On the Source of U.S. Trade Deficits: Global Saving Glut or Domestic Saving Drought?

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Abstract

Are U.S. trade deficits caused by high foreign saving—a global saving glut—or low domestic saving—a domestic saving drought? To answer this question, I conduct a wedge accounting analysis of U.S. trade balance dynamics during 1995–2011 using a dynamic general equilibrium model. I find that a global saving glut explains 96 percent of U.S. trade deficits in excess of those that would have occurred naturally as a result of productivity growth and demographic change. Contrary to widespread belief, however, investment distortions, not a global saving glut, account for much of the decline in real interest rates that has accompanied U.S. trade deficits.

Keywords: Trade deficit, global saving glut, wedge accounting, real exchange rate
JEL: F21, F32, F41

1. Introduction

The United States has run trade deficits for more than two decades. In a well-known speech, Bernanke (2005) argued that a high supply of saving in the rest of the world—a global saving glut—is responsible for U.S. trade deficits. More recently, however, Chinn and Ito (2007, 2008), Laibson and Mollerstrom (2010), and other researchers have argued that a low domestic supply of saving—a domestic saving drought—is the culprit. In this paper I use a dynamic general equilibrium model to quantify the contributions of domestic and foreign forces to U.S. trade balance dynamics between 1995–2011. I find that Bernanke (2005) was right: a global saving glut is, in fact, the primary cause of U.S. trade deficits.

Figure 1 depicts the key facts that motivate this study. As the U.S. trade deficit, shown in panel (a), grew, the U.S. real interest rate, shown in panel (b), fell dramatically. Bernanke (2005) argued that this decline is evidence that foreign forces, rather than domestic ones, caused U.S. trade deficits. By contrast, Kehoe et al. (2018), henceforth KRS, find that while an increased supply of saving in the rest of the world accounts for U.S. trade deficits, it does not explain the dynamics of the real interest rate; instead, increased foreign saving caused the U.S. real exchange rate to appreciate as shown in panel (c). Panel (d) shows that the U.S. investment rate rose during the

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Preprint submitted to Review of Economic Dynamics *July 3, 2018*

1990s as the U.S. trade deficit began to grow, but declined during the recessions of 2000-2001 and 2008–2009. Laibson and Mollerstrom (2010) argue that U.S. investment rate dynamics suggest that domestic forces had caused U.S. trade deficits; if foreign forces had caused these deficits, they argue, the U.S. investment rate should have continued to rise during the mid-2000s. The objective of this paper is to use the data shown in figure 1 in a wedge accounting analysis to identify the causes of U.S. trade deficits.

In section 2, I use a series of two-period models to illustrate analytically the economic principles that underpin my analysis. First, I use a simple endowment economy to express Bernanke (2005)'s argument as a wedge accounting exercise. This model features two wedges: saving wedges in the United States and the rest of the world that distort households' incentives to borrow or lend as in Gourinchas and Jeanne (2013) and KRS. I show that a U.S. trade deficit could be the result of a high foreign saving wedge—a global saving glut—or a low U.S. saving wedge—a domestic saving drought—but that only the former would cause the real interest rate to fall. Next, I explain why investment data, and thus investment wedges, are also needed to identify the causes of U.S. trade deficits, and I add these ingredients to the model to describe the full wedge identification procedure. Last, I show that when domestic and foreign products are imperfect substitutes, a global saving glut has less impact on domestic real interest rates because it causes the real exchange rate to appreciate instead, particularly in countries like the United States in which domestic products account for the bulk of aggregate consumption expenditures.

In my quantitative analysis, I use a dynamic general equilibrium model to determine the causes of U.S. trade deficits. Households in the United States and the rest of the world work, consume, and borrow or lend by trading bonds. Each country has three production sectors: goods, services, and construction. Firms in each sector use capital, labor, and domestic and foreign intermediate inputs to produce their output. I calibrate the parameters that govern the model's production and demand structure so that it replicates an input-output matrix from the World Input Output Database (Timmer et al., 2015). When calibrated, this multi-sector, input-output structure captures several important facts about the U.S. economy and its relationship to the rest of the world: trade deficits are driven by deficits in goods trade, particularly intermediate goods, as shown by figure 2; construction, which is not traded, is the largest input to the production of U.S. investment; and U.S. conumption consists mostly of domestic services.

The model has several exogenous forces that affect trade balance dynamics. Two of these forces, labor productivity growth and demographic change, are taken from external data sources. Productivity in the rest of the world grows faster than U.S. productivity, creating a permanent-income motive for the United States to lend. At the same time, the U.S. population becomes younger than the rest of the world's population, creating a motive for the United States to borrow. The former motive is stronger than the latter, however; together, productivity growth and demographic change lead the United States to run a large trade surplus in equilibrium. The remaining drivers of trade balance dynamics are saving, investment, and trade wedges. The saving wedges distort households' Euler equations, the investment wedges distort the arbitrage conditions that relate returns on investment to returns on bonds, and the trade wedges distort marginal rates of substitution between domestic and foreign goods. In my wedge accounting exercise, I calibrate these wedges so that the model matches the U.S. trade balance, real interest rate, and real exchange rate, and the investment rates in the United States and the rest of the world during 1995–2011. To isolate the effects of each of these wedges, I construct a set of counterfactual equilibria in which I hold all but one of these wedges constant. I find that the rest of the world's saving wedge explains 96 percent of the cumulative difference between the observed trade deficit and the trade surplus that would have occurred naturally as a result of productivity growth and demographic change. Hence, a global saving glut is the primary cause of U.S. trade deficits.

Like KRS, I find that while a global saving glut also explains U.S. real exchange rate dynamics, it is not the primary cause of the decline in U.S. real interest rates. My results indicate that while saving distortions in the rest of the world do play a role in this decline, waning investment distortions in the United States and the rest of the world are also important factors as argued by Yi and Zhang (2016). Although this finding contradicts widespread belief that U.S. trade deficits and low interest rates are closely related, it is consistent with theory (see section 2) and with empirical estimates of the impact of foreign lending on U.S. interest rates (Krishnamurthy and Vissing-Jorgensen, 2007; Warnock and Warnock, 2009).

