a lower long-run level than in the gradual rebalancing case,

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representing the idea that a sudden stop is associated with, or perhaps triggers, a long-term change in U.S. government debt policy.

We model the sudden stop in 2015–2016 in the same manner as Kehoe and Ruhl (2009), who model the Mexican sudden stop of 1995–1996 as a surprise. Agents in the model have perfect foresight before and after the sudden stop, but, if and when the sudden stop occurs, it is completely unexpected. We model the sudden stop as a surprise because U.S. interest rates currently indicate that financial markets do not assign a significantly positive probability to a U.S. debt crisis — just as they did not assign significantly positive probabilities to a crisis in Mexico in 1995 (which started during the last two weeks of 1994) or to the currently ongoing debt crises in the Eurozone. (See, for example, Arellano, Conesa, and Kehoe, 2012.) We think of the possibility of a debt crisis striking the United States as the possibility of the sort of self-fulfilling crisis modeled by Cole and Kehoe (2000) and Conesa and Kehoe (2012).

Replicating the three key facts

The trade balance post 2012 and all of the prices and quantities post 1992 are endogenous outcomes of the model. Here we show that the equilibrium of the calibrated model matches the U.S. data in the three key dimensions laid out in section 1. As figure 4 shows, we calibrate our model to match the U.S. trade balance exactly between 1992 and 2012. In this figure we have also plotted the trade balance from the model in which the saving glut never occurs. Notice that, in this counterfactual scenario, trade would be close to balanced throughout the period. In the baseline model, however, the saving glut has occurred, so the United States must repay its debt in the long run. The figure shows that, as long as the rebalancing process goes smoothly, the U.S. trade balance will switch from a deficit to a surplus in 2018, and will reach a surplus of more than 1.1 percent of GDP by 2024.

Figure 5 plots the model's real exchange rate in the baseline model against the data and the no-saving-glut counterfactual. Our model does a good job of matching the magnitude of the appreciation during 1992–2012: The real exchange rate appreciated by 27.9 percent in the data and 26.0 percent in the model before beginning to depreciate. The model, however, fails to capture the timing of the depreciation. In the data, the real exchange rate begins to depreciate in 2002, four years before the trade deficit begins to shrink. In our model, the real exchange rate moves in tandem with the trade balance, so it does not begin to depreciate until 2006. In our

model, consumers and firms begin to import fewer foreign goods and services only once they begin to become more expensive.

Figure 5 also shows that if the saving glut had never occurred, the U.S. real exchange rate would appreciate slowly over the long run, due in large part to the increase in the relative price of services, in which the United States has a comparative advantage. The saving glut did occur, however, and because the United States must run a trade surplus in the long run, its goods and services must become cheaper. Our model predicts that the real exchange rate will continue to depreciate for several years, eventually converging to a level that is 6.3 percent depreciated compared to that in the no-saving-glut counterfactual.

Figure 6 plots the sector-level trade balances in the model alongside the data. The model matches both the goods and services trade balances closely between 1992 and 2012. This aspect of the model's performance is due to our choice of Armington elasticities. Had we used the same elasticity in both sectors, the goods trade balance would not have moved enough, while the services trade balance would have been too volatile. The figure also shows that in the absence of the saving glut, the services trade balance would not have been substantially different, while the goods trade balance, reflected in the aggregate trade balance, would have been almost flat. In the long run, the model predicts that the goods trade balance will be 1.4 percent of GDP higher by 2024 than it would have been if the saving glut had never occurred. Despite this, the model predicts that the goods trade balance will be negative in the balanced growth path: The services sector will be the source of the entire long-run trade surplus.

Figure 7 plots the employment shares for goods and services in the model and the data. In the baseline gradual rebalancing scenario, our model matches the data closely between 1992 and 2001, after which the goods employment share falls more in the data than in the model. For 1992–2011, our baseline model captures 75.2 percent of the decline in the goods sector's employment share that we observe in the data. In the no-saving-glut counterfactual, however, the model still captures 60.5 percent of the decline (the decline in the counterfactual is only 19.5 percent smaller than the decline in the baseline rebalancing scenario). The figure suggests that, while the saving glut did temporarily accelerate the decline in goods-sector employment, the bulk of the decline is attributable to the fact that labor productivity has grown faster in the goods sector than in the rest of the economy.

The implication of this result is that, contrary to popular belief, the end of the saving glut will have very little impact on employment in the goods sector. By 2024, the model indicates that the goods sector's share of employment will be almost exactly the same regardless of whether or not the saving glut had happened. Despite the fact that the U.S. economy must run a trade surplus in the long run to repay its debt, the goods sector's employment share will continue to decline once the saving glut ends. There are two main reasons for this result. First, labor productivity continues to grow faster in goods than in other sectors in our model even after the saving glut ends. This aspect of structural change has been a consistent force in the U.S. economy since the 1960s, and we see no reason that it should end when the saving glut does. Second, the United States can repay its debt with the trade surplus generated by the services sector; our model predicts that the United States will continue to run a deficit in goods trade once the saving glut ends and the aggregate U.S. trade balance reverses.

Figure 7 also shows that the model captures several aspects of the construction sector's employment share between 1992 and 2011. Between 1992 and 2006, the construction sector's employment share rises in both the model and the data, although our model generates a larger increase. Our model overexplains the boom in construction sector employment just by introducing the saving glut. The subsequent bust is smaller in the model than in the data, but this is primarily because we have not introduced the financial crisis of 2008–2009 in any form other than the way in which it affected the trade balance. If we were to introduce additional features to the model to more accurately model the crisis, we would undoubtedly do better in this regard, but this is not the focus of our paper. As the figure shows, our model suggests that the effects of the saving glut on the construction sector will largely dissipate by 2016; just like in the goods sector, the construction sector's long-run employment share dynamics will be driven primarily by productivity growth rather than the rebalancing process.

A sudden stop in 2015–2016

The results we have presented so far focus on the scenario in which the rebalancing process is gradual and orderly. Figures 4–7 also illustrate what our model predicts if this process instead involves a sudden stop in 2015–2016. Figure 4 illustrates the dynamics of the aggregate trade balance in the sudden-stop scenario compared to the rebalancing scenario; figure 5 shows analogous results for the real exchange rate We see that a sudden stop would trigger an

immediate reversal in capital flows and a large real exchange rate depreciation. The trade balance would rise from −1.4 percent of GDP to 2.6 percent on impact, and the real exchange rate would depreciate by 10.7 percent. These effects, however, would be short-lived. By 2024 the trade balance and real exchange rate would be almost identical to their levels in the gradual rebalancing scenario. While a sudden stop involves quicker debt repayment, the effect on the long-term need to repay is small in our model. The United States has borrowed so much from the rest of the world in the last two decades that two years of rapid repayment do not make much of a dent in the overall stock of debt.