U.S. investment dynamics are driven both by domestic investment distortions and a global saving glut. Thus, Laibson and Mollerstrom (2010) are partly right; in isolation, a global saving glut would have caused U.S. investment to rise throughout the 2000s, but a drop in the U.S. investment wedge counteracted this effect. The trade wedge helps the model to capture the J-curve dynamics (Backus et al., 1994; Alessandria and Choi, 2018) of the U.S. trade balance and real exchange rate in the short run, particularly between 2002 and 2006, but plays little role in explaining cumulative U.S. trade deficits or the long-term real exchange rate appreciation that accompanied them.

My paper makes several contributions to the extensive literature on U.S. trade deficits, and, more broadly, global trade imbalances. Explanations for global imbalances abound: mercantilist government policy in emerging economies (Dooley et al., 2003, 2007); emerging economies' poor financial systems (Caballero et al., 2008; Mendoza et al., 2009); U.S. government fiscal policy (Chinn and Prasad, 2003; Chinn and Ito, 2007, 2008); asset price bubbles (Kraay and Ventura, 2007; Laibson and Mollerstrom, 2010; Gete, 2015); and cross-country differences in growth rates (Engel and Rogers, 2006; Choi et al., 2008; Backus et al., 2009), demographic trends (Sposi, 2017), or macroeconomic volatility (Fogli and Perri, 2015). These explanations can, broadly speaking, be split into two groups: foreign forces like mercantilism and poor financial development that boost saving (or depress investment) in the rest of the world; and domestic forces like asset bubbles and fiscal policy that depress saving (or boost investment) in the United States. My paper is the first to quantify the contributions of foreign and domestic forces to U.S. trade deficits. Additionally, I provide empirical evidence that a global saving glut is the product of capital controls and domestic financial frictions in the rest of the world; I find that saving distortions in the rest of the world are highly correlated with measures of capital account openness and domestic financial development in the rest of the world relative to the United States.

Several other papers use wedge accounting, which was originally developed by Cole and Ohanian (2002) and Chari et al. (2007) to study closed-economy business cycles, to analyze international capital flows. In a seminal paper, Gourinchas and Jeanne (2013) document that fast-growing countries save, rather than borrowing as neoclassical theory predicts, and show that saving wedges account for this pattern. Their small-open-economy analysis, however, cannot separately identify the roles of domestic and foreign distortions. Similarly, Choi et al. (2008), Gete (2015), and KRS simply assume that trade imbalances are driven by foreign saving wedges. Ohanian et al. (2015)

and Sposi (2017) conduct wedge-accounting analyses of global imbalances using multi-country general equilibrium models, but their one-good environments abstract from the important features of U.S. trade and investment highlighted above and cannot explain exchange rate or interest rate dynamics. My paper is the first to conduct a wedge-accounting analysis of U.S. trade deficits using a general equilibrium model with a realistic input-output production structure, and the first to identify the contributions of domestic and foreign forces to U.S. real exchange rate and real interest rate dynamics.

Finally, my paper builds on work by KRS, who use a similar model to analyze the contribution of trade deficits to declining goods-sector employment in the United States. They assume that U.S. trade deficits are driven by a global saving glut and show that this assumption is consistent with the behavior of the U.S. real exchange, investment, and other macroeconomic variables. My quantitative analysis fills a number of gaps left by KRS: my model incorporates capital formation and a detailed input-output structure in the rest of the world; my wedge accounting procedure quantifies the contributions of saving distortions in both the United States and the rest of the world to U.S. trade deficits as well as the contributions of investment and trade distortions; and my approach to measuring demographic change and productivity growth in the rest of the world highlights the importance of fast-growing emerging economies like China for the behavior of the U.S. trade balance. Additionally, my findings about the relationship between foreign saving distortions and interest rates resolve a puzzle identified by KRS, who cannot explain why a global saving glut does not significantly affect U.S. real interest rates in their model, and I present evidence on the underlying causes of a global saving glut.

2. Analytical wedge accounting

Before describing my quantitative analysis, I use a series of two-period models to illustrate three points: why U.S. trade deficits are more likely to have been caused by a global saving glut than a domestic saving drought; how macroeconomic data can be used to identify the wedges that represent these forces; and why a global saving glut may have had more impact on real exchange rates than on interest rates.

2.1. *Global saving glut or domestic saving drought?*

Between 1995 and 2011, U.S. real interest rates fell by almost 250 basis points as U.S. trade deficits grew. In a well-known speech, Bernanke (2005) argued that this was evidence that a global saving glut—an increase in the supply of saving in the rest of the world—was responsible for U.S. trade deficits, not lower saving in the United States. Here, I use a simple, two-period endowment economy to illustrate how we can express Bernanke (2005)'s logic as a wedge accounting exercise.

The economy consists of two countries: the United States ($i = us$) and the rest of the world ($i = rw$). Each country's representative household receives an exogenous endowment, y, in each period, and chooses how much to borrow or save taking the world interest rate, R, as given. The two countries are identical except for saving wedges, $\tau_{i,s}$, which distort households' saving decisions, and lump-sum transfers, T_i, which ensure that these wedges have only marginal effects. The wedges and transfers enter households' budget constraints in the same way as in Gourinchas and

Jeanne (2013) and Ohanian et al. (2015).[1] Throughout this paper, I use the term "global saving glut" to refer to an increase in the rest of the world's saving wedge and the term "domestic saving drought" to refer to a decrease in the U.S. saving wedge.

The problem of the representative household in country i is to choose a sequence of consumption, $(c_{i,1}, c_{i,2})$, and bonds, b_i, to maximize its lifetime utility,

$$\log c_{i,1} + \log c_{i,2} \tag{1}$$

subject to the budget constraints,

$$c_{i,1} + b_i = y, \tag{2}$$
$$c_{i,2} = y + \tau_{i,s} R b_i + T_i. \tag{3}$$

An equilibrium in this environment is an allocation, $(c_{i,1}, c_{i,2}, b_i)_{i=us,rw}$, and an interest rate, R, that solve each country's household problem and satisfy market clearing conditions for output and bonds:

$$c_{us,t} + c_{rw,t} = 2y, \;\; \forall t = 1, 2, \tag{4}$$
$$b_{us} + b_{rw} = 0. \tag{5}$$

Since there is no investment in this economy, each country's first-period trade balance is simply equal to its saving, $y - c_{i,1}$. Market clearing requires that a U.S. trade deficit is matched by a trade surplus in the rest of the world (or vice versa):

$$tb_{us} = -tb_{rw}. \tag{6}$$

Thus, a U.S. trade deficit could be caused by low supply of saving in the United States or high supply of saving in the rest of the world. The objective of the wedge accounting exercise in this simple environment is to determine which of these forces could generate a U.S. trade deficit and a decline in the world interest rate simultaneously.

The household's problem is characterized by an Euler equation,

$$\frac{1}{c_{i,1}} = R\tau_{i,s}\frac{1}{c_{i,2}}, \tag{7}$$

and an intertemporal budget constraint,

$$c_{i,1} + \frac{c_{i,2}}{R} = y\frac{1+R}{R}. \tag{8}$$

The Euler equation illustrates the channel through which the saving wedges affect trade balances. An increase in a country's saving wedge reduces consumption in period 1 in favor of period-2

[1] As is common in wedge accounting exercises, the saving and investment wedges enter households' budget constraints in the form of taxes. The government rebates the proceeds of these taxes to households in a lump-sum fashion, ensuring that wedges do not enter national or global resource constraints. KRS model saving wedges as preference shocks that temporarily alter households' discount factors; their approach is isomorphic to the tax representation.

consumption, raising the country's saving rate, while a decrease in a country's saving wedge has the opposite effect. Combining the Euler equation and intertemporal budget constraint yields a partial-equilibrium solution for country i's trade balance,

$$tb_i = \left[1 - \left(\frac{1}{1+\tau_{i,s}}\right)\left(\frac{1+R}{R}\right)\right] y, \tag{9}$$

which is increasing in its saving wedge and decreasing in the interest rate. Thus, a U.S. trade deficit could be driven by a decline in the U.S. saving wedge or a decline in the interest rate.

The interest rate, however, is endogenous, and is ultimately determined by the rest of the world's saving wedge as well as the United States'. The solution for the equilibrium interest rate,

$$R = \frac{\sum_{i=us,rw}\left(\frac{1}{1+\tau_{i,s}}\right)}{2 - \sum_{i=us,rw}\left(\frac{1}{1+\tau_{i,s}}\right)}, \tag{10}$$

is decreasing in both saving wedges. Combining these observations, we can conclude that a global saving glut is the most likely explanation for a U.S. trade deficit that coincides with a drop in the world interest rate. A domestic saving drought would also reduce the U.S. trade balance, but it would increase the world interest rate instead of decreasing it.

Figure 3 illustrates this point graphically using a supply-and-demand analysis.[2] Panel (a) shows the effects of a global saving glut on the U.S. trade balance and world interest rate. The upward-sloping red line, labeled tb_{us}, depicts the U.S. trade balance as a function of the interest rate. The downward-sloping blue line, labeled $-tb_{rw}$, depicts the rest of the world's trade deficit schedule—the negative of the rest of the world's trade balance as a function of the interest rate—before the saving glut occurs. Point A, the intersection between these two curves, represents the initial equilibrium. The saving glut shifts the rest of the world's trade deficit schedule leftward to the purple line labeled $-tb'_{rw}$. Point B, the intersection between this line and the U.S. trade balance, depicts the saving-glut equilibrium. Compared to the initial equilibrium, the U.S. trade balance and interest rate are both lower during the saving glut, just as we see in the data. Panel (b) illustrates the effects of a domestic saving drought. Starting from the same initial equilibrium, a domestic saving drought shifts the U.S. trade balance curve inward. The equilibrium U.S. trade balance again falls, but this time the equilibrium interest rate rises.

2.2. *Wedge identification*

Clearly, we must use data on both trade balances and interest rates to identify the cause of U.S. trade deficits. National income accounting implies that we must also use data on investment. To see this, recall that a country's trade balance is equal to the difference between its saving and its investment, and so a trade deficit could, in fact, be the result of an increase in investment instead of a decline in saving as we have analyzed above. Suppose we had a model that matched the U.S. trade balance but not the U.S. investment rate (which is true of the endowment economy analyzed above by construction). Then the national income accounting identity implies that the

[2] Similar graphical analyses appear in Schmitt-Grohe et al. (2016) and Chinn and Ito (2008).

model would not match U.S. consumption, either, and consequently we could not use the Euler equation (7) to identify the U.S. saving wedge. Alternatively, if we used data on U.S. consumption directly in the Euler equation to infer the saving wedge, the model would not match the U.S. trade balance. In order to identify saving wedges from trade balance dynamics using Euler equations, our model must match investment as well as the interest rate. Thus, investment wedges are needed as well as saving wedges to properly account for the sources of U.S. trade deficits.

To illustrate the wedge identification procedure that I use in my quantitative analysis, suppose now that each country still receives an exogenous endowment, y, in the first period, but that second-period output, k_i^α, depends on investment, k_i. In addition to the saving wedges, this version of the model also has investment wedges, $\tau_{i,k}$, which also enter the household's problem as taxes as in Gourinchas and Jeanne (2013).[3] The solution to the household's problem is characterized by an Euler equation, which is identical to (7), and an arbitrage condition which relates the return on bonds to the return on investment:

$$R = \tau_{i,k} \alpha k_i^{\alpha-1}. \tag{11}$$

A high investment wedge pushes the marginal product of capital downward, raising investment, while a low investment wedge raises the marginal product, reducing investment.