Figure 6 shows that the large, temporary trade balance reversal comes mostly from the goods sector. The goods trade balance rises by 3.4 percent of GDP on impact, while the services trade balance rises by 0.6 percent. Figure 7 shows that, despite the large increase in the goods trade balance, we do not see a large reallocation of labor toward the goods sector. The goods sector's labor compensation share rises from 14.4 percent to 15.1 percent on impact, but this is short-lived, just like the other effects of the sudden stop. Once the sudden stop ends, rapid productivity growth continues to push goods employment downward, and by 2024 the goods sector's labor compensation share is almost exactly as it would have been if the sudden stop had not occurred. As compared with the goods sector, construction sees a much larger (although just as temporary) impact from the sudden stop. The construction sector's share of labor compensation falls by more than one-third, from 6.9 percent to 4.7 percent. There are two channels at work. First, construction is the only nontradable sector, so it is more sensitive to changes in capital flows. Second, the bulk of the construction sector's output is used to produce investment. The sudden stop causes the U.S. real interest rate to rise by more than 260 basis points, leading to a large decline in investment, which substantially reduces demand for construction.

In short, a sudden stop in the United States would look, in many respects, similar to past sudden stop episodes in emerging economies. There would be a large trade balance reversal and real exchange rate depreciation, and severe disruption in the construction sector, but these effects would be short-lived — once the sudden stop ends, the U.S. economy would return to roughly the same trajectory on which it would have been had the sudden stop never happened. While a sudden stop would temporarily stem the decline in goods-sector employment, this trend would continue unabated once the sudden stop ends.

Welfare implications of the saving glut

We have shown that the saving glut has had a large impact on some aspects of the U.S. economy and that a sudden stop will cause substantial short-term disruption. Here we ask two related questions: Did the saving glut make U.S. households better or worse off? How does the answer depend on whether the saving glut ends in a gradual rebalancing or a sudden stop?

To answer these questions, we construct a measure of real income in 1992 denominated in 1992 U.S. dollars. Our real income index is based on an alternative — but equivalent — specification of the representative household's preferences that is homogeneous of degree one,

$$(14) \qquad \left[\sum_{t=1992}^{\infty} \beta^t \left(\varepsilon^{us} \left(\frac{c_{gt}^{ush}}{n_t^{us}} \right)^{\rho} + (1-\varepsilon^{us}) \left(\frac{c_{st}^{ush}}{n_t^{us}} \right)^{\rho} \right)^{\frac{\eta\psi}{\rho}} \left(\frac{\overline{\ell}_t^{us} - \ell_t^{us}}{\overline{\ell}_t^{us}} \right)^{(1-\eta)\psi} \right]^{\frac{1}{\psi}}.$$

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

$$(15) \qquad \sum_{t=1992}^{\infty} \left(\prod_{s=1992}^{t-1} q_s \right) \left(p_{gt}^{us} c_{gt}^{ush} + p_{st}^{us} c_{st}^{ush} + w_t^{us} (\overline{\ell}_t^{us} - \ell_t^{us}) \right).$$

The prices and quantities above represent equilibrium objects in our benchmark gradual rebalancing scenario, the one in which the saving glut occurs, but a sudden stop does not. To convert this object to 1992 dollars, we scale it so that consumption expenditures in the model are equal to 1992 private consumption in the NIPA tables. We use the resulting scaling factor to calculate real income in alternative scenarios, like the counterfactual in which the saving glut does not occur or the scenario in which both the saving glut and a 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 saving glut begins, an unforeseen change in government spending policy occurs: Government spending as a fraction of GDP tracks the data between 1993 and 2012, then rises to 22.9 percent over time. This reflects policy changes that have occurred over the past two decades, such as increased health care 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. We report our welfare results under an alternative assumption: In 1992, agents expect government consumption, as a fraction of GDP, to follow the path it actually took

between 1992 and 2012, and then follow the same trajectory to 22.9 percent that we used in the saving-glut scenario in our main exercise. In the saving-glut and sudden-stop scenarios, 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-saving-glut counterfactual, the saving glut with gradual rebalancing, and the sudden stop. This modification has virtually no impact on any of the results reported above, and it 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 saving glut is good or bad, and just how costly a sudden stop would be.

The first column of table 3 presents our results on the welfare impact of the saving glut and sudden stop for our baseline model. In panel (a) we report real income of U.S. households in 1992 relative to the gradual rebalancing scenario. Our model indicates that real income of U.S. households in 1992 would have been 689 billion dollars lower if the saving glut had never occurred. This is a large sum, 10.9 percent of U.S. GDP in 1992. Twenty years of increased consumption of foreign imports have made U.S. households substantially better off — as long as the saving glut ends in gradual rebalancing. If the saving glut ends in a sudden stop, however, 1992 real income of U.S. households will fall by 1,019 billion dollars compared with the gradual rebalancing scenario. In other words, if the saving glut ends in a sudden stop rather than gradual rebalancing, U.S. households would have been better off if the saving glut had never occurred at all, despite the fact that the welfare impact of the sudden stop is discounted by 23 years (1992 to 2015). We also report welfare in a version of our model in which a sudden stop occurs but TFP does not fall. In this case, welfare falls by only 386 billion dollars — a sudden stop without an accompanying TFP shock would be painful, but would not completely wipe out the welfare gains generated by the saving glut.

6. Sensitivity analysis

We have performed extensive sensitivity analysis with our model. Our main results about the reallocation of labor across sectors and the impact of a sudden stop are robust to all the modeling alternatives that we have tried. In this section, we discuss four modeling alternatives in detail: (1) We relax our baseline model's assumption of perfect foresight by studying a version of our model in which the duration of the saving glut is uncertain — ω_t^{rw} now follows a

stochastic process — and agents have rational expectations. (2) We remove the input-output relationships between sectors. (3) We do not allow services to be traded internationally. (4) We calibrate the preferences of U.S. households, rather than those of households in the rest of the world, to generate observed U.S. borrowing — a *domestic saving drought* instead of a global saving glut.

Stochastic saving glut

In our baseline model, agents in both the United States and the rest of the world have perfect foresight once the saving glut begins; they know exactly when it will end and the rate at which it will rebalance. We have also run numerical experiments with a model in which there is uncertainty about the length of the saving glut. In this version of the model, once the saving glut begins, there is a 10 percent chance in each year between 1993 and 2011 that the saving glut will end in the following year, and the rest of the world's demand for saving will begin to decrease again. The other 90 percent of the time, the saving glut will continue for at least one additional year. The realized path the economy takes is the one in which the saving glut persists through 2012, and, while this is unconditionally the most likely path the economy can take, it is not very likely from the perspective of agents in 1992. Our experiments indicate that this kind of uncertainty has no discernible impact on our results, so we do not report them here. This is because we recalibrate the weights ω_t^{rw} in the utility function of households in the rest of the world to generate the observed U.S. trade deficit.

The introduction of uncertainty into our model represents a substantial technical departure from our baseline model. 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 saving-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 in proportion to the number of periods with uncertainty, so the dimensionality of the problem increases rapidly. Although the introduction of uncertainty does not have a significant impact on our results in this paper, the stochastic model should be useful in other contexts.

No input-output production structure

Our baseline model incorporates an input-output structure in which each sector of the U.S. economy purchases intermediate inputs from other sectors, and combines these inputs with capital and labor to produce output. Here we demonstrate the importance of this approach for our results by studying an alternative version of our model in which we remove this input-output structure. We set all intermediate input values in our 1992 input-output matrix to 0, then adjust the remainder of the matrix so that it is once again consistent with the national accounts and sectoral labor compensation data for 1992. We re-calibrate our model and perform the same quantitative exercises described above: gradual rebalancing, the no-saving-glut counterfactual, and the sudden stop.

Removing the input-output structure has little impact on our model's predictions for the disaggregated trade balances or the real exchange rate, so we focus on the employment results in figure 8. In the no-saving-glut scenario, the goods sector's labor compensation share declines at a much lower rate than in the baseline model. By 2024, that share falls to 17.4 percent compared with 13.1 percent in the model with intermediate inputs: Removing intermediate inputs from the model substantially reduces the amount of structural change in the model. The structural change literature emphasizes the importance of the elasticity of substitution between goods and services in consumption for reallocation of labor across sectors driven by asymmetric productivity growth; a lower elasticity leads to more reallocation (see, for example, Ngai and Pissarides, 2007). In our calibration the elasticity in consumption is 0.5, a standard value in the literature. The Leontief input-output structure in the model implies that the elasticity of substitution between goods and services in intermediate usage is 0, and, as a consequence, the elasticity of substitution between goods and services in gross output is less than 0.5. When we remove intermediate inputs, the elasticity in gross output rises substantially, lowering the amount of reallocation of labor from goods to services in the long run.

Notice that removing intermediate inputs leads our model to attribute a much larger decline in goods-sector employment to the saving glut than does our baseline model — albeit a temporary one, just as before. The path of the goods sector's share of labor compensation between 1992 and 2006 in the model without intermediates is similar to the path in the baseline model. Relative to the no-saving-glut counterfactual, however, the 1992–2006 decline in goods-sector employment is larger in the model without intermediates than the baseline model: In the

no-intermediates model, the goods sector's labor compensation share in 2006 is 15.2 percent in the gradual rebalancing scenario, compared with 17.3 percent in the no-saving-glut model, a difference of 2.1 percent. In the baseline model, that share is 14.6 percent in the rebalancing scenario versus 16.4 percent, a difference of only 1.8 percent. The reverse is also true — the end of the saving glut leads to a larger long-run increase in goods-sector employment relative to the no-saving-glut counterfactual.

Our model also predicts that a sudden stop will have a larger (albeit temporary) impact on goods-sector employment when we remove intermediate inputs. This is because goods are used more as intermediates than services, and the TFP shock that accompanies the sudden stop reduces intermediate demand. This channel disappears when we remove intermediates from the model. Consequently, removing intermediates from the model not only causes us to increase the impact of the saving glut on goods-sector employment, it also causes us to increase the short- and long-run impact of the end of the saving glut on goods-sector employment in both the gradual rebalancing and sudden stop scenarios.

Nontradable services

Here we study how our results change when we adopt the standard modeling convention in which services are nontradable. We recalibrate our model as in the previous section so that the goods sector is responsible for total U.S. imports and exports in the 1992 and then perform the same quantitative exercises described above.

Figure 9 plots the goods sector's labor compensation share in the version of the model without services trade, our baseline results, and the data. In the no-saving-glut counterfactual, ignoring services trade has no impact on the goods sector's labor compensation share in the short or long run. Once we introduce the saving glut, however, ignoring services trade makes the goods sector's labor compensation share fluctuate more. When the U.S. trade deficit rises between 1992 and 2006, the goods sector's employment share falls from 19.7 percent to 14.2 percent in the no-services-trade version of the model, versus 14.6 percent in the baseline model. Once the U.S. trade deficit begins to fall in 2007, we see a larger temporary recovery in goods employment in the no-services-trade model, since the United States must run a surplus in goods trade to repay its debt. The sudden stop scenario illustrates the point more clearly: The sudden increase in goods-sector employment in 2015 is noticeably larger in the model without services

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trade. By 2024, however, the goods sector's employment share is on almost the same trajectory in both the no-services-trade and baseline models. In short, services trade is quantitatively important in explaining the impact (or lack thereof) of the saving glut on goods-sector employment over the past two decades, but it is not important in explaining longer-term trends in structural change.

Domestic saving drought

In our baseline model, we have adopted the global-saving-glut hypothesis proposed by Bernanke (2005), which posits that U.S. borrowing from the rest of the world since the early 1990s has been driven primarily by increased demand for saving in the rest of the world. A number of other researchers, such as Chinn and Ito (2007), Gruber and Kamin (2007), and Obstfeld and Rogoff (2009), argue that domestic factors such as monetary policy, housing market policy, and innovations in financial markets were the primary cause of U.S. borrowing. In this section, we study a version of our model in which the preferences of U.S. households, rather than the preferences of households in the rest of the world, drive the U.S. trade balance. Following Chinn and Ito (2007), we refer to this version of the model as the *domestic-saving-drought* model. In the saving-drought model, the preferences of U.S. households take the same form as in (10) and we calibrate the U.S. preference parameter ω_t^{us} so that the model matches the U.S. trade balance exactly during 1992–2012, after which it gradually converges to its long-run level of 1.

To assess which of the models is more consistent with the data, we focus on investment. Figure 10 shows that, before the financial crisis of 2009, U.S. investment rose steadily as a fraction of GDP. This is consistent with the saving-glut story: U.S. households took advantage of cheap foreign goods to increase both investment and consumption, since the relative value they placed on future consumption remained unchanged. If U.S. borrowing was instead driven by reduced demand for saving in the United States, U.S. households should have reduced investment in favor of increased consumption. Figure 10 also shows that except for the year 1993, investment in the baseline model moves in the same direction as the data. By contrast, investment in the saving-drought model falls dramatically beginning in 1997 while it continues to rise in the data (except during the 2001 recession, which we have not attempted to incorporate into the model). During the financial crisis of 2008–2009 (which we have modeled solely

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through the increasing trade balance), investment falls in the baseline model and the data, but rises in the saving-drought model. The correlation between investment in the saving-glut model and the data in first differences is 0.7; the same correlation between investment in the saving-drought model and the data is −0.6.

To sum up, while our baseline saving-glut model's results are consistent with the data on investment, the saving-drought version of our model is not: Investment in the saving-drought model is negatively correlated with the data. This finding is both a justification of our approach to modeling U.S. borrowing and evidence in favor of the saving-glut hypothesis.