The solution to the household's problem in this version of the model implies that each country's trade balance is increasing in its saving wedge, decreasing in its investment wedge, and increasing in the interest rate:

$$tb_i = \left(\frac{\tau_{i,s}}{1+\tau_{i,s}}\right) y - R^{\frac{1}{\alpha-1}} \left[\left(\frac{1}{1+\tau_{i,s}}\right) (\alpha \tau_{i,k})^{\frac{\alpha}{1-\alpha}} + \left(\frac{\tau_{i,s}}{1+\tau_{i,s}}\right) (\alpha \tau_{i,k})^{\frac{1}{1-\alpha}} \right]; \tag{12}$$

in addition to a decrease in the U.S. saving wedge or a decrease in the interest rate, a U.S. trade deficit could be caused by an increase in the U.S. investment wedge. The equilibrium interest rate,

$$R = \left\{ \frac{\sum_{i=us,rw} \left(\frac{\tau_{i,s}}{1+\tau_{i,s}}\right) y}{\sum_{i=us,rw} \left[\left(\frac{1}{1+\tau_{i,s}}\right) (\alpha \tau_{i,k})^{\frac{\alpha}{1-\alpha}} + \left(\frac{\tau_{i,s}}{1+\tau_{i,s}}\right) (\alpha \tau_{i,k})^{\frac{1}{1-\alpha}} \right]} \right\}^{\frac{1}{\alpha-1}}, \tag{13}$$

is decreasing in both saving wedges and increasing in both investment wedges. Thus, adding investment does not alter the conclusion of the endowment-economy analysis: foreign distortions have caused U.S. trade deficits. Both foreign distortions that could generate a U.S. trade deficit—a global saving glut or a decrease in the rest of the world's investment wedge—would lower the interest rate, while both domestic distortions that could generate U.S. trade deficits would raise the world interest rate.

The goal of the wedge accounting exercise in this version of the two-period model is to identify the values of the saving and investment wedges such that the equilibrium matches each country's investment and trade balance as well as the interest rate. We can use these data in the model's equilibrium conditions to complete the identification as follows. First, use the arbitrage conditions (11) to back out the investment wedges, $\tau_{i,k}$, implied by the interest rate and investment data.

[3] The tax representation of the investment wedge is equivalent to Eaton et al. (2016)'s investment efficiency shock.

Second, use the national income accounting identity, $y = c_{i,1} + k_i + tb_i$, to back out each country's consumption from the trade balance and investment data. Last, use consumption and the interest rate in the Euler equations (7), to back out the saving wedges, $\tau_{i,s}$.[4] The identification procedure is straightforward in this two-period model, but the principles behind it carry over directly to the quantitative analysis.

2.3. *Exchange rates and interest rates*

In addition to declining interest rates, U.S. trade deficits have also been accompanied by real exchange rate appreciation. My quantitative analysis, like that of KRS, indicates that while a global saving glut explains both U.S. trade deficits and U.S. real exchange rate appreciation, it does not, in fact, explain the bulk of the decline in the U.S. real interest rate. This finding stands in stark contrast to the analysis above in which the behavior of the real interest rate was the key to identifying the cause of U.S. trade deficits. In this analysis, however, and in many other studies of U.S. trade deficits (Engel and Rogers, 2006; Choi et al., 2008; Laibson and Mollerstrom, 2010), the real exchange rate is constant because domestic and foreign products are perfect substitutes. Here, I show that when this assumption is relaxed, a global saving glut has less impact on the real interest rate because it causes real exchange rate appreciation instead.

Consider now a version of the two-period endowment economy studied in section 2.1 in which the countries' endowments are not perfectly substitutable. Each period, the U.S. receives an endowment of good x, while the rest of the world receives an endowment of good z. These endowments are constant and symmetric; each country receives the same quantity y of its good in both periods. As in Cole and Obstfeld (1991) and Backus et al. (1994, 1995), each country's aggregate consumption basket is an Armington aggregate of goods x and z:

$$c_{us,t} = x_{us,t}^{\omega} z_{us,t}^{1-\omega}, \tag{14}$$

$$c_{rw,t} = z_{rw,t}^{\omega} x_{rwxsy,t}^{1-\omega}. \tag{15}$$

The home-bias parameter ω governs the domestic share of total consumption expenditures. Following Heathcote and Perri (2002), let $p_{i,t}$ and $q_{i,t}$ denote the prices of goods x and z in terms of country i's consumption good; the price of each country's consumption is normalized to one without loss of generality. The U.S. real exchange rate, e_t, is given by the law of one price:

$$e_t p_{rw,t} = p_{us,t}, \quad e_t q_{rw,t} = q_{us,t}. \tag{16}$$

Households have the same preferences as in the one-good version of the model. Bonds are denominated in units of U.S. consumption, so the interest rate in this model maps directly to the U.S. real interest rate in the data.

In this version of the model, real exchange rate appreciation always accompanies a global saving glut (or a domestic saving drought). In equilibrium, the real exchange rate in period 1

[4] The careful reader may note that we have five data moments, $k_{us}, k_{rw}, tb_{us}, tb_{rw}$, and R, but only four wedges, $\tau_{us,s}, \tau_{us,k}, \tau_{rw,s}$, and $\tau_{rw,k}$. The data moments are not independent, however; the market clearing condition (6) makes one country's trade balance data redundant.

relative to the period-2 real exchange rate is given by

$$\frac{e_1}{e_2} = \frac{\tau_{us,s}}{\tau_{rw,s}}. \tag{17}$$

A global saving glut causes the U.S. real exchange rate to appreciate in period 1, when the U.S. runs a trade deficit, and then depreciate in period 2, when the U.S. runs a trade surplus to repay its debt. This one-for-one relationship between the saving wedges and the real exchange rate carries over into the quantitative analysis, where I find that a global saving glut explains the bulk of both U.S. trade deficits and real exchange rate appreciation.