7. Directions for future research and concluding remarks

We have developed a model of the United States and the rest of the world that incorporates a number of unique features — in particular, tradable services — and show that, when we incorporate increased foreign borrowing and productivity growth in the goods sector that is faster than in services and construction, the model accounts for three key facts about the U.S. economy during 1992–2012: (1) The real exchange rate appreciated, then depreciated; (2) the trade balance dynamics are driven almost entirely by the goods trade balance; and (3) labor shifted away from the goods sector toward services and construction. We use our model to show that while the faster productivity growth in the goods sector is responsible for the bulk of the shift in employment away from the goods sector, the saving glut is in fact responsible for the boom in construction employment during this period.

One of our main results is that the manner in which the saving glut ends — gradual rebalancing or a sudden stop — will not have much impact on the long-run trajectory of the U.S. economy. This does not imply, however, that the saving glut itself has not had a major long-run impact on the U.S. economy: The U.S. economy's current long-run trajectory is very different from the one it would have taken had the saving glut not occurred. Figures 4–5 illustrate this point by plotting the aggregate trade balance and real exchange rate in our gradual rebalancing scenario against the counterfactual in which the saving 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 saving glut did happen, however, our model predicts that the United States will have to run a trade surplus of around 1 percent of GDP in perpetuity. To do

so, the U.S. real exchange rate will depreciate by about 6 percent compared with what it would have been if the saving glut had not taken place.

Our analysis identifies two puzzles. Here we discuss these puzzles and point out directions that future research could take in addressing them.

The first puzzle is: 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 foreign goods and services stopped getting cheaper and started getting more expensive, as seen in the data in figure 3? A partial resolution to this puzzle might be found in the J-curve literature (Backus, Kehoe, and Kydland, 1994), in that, time-to-build and import pattern adjustment frictions can delay quantities adjusting to price changes. This mechanism is not likely to explain the substantial four-year lag, however. A more plausible resolution to the puzzle is the increase in the importance of China in U.S. borrowing during the period. In figure 11 we decompose the U.S. real exchange rate into the real exchange rates with China and with the United States' other major trade partners. We see that the overall real exchange rate and the exchange rate with non-China countries move closely in the early part of the period, but diverge in the latter part. Following 2002, the aggregate real exchange rate behaves much like the real exchange rate with China. Incorporating the increasing importance of China into our model is not simply a matter of changing weights in our real exchange rate. Instead, it would involve distinguishing between the countries that have purchased the bulk of U.S. bonds during the saving glut, like China, Japan, and Korea, and those that have run more balanced trade with the United States. To accurately capture this, we would need to model a world with (at least) three countries and some sort of asset market segmentation, where countries like China choose to lend to the United States rather than to other countries.

The second puzzle is that the saving glut has only a small effect on U.S. interest rates, as seen in figure 12, in contrast to Bernanke's (2005) judgment. The largest fall in the U.S. real interest rate in the model with the saving glut over 1992–2012, compared with the model with no saving glut, is 44 basis points (3.70 percent per year compared with 3.26 percent) in 2009. This is in line with Greenspan's (2005) judgment that foreign lending accounted for less than 50 basis points of the drop in interest rates. Warnock and Warnock (2009) have estimated that foreign lending drove down U.S. real interest rates by a somewhat larger amount, about 80 basis points, throughout the period. Krishnamurthy and Vissing-Jorgensen (2007) provide similar estimates.

In our model, the impact of the saving glut on interest rates depends on how substitutable foreign goods are for U.S. goods. With the Armington elasticities that we have chosen, we find that the saving glut generates the right magnitude of appreciation of the U.S. real exchange rate in figure 5, but not the right magnitude in the drop in the U.S. real interest rate in figure 12. If we make foreign goods more substitutable for U.S. goods, we can generate more of a drop in the U.S. real interest rate in 2006–2012 — although still nowhere near as large as the drop observed in the data — but the model would then predict a much smaller appreciation in the U.S. real exchange rate.

Notice that in figure 12 our model predicts that the U.S. interest rate is driven up by appreciation of the dollar and is driven down by depreciation. The falling prices of foreign goods during 1993–2006 induce U.S. households to increase consumption faster than they do in the model without a saving glut, generating the observed trade deficit. The first-order conditions for utility maximization imply that U.S. households are willing to do this only if interest rates are higher. As the dollar depreciates during 2006–2012, consumption grows more slowly than in the no-saving-glut model and interest rates are lower.

Since our model's results contradict Bernanke's (2005) reasoning that the saving glut is responsible for the low level of U.S. interest rates in the early 2000s, it is worth examining how the saving glut is compatible with high interest rates in the United States. Consider the interest rate parity condition that makes households in the rest of the world indifferent between holding U.S. bonds and the rest of the world's bonds:

(16) $$1 + r_{t+1}^{us} = (1 + r_{t+1}^{rw}) \frac{rer_{t+1}}{rer_t}.$$

As the demand for savings increases in the rest of the world, the interest rate there increases. At the same time, the fall in the relative price of goods in the rest of the world causes the U.S. real exchange rate to appreciate, that is, to fall. Our interest rate parity condition does not pin down the direction of change in the U.S. interest rate; in principle, it could go up or down. What tells us that the interest rate is higher in the saving-glut model than it is in the no-saving-glut model is the requirement that the saving glut generates the observed increase in the U.S. trade deficit, which implies that consumption in the United States increases faster during the saving glut than it would have done with no saving glut.

To account for the very low U.S. interest rates seen in the data, we need to look elsewhere, possibly to the sorts of U.S. policies discussed by Obstfeld and Rogoff (2009) and Bernanke, Bertaut, DeMarco, and Kamin (2011). It is worth pointing out, however, that modeling the source of the global imbalances over 1992–2012 as being generated by U.S. savings behavior does not work well. The domestic-saving-drought model is successful in generating lower U.S. interest rates during 1993–2006, as the dollar appreciates, but it generates higher U.S. interest rates during 2006–2012, as the dollar depreciates. The low interest rates during the entire period pose a puzzle for both models.

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Table 1: 1992 Input-output matrix (billions of 1992 dollars)

Industry	Inputs			Final demand					Total demand
	Goods	Services	Construction	Private consumption	Government consumption	Investment	Exports	−Imports	
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)	Gross output in 1992 less imports, percent GDP	(52.8,107,10.7)
a_{gg}, a_{sg}, a_{cg}	(0.40,0.19,0.01)	Share of intermediates in goods in 1992	(0.41,0.19,0.01)
a_{gs}, a_{ss}, a_{cs}	(0.06,0.22,0.02)	Share of intermediates in 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 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 in 1992	(0.32,0.21,0.47)
G	2.85	Investment in 1992, percent GDP	17.2
Household parameters and initial conditions			
$\bar{b}_{1992}^{ush}$	40.3	Net foreign assets in 1992, percent GDP	7.75
$\bar{k}_{1992}^{us}$	176.25	Real interest rate in 1992, percent per year	4.00
β^{us}, β^{rw}	(0.996,0.996)	Long-term real interest rate, percent per year	3.00
$\varepsilon^{ush}, \varepsilon^{rw}$	(0.07,0.19)	Share of goods in private consumption in 1992	21.0
ρ	-1.00	Elasticity of substitution, goods to services	0.50
η	0.28	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}	(1.78,1.09)	Gross output in goods/services in 1992 including imports	(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}	(1.67,1.10)	RW goods/services consumption in 1992	(78.0,161.7)
μ_g^{rw}, μ_s^{rw}	(0.69,0.98)	U.S. exports in 1992 in 1992	(7.06,2.95)
ζ_g, ζ_s	(0.67,0.01)	Elasticity of substitution, domestic to foreign	(3.00, 1.00)
Government parameters and initial conditions			
$\bar{b}_{1992}^{usg}$	-48.1	U.S. government debt in 1992, percent GDP	48.1
τ_k^{us}	0.415	Depreciation rate, percent per year	6.6
τ_{k1993}^{us}	0.396	Investment in 1992, percent GDP	17.2
ε^{usg}	0.19	Share of goods in government consumption	0.19
Time series parameters			
$\{\tilde{n}_t^{us}, \tilde{n}_t^{rw}, \bar{\ell}_t^{us}, \bar{\ell}_t^{rw}\}_{t=0}^{\infty}$		*World Population Prospects: 2010 Revision*	
$\{\omega_t^{rw}\}_{t=0}^{\infty}$		U.S. trade balance, 1992–2012	
$\{\gamma_{jt}^{us} \gamma_{jt}^{rw}\}_{t=0}^{\infty}$		Labor productivity growth in goods/services/construction, 1992–2011	
$\{\nu_t, \upsilon_t\}_{t=0}^{\infty}$		CBO historical data and projections	

Table 3: Welfare impact of saving glut and sudden stop

Change in real income compared with rebalancing scenario (billions of dollars)	Baseline	Nontradable services	No intermediates
No-saving-glut counterfactual	-689	-696	-492
Sudden stop (no TFP shock)	-386	-378	-429
Sudden stop (TFP shock)	-1,019	-1,020	-1,063

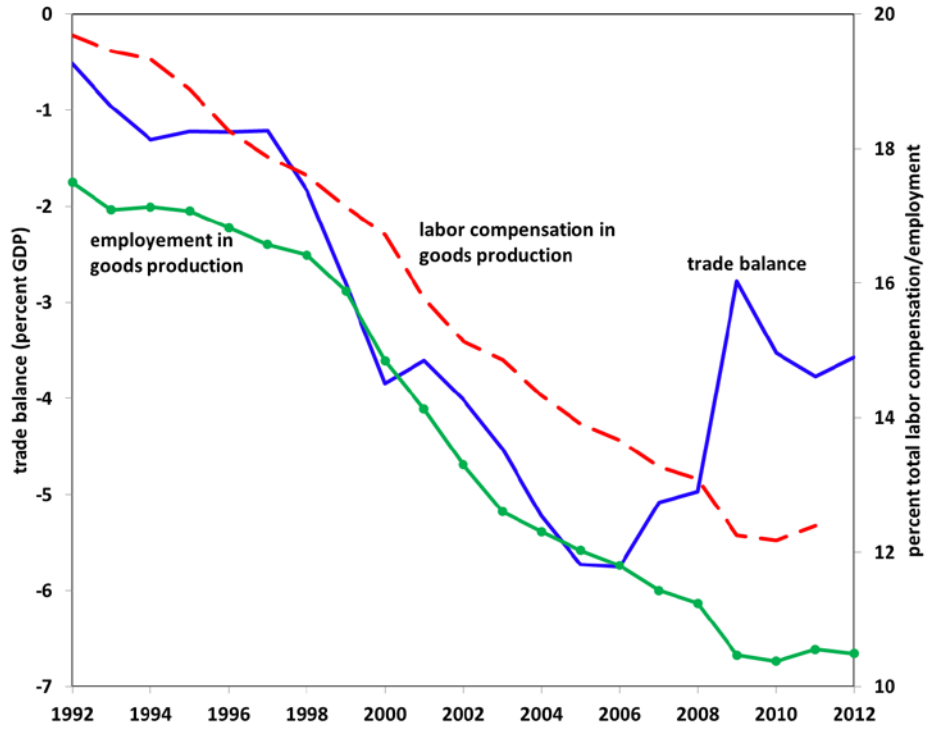**Figure 1: U.S. trade balance vs. goods sector's employment share**