A global saving glut also lowers the U.S. real interest rate in this version of the model, but the size of this effect depends on the degree of home bias. The equilibrium interest rate in this version of the model is given by

$$\begin{aligned} R = &\left\{ \left[\omega\tau_{us,s}(1+\tau_{rw,s}) + (1-\omega)\tau_{rw,s}(1+\tau_{us,s})\right]^{-\omega} \left[(1-\omega)\tau_{us,s}(1+\tau_{rw,s}) + \omega\tau_{rw,s}(1+\tau_{us,s})\right]^{\omega-1} \right\} \\ &/ \left\{ \left[\omega(1+\tau_{rw,s}) + (1-\omega)(1+\tau_{us,s})\right]^{-\omega} \left[(1-\omega)(1+\tau_{rw,s}) + \omega(1+\tau_{us,s})\right]^{\omega-1} \right\}. \end{aligned} \tag{18}$$

As in the one-good version of the model, the equilibrium interest rate is decreasing in both saving wedges, but it is less sensitive to these wedges when the home bias parameter, ω, is high. Formally,

$$\frac{\partial R}{\partial \tau_{i,s}} < 0, \quad \frac{\partial^2 R}{\partial \tau_{i,s} \partial \omega} > 0. \tag{19}$$

Thus, a global saving glut has less impact on the real interest rate when the share of domestic goods in aggregate consumption is high. The logic behind this result is straightforward: when consumption consists mostly of domestic goods, trade imbalances have less impact on consumption growth, and so the Euler equation requires a smaller change in the real interest rate. In the United States, services account for the majority of consumption expenditures and home bias in the services sector is extremely high. Consequently, a global saving glut may bear less responsibility for falling real interest rates in the United States than the one-good analysis suggests. My quantitative results indicate that while a global saving glut explains some of the drop in U.S. real interest rates, the investment wedges account for most of this drop. This highlights another reason that investment wedges are needed as well as saving wedges to properly account for the source of U.S. trade deficits.

The two-period analysis above glosses over one subtlety about the joint dynamics of the U.S. trade balance and real exchange rate: when the real exchange rate began to depreciate in 2002, the trade deficit continued to grow for four more years. This phenomenon, often called the J-curve, can result from adjustment costs or habits (Krugman, 1986; Engel and Wang, 2011), marketing capital (Drozd and Nosal, 2012), or export participation dynamics (Alessandria and Choi, 2018). In my quantitative analysis I include one more wedge, a trade wedge as in Alessandria et al. (2013), to stand in for these mechanisms and ensure that the model matches the behavior of the U.S. real exchange rate as well as trade balances, investment, and interest rates. I find that the trade wedge plays little role in driving cumulative U.S. trade deficits or the real exchange rate appreciation that has accompanied them. I discuss the role of the trade wedge in more detail in section 6.2.

3. Quantitative model

I turn now to the quantitative model. Time is discrete and the length of a period is one year. The initial period, $t = 0$, corresponds to the year 1995. The United States and the rest of the world each have three sectors: goods ($s = 1$); services ($s = 2$); and construction ($s = 3$). The representative household in each country works, consumes, saves, and invests to maximize its utility subject to a sequence of budget constraints. Competitive firms in each sector produce gross output using capital, labor, and intermediate inputs. Goods and services are both tradable, and are used by households for consumption and investment and by firms as intermediates. Construction is nontradable and is used only as an input in the production of investment. As in KRS and Eaton et al. (2016), there is no uncertainty; all agents in the model have perfect foresight.

The model has several exogenous driving forces that could affect trade balance dynamics: labor productivity growth, demographic change, and, as in the two-period production model, saving and investment wedges. The quantitative model also includes a trade wedge (Alessandria et al., 2013) that ensures it can match the joint dynamics of the U.S. trade balance and real exchange rate. In what follows, I use bars to distinguish these exogenous time-varying parameters from endogenous variables and constant parameters. In the benchmark equilibrium, I set the five wedges so that the model matches five time series between 1995 and 2011: the U.S. trade balance, investment rate, real exchange rate, and real interest rate; and the investment rate in the rest of the world. To measure each wedge's contribution to the dynamics of the U.S. trade balance and other variables during this period, I construct a counterfactual equilibrium in which the other wedges are held constant. To measure the contributions of productivity growth and demographic change, I construct another counterfactual in which all wedges are held constant.

3.1. Production

Gross output in country i's sector s, $y^s_{i,t}$, is produced using capital, labor, and intermediate inputs of goods and services according to a nested CES technology:

$$y^s_{i,t} = \left\{ \lambda^s_i \left[\left(k^s_{i,t}\right)^{\alpha} \left(\bar{\gamma}_{i,t} \ell^s_{i,t}\right)^{1-\alpha} \right]^{\eta} + (1 - \lambda^s_i) \left[\sum_{r=1}^{2} \pi^{s,r}_i \left(\sum_{j=us,rw} \mu^{s,r}_{i,j} \left(m^{s,r}_{i,j,t}\right)^{\zeta^r} \right)^{\frac{\kappa}{\zeta^r}} \right]^{\frac{\eta}{\kappa}} \right\}^{\frac{1}{\eta}}. \tag{20}$$

There are three layers of aggregation. At the top level, value added is combined with a bundle of intermediates. Value added is a standard Cobb-Douglas aggregate of capital, $k^s_{i,t}$, and labor, $\ell^s_{i,t}$. The elasticity of subsititution between value added and intermediates is $1/(1 - \eta)$. At the middle level, intermediate input bundles from the goods and services sectors are aggregated to form the overall intermediate bundle. The elasticity of substitution between intermediates from different sectors is $1/(1-\kappa)$. At the lowest level, intermediates from each country $j = us, rw$ are aggregated to form the sector-specific intermediate bundles. The elasticity of substitution between sector-r intermediates from different countries is $1/(1-\zeta^r)$. I allow this elasticity to differ across sectors to capture the fact that the United States' goods trade balance is more volatile than its services trade balance (KRS, Barattieri, 2014). The parameters λ^s_i, $\pi^{s,r}_i$, and $\mu^{s,r}_{i,j}$ govern expenditure shares.

The labor productivity terms, $\bar{\gamma}_{i,t}$, are the first set of exogenous time-series parameters that could drive U.S. trade deficits. Holding other parameters fixed, faster productivity growth creates a permanent-income motive for households to save less or borrow more (Gourinchas and Jeanne, 2013). In equilibrium, the difference between U.S. productivity growth and productivity growth in the rest of the world is what matters for the U.S. trade balance. In the long run, I assume that labor productivity in both countries grows at the same rate, $g_{\bar{\gamma}}$, so that the equilibrium converges to a balanced growth path.