Figure 2: Labor productivity in goods, services, and construction
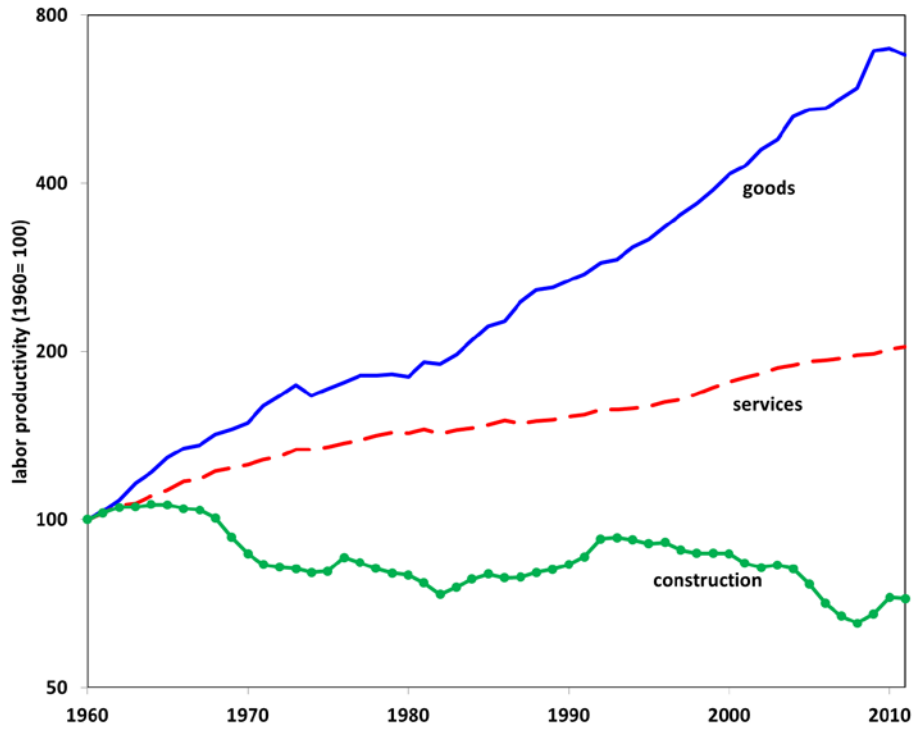
Figure 3: U.S. trade balance, current account balance, and real exchange rate
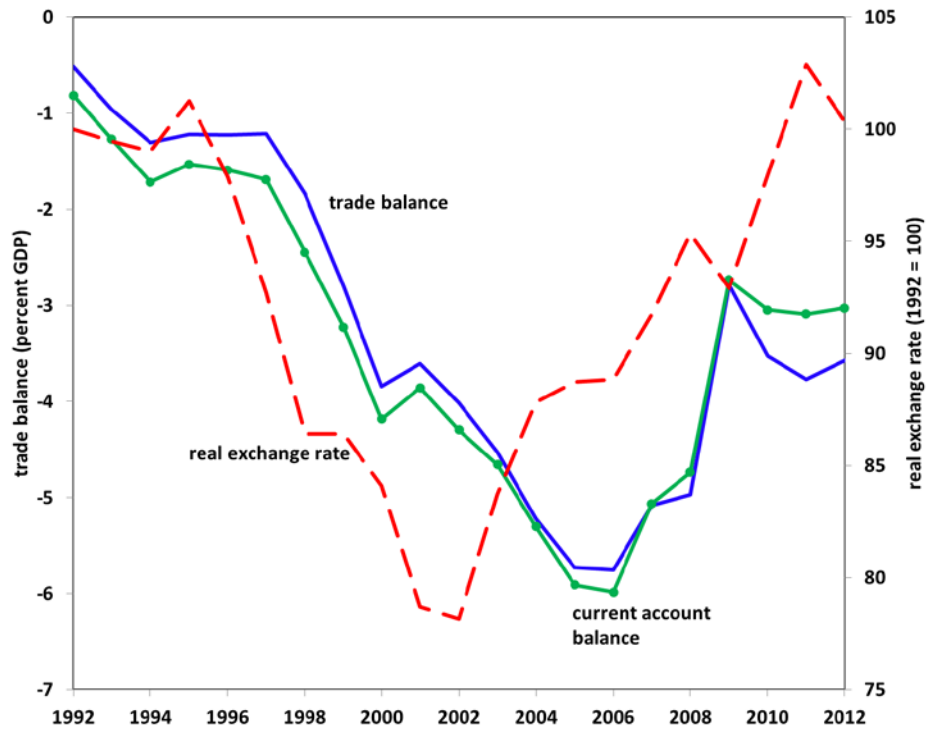
Figure 4: U.S. trade balance in the model and the data
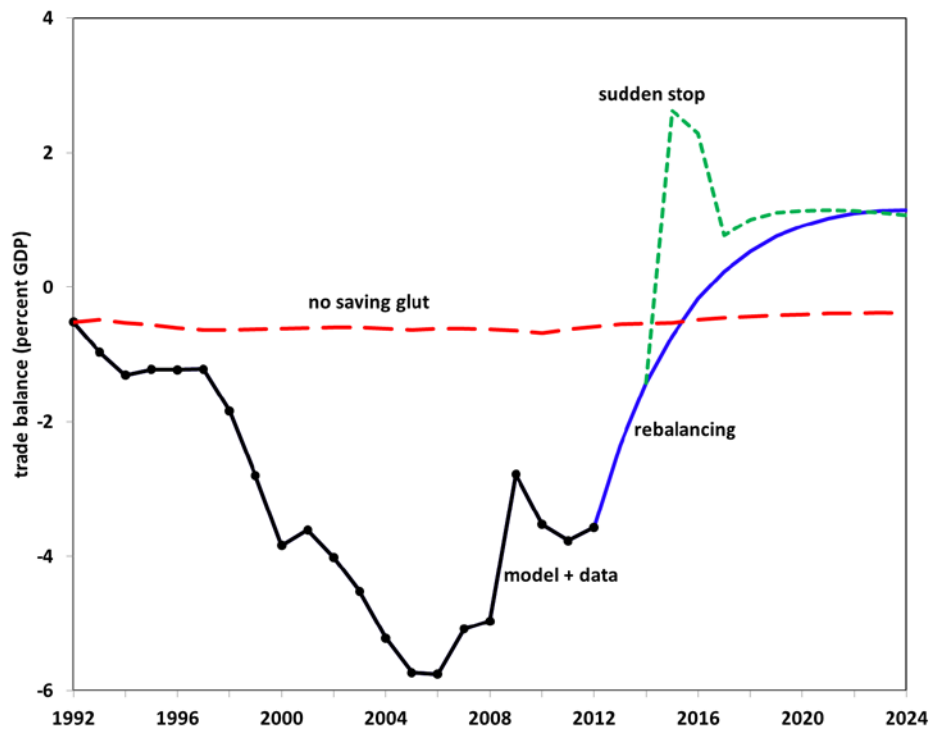
Figure 5: U.S. real exchange rate in the model and the data
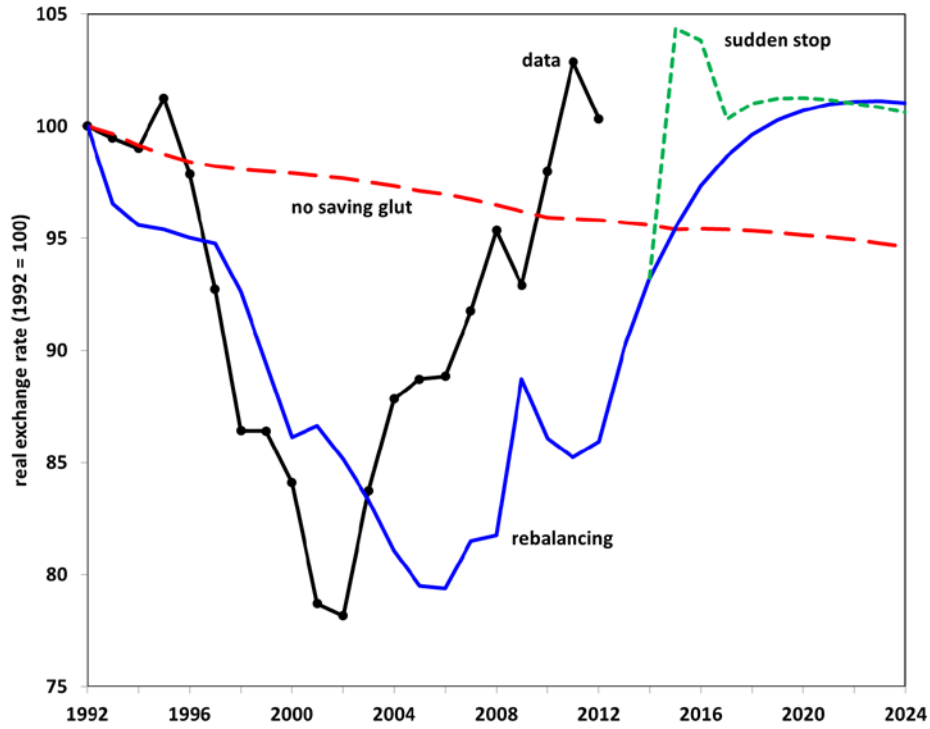
Figure 6: Disaggregated trade balances in the model and the data
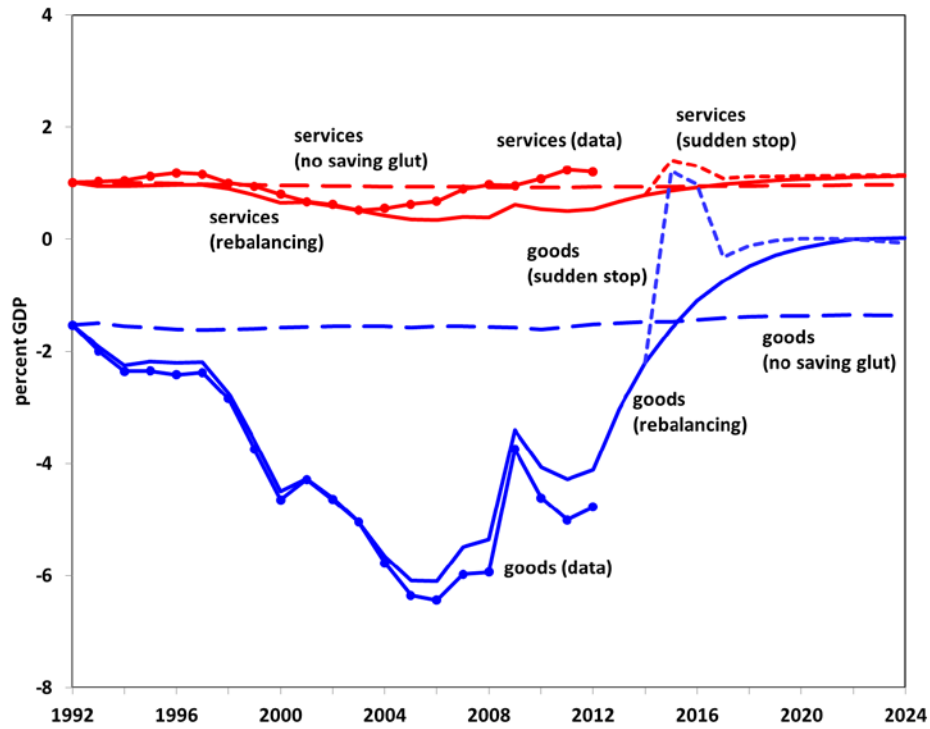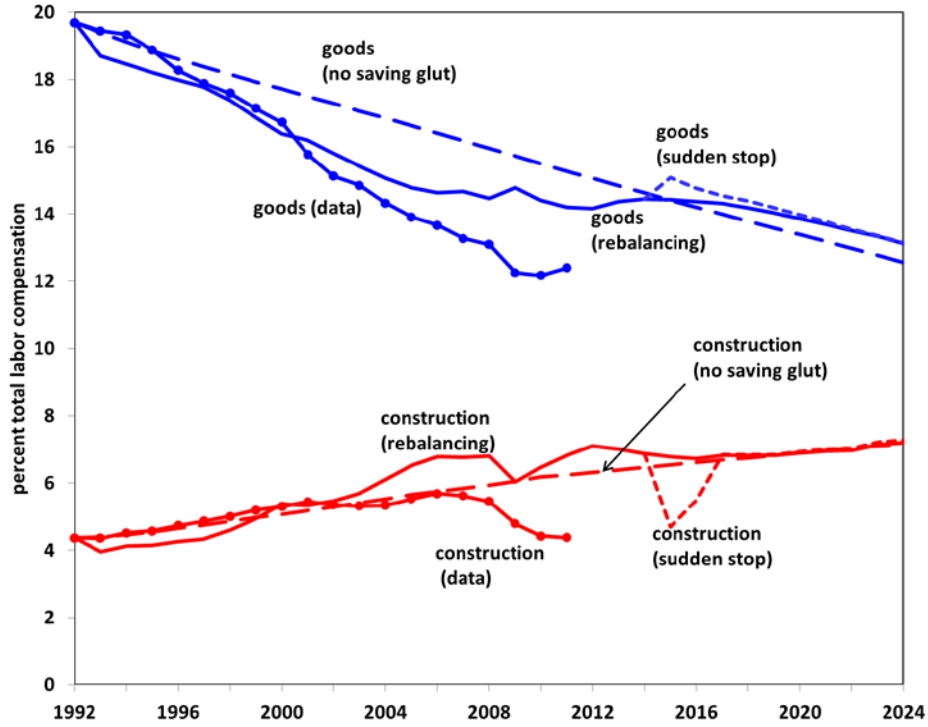
Figure 7: Goods and construction employment shares in the model and the data

Figure 8: Goods employment share in no-input-output model vs. baseline model
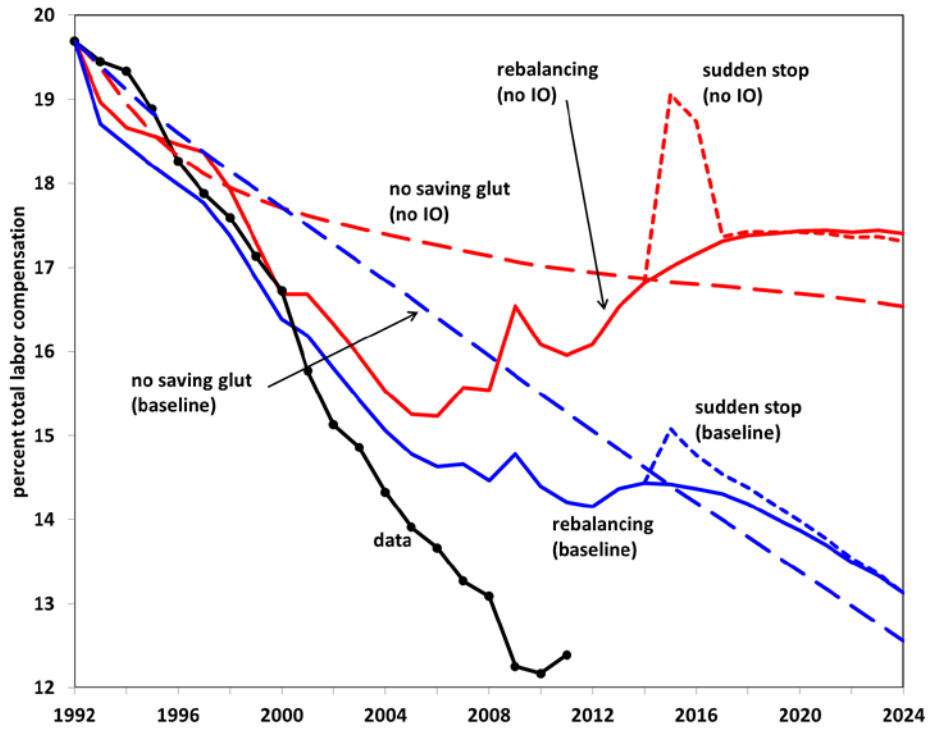
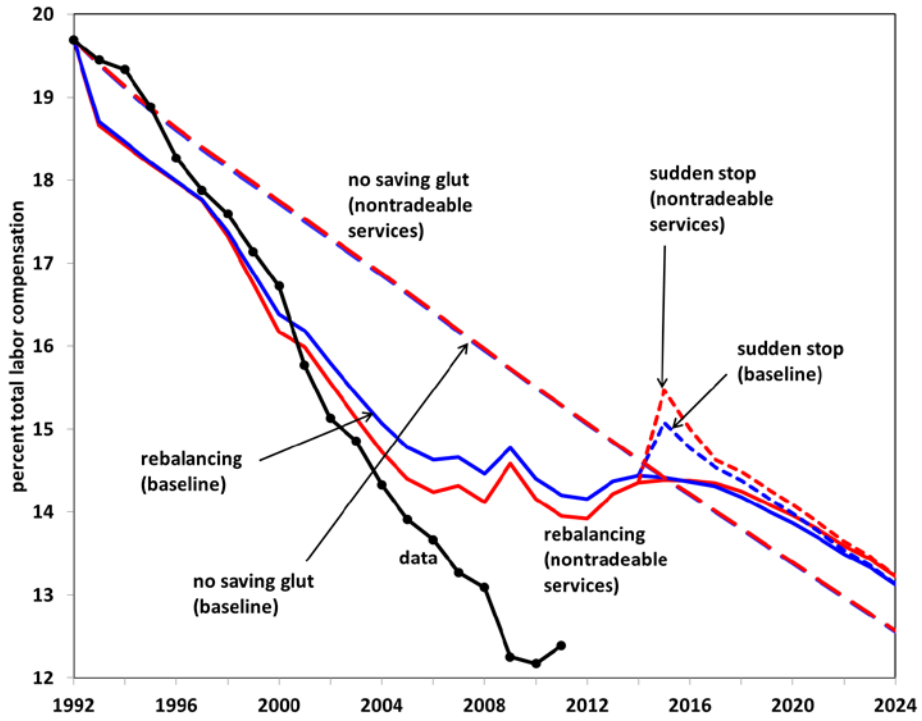**Figure 9: Goods employment share in no-services-trade model vs. baseline model**