Gross output producers are perfectly competitive. Each period, they take prices as given and choose factors and intermediate inputs to maximize profits,

$$q^s_{i,t}y^s_{i,t} - w_{i,t}\ell^s_{i,t} - r^s_{i,t}k^s_{i,t} - \sum_{j=us,rw}\sum_{r=1}^{2}\left(1 + \mathbb{1}_{\{j\neq i\}}(\bar{\tau}_{i,m,t} - 1)\right) q^r_{j,t}m^{s,r}_{i,j,t}, \tag{21}$$

subject to (20). $q^s_{i,t}$ is the price of output in country i's sector s, $w_{i,t}$ is the wage, and $r^s_{i,t}$ is the capital rental rate, which can differ across sectors on the short run because adjusting each sector's capital stock is costly; in equilibrium, returns on capital net of adjustment costs are be equalized across sectors. I describe the law of motion for capital in more detail below. The trade wedges, $\bar{\tau}_{i,m,t}$, are the next time-series parameters that could generate U.S. trade deficits. They distort the price elasticities of each country's intermediate imports, altering the relationship between trade balances and real exchange rates. This allows the model to generate deviations from the Marshall-Lerner condition like that which occurred during the United States in 2002–2006, when the trade deficit continued to grow even as foreign goods started to become more expensive.

3.2. *Final demand aggregation*

Armington aggregators in each country facilitate trade in final goods and services. They combine domestic and foreign products into sector-specific nontradable composites that households use for consumption and investment. Country i's sector-s composite is given by

$$g^s_{i,t} = \left\{\sum_{j=us,rw}\theta^s_{i,j}\left(z^s_{i,j,t}\right)^{\sigma^s}\right\}^{\frac{1}{\sigma^s}}. \tag{22}$$

The sector-specific elasticities of substitution between domestic and foreign products are $1/(1-\sigma^s)$, and the parameters $\theta^s_{i,j}$ govern expenditure shares. Armington aggregators are perfectly competitive and choose inputs of domestic and foreign products to maximize profits,

$$p^s_{i,t}g^s_{i,t} - \sum_{j=us,rw}\left(1 + \mathbb{1}_{\{j\neq i\}}(\bar{\tau}_{i,m,t} - 1)\right) q^s_{j,t}z^s_{i,j,t}, \tag{23}$$

where $p^s_{i,t}$ is the price of the composite. Note that the trade wedges, $\bar{\tau}_{i,m,t}$, distort imports of final goods and services as well as intermediate inputs.

The aggregate consumption basket, $c_{i,t}$, is a CES aggregate of composite goods and services,

$$c_{i,t} = \left\{\sum_{s=1}^{2}\epsilon^s_i\left(z^{c,s}_{i,t}\right)^{\rho}\right\}^{\frac{1}{\rho}}. \tag{24}$$

Following Bems (2008), investment, $x_{i,t}$, is a Cobb-Douglas aggregate of composite goods, composite services, and domestic construction,

$$x_{i,t} = \left(z_{i,t}^{x,1}\right)^{\varepsilon_i^1} \left(z_{i,t}^{x,2}\right)^{\varepsilon_i^2} \left(z_{i,t}^{x,3}\right)^{1-\varepsilon_i^1-\varepsilon_i^2}. \tag{25}$$

The elasticity of substitution between goods and services in consumption is $1/(1-\rho)$. ϵ_s^i and ε_s^i govern expenditure shares in consumption and investment, respectively. Construction is not traded, consumed, or an intermediate input, so all domestic construction output is used for investment in equilibrium. The prices of consumption, $p_{i,t}^c$, and investment, $p_{i,t}^x$, are given by the standard ideal price formulae.

3.3. Household's problem

Each country is populated by a continuum of identical households. The representative household in country i has preferences,

$$\sum_{t=0}^{\infty} \beta^t \frac{1}{\psi} \left[\left(\frac{c_{i,t}}{\bar{n}_{i,t}} \right)^{\phi_i} \left(\frac{\bar{\ell}_{i,t} - \ell_{i,t}}{\bar{\ell}_{i,t}} \right)^{1-\phi_i} \right]^{\psi}, \tag{26}$$

over sequences of consumption and labor. The household's problem is to choose consumption, labor, bond holdings, and investment to maximize its lifetime utility subject to a sequence of budget constraints,

$$p_{i,t}^c c_{i,t} + \sum_{s=1}^{3} p_{i,t}^x x_{i,t}^s + b_{i,t+1} = w_{i,t}\ell_{i,t} + \bar{\tau}_{i,s,t} \left(R_t b_{i,t} + \sum_{s=1}^{3} \bar{\tau}_{i,k,t} r_{i,t}^s k_{i,t}^s \right) + T_{i,t}, \tag{27}$$

a law of motion for capital in each sector,

$$k_{i,t+1}^s = H\left(\frac{x_{i,t}^s}{k_{i,t}^s} \right) k_{i,t}^s + (1-\delta) k_{i,t}^s, \tag{28}$$

and initial conditions for bonds, $b_{i,0}$, and capital in each sector, $k_{i,0}^s$. The parameter ϕ governs the household's disutility from working. Bonds are denominated in units of the U.S. consumer price index, which is normalized to one without loss of generality. R_t is the real interest rate.

Adjusting sectoral capital stocks is costly, so the household must choose investment in each sector separately. Following Lucas and Prescott (1971), Eaton et al. (2016), and Sposi (2017), the adjustment cost function, H, is given by

$$H(x/k) = \frac{1}{\varphi} \left[(\delta + g_{\bar{y}})^{1-\varphi} \left(\frac{x}{k} \right)^{\varphi} - (1-\varphi)(\delta + g_{\bar{y}}) \right]. \tag{29}$$

The smaller the parameter φ, the more difficult it is for firms to make large changes to their capital stocks. This specification ensures that in a balanced growth path, when labor productivity in both countries grows at $g_{\bar{y}}$, there are no adjustment costs.

$\bar{n}_{i,t}$ and $\bar{\ell}_{i,t}$ are exogenous time-series parameters that govern demographic change within and across countries. $\bar{n}_{i,t}$ is country i's adult-equivalent population and $\bar{\ell}_{i,t}$ is its working-age population. These two parameters allow the model to capture the impact of demographic changes on the U.S. trade balance. A country whose population is growing or becoming younger has a permanent-income motive to borrow, while a shrinking or aging country has an incentive to save.