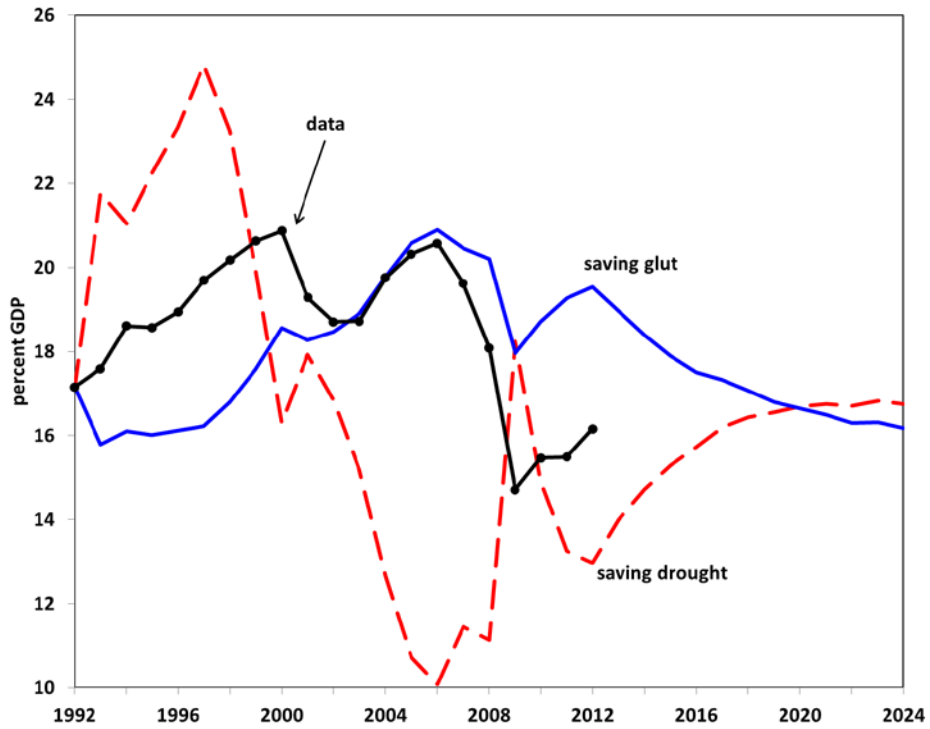**Figure 10: Investment in domestic saving-drought model vs. baseline model**

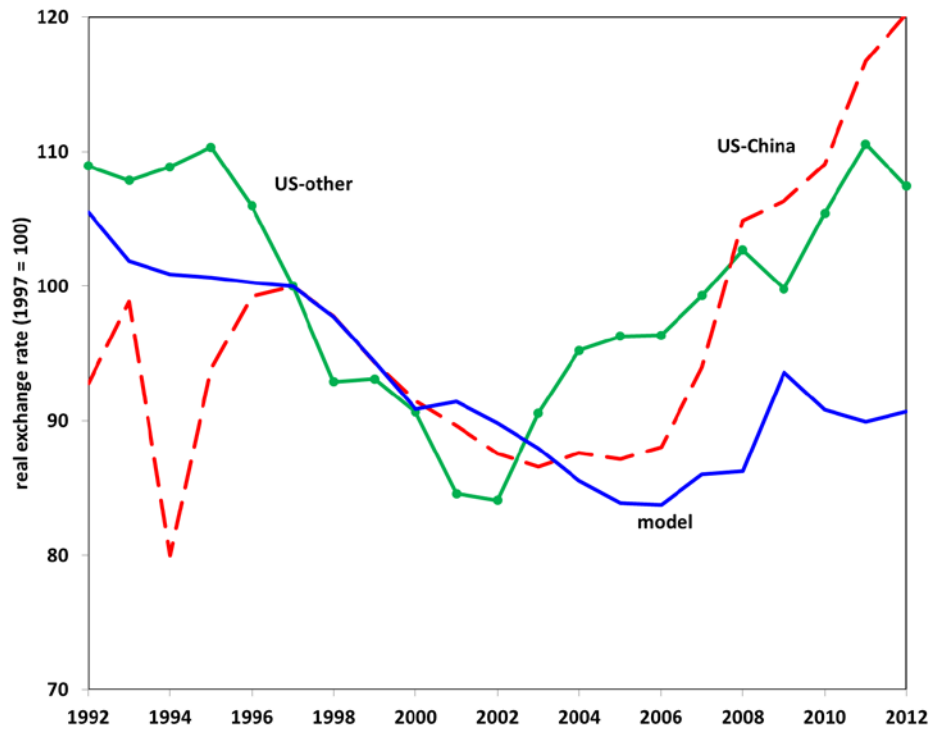**Figure 11: U.S. real exchange rates with China and other trade partners**

Figure 12: U.S. real interest rate in the model and the data