The last exogenous time series parameters that could drive U.S. trade deficits are the saving wedge, $\bar{\tau}_{i,s,t}$, and the investment wedge, $\bar{\tau}_{i,k,t}$, which enter the household's problem in the same way as in the two-period model. As before, the lump-sum transfers, $T_{i,t}$, ensures that all wedges have only marginal effects.

3.4. Market clearing

There are several markets that must clear in each period. First, gross output of goods and services in each country must equal the sum of intermediate demand from domestic and foreign producers and final demand from domestic and foreign Armington aggregators:

$$y^s_{i,t} = \sum_{j=us,rw} \sum_{r=1}^{3} m^{j,i}_{r,s,t} + \sum_{j=us,rw} z^s_{j,i,t},\ \forall i = us, rw,\ \forall s = 1, 2. \tag{30}$$

Second, gross output of construction is used solely as an input to the production of investment:

$$y^3_{i,t} = z^{x,3}_{i,t},\ \forall i = us, rw. \tag{31}$$

Third, supply of goods and services composites in each country must equal demand:

$$g^s_{i,t} = z^{c,s}_{i,t} + z^{x,s}_{i,t},\ \forall i = us, rw,\ \forall s = 1, 2. \tag{32}$$

Fourth, production of each country's investment good must equal demand:

$$x_{i,t} = \sum_{s=1}^{3} x^s_{i,t},\ \forall i = us, rw. \tag{33}$$

Fifth, the labor markets must clear:

$$\ell_{i,t} = \sum_{s=1}^{3} \ell^s_{i,t},\ \forall i = us, rw. \tag{34}$$

Sixth, capital supplied by households to each sector, $k^s_{i,t}$, must equal firms' demand for capital in that sector. Seventh, the bond market must clear:

$$b_{us,t+1} + b_{rw,t+1} = 0. \tag{35}$$

3.5. Equilibrium

Given a sequence for the time-series parameters, $\{\left(\bar{\gamma}^i_t, \bar{n}^i_t, \bar{\ell}^i_t, \bar{\tau}_{i,s,t}, \bar{\tau}_{i,k,t}, \bar{\tau}_{i,m,t}\right)_{i=us,rw}\}_{t=0}^{\infty}$, and a set of initial conditions, an equilibrium is a sequence of prices and quantities that satisfy the optimality conditions of firms, aggregators, and households, and all market clearing conditions. In the long run, I assume that productivity and demographic parameters grow at constant, symmetric rates and that all wedges are zero so that the equilibrium converges to an undistorted balanced growth path. When I solve the model numerically I require the equilibrium to converge to a balanced growth path after 100 periods.

4. Calibration

My calibration procedure has three stages. First, I assign standard values to some constant parameters like the discount factor and elasticities of substitution. Second, I calibrate the other constant parameters using input-output data. Third, I set the initial conditions and the time series parameters for productivity and demographics using other external data sources. Last, I calibrate the wedges so that the equilibrium matches five time series: the U.S. trade balance, investment rate, real interest rate, and real exchange rate; and the rest of the world's investment rate.

4.1. Input-output data

I use data from the World Input Output Database (Timmer et al., 2015), henceforth WIOD, to calibrate a number of the model's parameters. This dataset, which has been widely used in international economics, contains data on production, intermediate inputs, and final demand for 40 countries and 35 industries during 1995–2011. Unlike national input-output tables, the WIOD data break down each reporter country's exports and imports by use (intermediate, consumption, or investment), providing a complete picture of the world's input-output structure. I aggregate industries into three sectors: goods, which includes agriculture, resource extraction, and manufacturing; construction; and services, which includes all other industries. The rest of the world consists of all countries in the WIOD database other than the United States. In what follows, I refer to these countries as the rest of the world's constituents.

I use the WIOD data in three ways. First, I use the aggregated input-output matrix for 1995 to calibrate the model's expenditure share parameters (section 4.3). This matrix is shown in table 1. Second, I use the GDP time series for the countries in the rest of the world as weights to average country-level data from other sources to construct labor productivity and demographic time series for the rest of the world (section 4.4). This time-varying weighting scheme captures the rising importance of emerging economies, particularly China, in the world economy over the period. Third, I use WIOD time series on GDP and investment along with data from other sources to calibrate the wedges (4.5).

4.2. Assigned parameters

I set the discount factors, β, so that in a balanced growth path the real interest rate is 2.5 percent per year.[5] ϕ_i, the shares of consumption in flow utility, are set so that each country's household supplies one third of its time endowment as labor in a balanced growth path. I set the depreciation rate, δ, to 6 percent and the capital share, α, to one third. I set the capital adjustment cost parameter, φ, to Sposi (2017)'s value of 0.8.[6].

The other assigned parameters are elasticities of substitution. I use the standard value of 0.5 for the intertemporal elasticity of substitution, $1/(1-\psi)$. I follow KRS and set the Armington

[5] Estimates of U.S. long-run real interest rates range from 0.5 percent to 5 percent per year (McGrattan and Prescott, 2000; King and Low, 2014; Congressional Budget Office, 2012, 2015, 2017). KRS use the CBO's 2012 projection of 3 percent. Recent CBO projections are slightly lower (Congressional Budget Office, 2017). My results are not sensitive to this choice; when the long-run real interest rate is set to 0.5 percent, for example, a global saving glut explains 98 percent of cumulative U.S. trade deficits.

[6] Eaton et al. (2016) use a value of 0.5 for quarterly data

elasticities for intermediate and final goods, $1/(1-\zeta_1)$ and $1/(1-\sigma_1)$, to three and two, respectively, and set both services Armington elasticities, $1/(1-\zeta_2)$ and $1/(1-\sigma_2)$, to one. Figure 2 shows that these values allow the model to match closely the dynamics of the disaggregated U.S. trade balances in each of these four categories. The intermediate goods balance is the most volatile, followed by the final goods balance, while both services trade balances are stable. The remaining elasticities are set to Atalay (2017)'s estimates. The elasticity of substitution between value added and intermediates, $1/(1-\eta)$, is set to 0.03 and the elasticity of substitution between goods and services intermediates, $1/(1-\kappa)$ is set to 0.05. The elasticity of substitution between goods and services in consumption, $1/(1-\rho)$, is set to 0.65. Table 2 lists all of the assigned parameter values.

4.3. *Calibrated parameters*

I calibrate the expenditure share parameters, $\lambda_i^s, \pi_i^{s,r}, \mu_{i,j}^{s,r}, \theta_{i,j}^s, \epsilon_i^s$, and ε_i^s, so that first-period equilibrium expenditures on factors, intermediate inputs, consumption, and investment match the values in the 1995 input-output matrix shown in table 1. This stage of the calibration uses marginal-product-pricing equations and other equilibrium conditions to infer the parameter values that are required to reproduce the data. KRS describe this procedure in more detail. The parameter vectors in this section contain many elements (for example, $\mu_{i,j}^{s,r}$ has 36 = 3*3*2*2 elements) so I do not report them in the text of the paper. They can be found in the online appendix.

4.4. *Initial conditions, productivity, and demographics*

I take the initial conditions for bonds holdings, $b_{i,0}$, from the widely-used Lane and Milesi-Feretti (2007) dataset. I set U.S. initial bond holdings to the ratio of U.S. net foreign assets to GDP in 1995, and then set the rest of the world's initial bond holdings using the bond market clearing condition. To set the initial conditions for sectoral capital stocks, $k_{i,0}^s$, I first use the Penn World Tables to compute aggregate initial capital stocks. I use the 1995 U.S. capital-output ratio directly. For the rest of the world, I take the average of the constitutent countries' capital-output ratios weighted by their 1995 GDPs. With these aggregate capital-output ratios in hand, I allocate capital stocks proportinally across sectors by assuming that each sector's share of aggregate capital is the same as its share of GDP in the 1995 input-output matrix. Table 2 also lists initial bond holdings and aggregate capital stocks.

The time series for the demographic parameters, $\bar{n}_{i,t}$ and $\bar{\ell}_{i,t}$, are set using the U.N. World Population Prospects dataset (United Nations, Department of Economic and Social Affairs, Population Division, 2015), which provides historical data and future projections for country populations and dependency ratios between 1950 and 2100. I use these data to compute time series for adult-equivalent and working age populations for the United States and each of the rest of the world's constitutents. I use the U.S. demographic series directly. To construct the rest of the world's demographic series, I take the average growth rates of its constitutents' series using a time-varying weighting scheme that captures the growing importance of China and other emerging economies. In each year between 1995 and 2011, each constituent country's weight is equal to its share of the rest of the world's GDP in that year. From 2012 onward, I use 2011 GDP shares as constant weights. Panel (a) of figure 4, which plots the demographic time series parameters used in the model, shows that while the rest of the world's population grows faster than the United States', it also grows older.

I use the Conference Board's Total Economy Database to set the time series for the labor productivity parameters, $\bar{\gamma}_{i,t}$. For the United States, I use the dataset's measure of labor productivity per hour without adjustment during 1995–2011. I construct the rest of the world's productivity series during this period by computing the average of its constituents' productivity growth rates using the same time-varying weights as above. From 2012 onward, I assume that the United States' and the rest of the world's labor productivities grow constantly at their average growth rates during 1995–2011. Panel (b) of figure 4 shows that between 1995 and 2005, labor productivity in both countries grew at about the same rate, consistent with Choi et al. (2008) and Engel and Rogers (2006). From 2005 onward, however, labor productivity has grown faster in the rest of the world than in the United States; this is due to primarily to rapid growth in China. The average annualized labor productivity growth rate in the rest of the world between 1995 and 2011 was 3.1 percent, about one percent higher than in the United States.

To ensure that the model's equilibrium converges to a balanced growth path, I follow KRS and assume that in 2031, 20 years after the observation period ends, $\bar{n}_{i,t}$ and $\bar{\ell}_{i,t}$ begin to converge to constants and $\bar{\gamma}_{i,t}$ begin to approach constant 2 percent growth. In particular, I assume that the demographic series and productivity growth rates converge in a linear fashion over ten years, so that the model is in what one could call "balanced growth parameter space" beginning in 2041. None of the results are sensitive to these timing choices.

4.5. Wedges

In the last stage of the calibration procedure, I calibrate values for the wedges, $\bar{\tau}_{i,s,t}$, $\bar{\tau}_{i,k,t}$, and $\bar{\tau}_{i,m,t}$, such that the model's equilibrium matches five time series during 1995–2011: the U.S. trade balance, investment rate, real interest rate, and real exchange rate; and the rest of the world's investment rate. The GDP and investment series are computing using the aggregated WIOD data. I use the IMF's real effective exchange rate measure, and the real interest rate is computed by subtracting the U.S. inflation rate from the yield on 10-year Treasury bonds. Since only one trade wedge is needed to match the real exchange rate, I set the U.S. trade wedge to zero and calibrate only the rest of the world's trade wedge; doing the reverse yields the same results.

I assume that the economy is undistorted in the long run: the saving and investment wedges converge to one, and the rest of the world's trade wedge converges to zero. In particular, I assume that from 2012 onward, the wedges follow the laws of motion,

$$\bar{\tau}_{i,s,t} = \rho_\tau \bar{\tau}_{i,s,t-1} + (1-\rho_\tau), \quad \bar{\tau}_{i,k,t} = \rho_\tau \bar{\tau}_{i,k,t-1} + (1-\rho_\tau), \quad \bar{\tau}_{i,m,t} = \rho_\tau \bar{\tau}_{i,m,t-1} + (1-\rho_\tau). \tag{36}$$

I set the persistence parameter, ρ_τ, to 0.65, which is approximately the degree of persistence exhibited by U.S. GDP in annual data. None of my results are sensitive to the value of this parameter.

Figure 5 plots the calibrated time series for the five wedges. Panels (a) and (b) show the two saving wedges. The U.S. saving wedge is stable, while the rest of the world's saving wedge starts low and then rises, boosting saving in the rest of the world as the U.S. trade deficit grows. Panels (c) and (d) show the investment wedges. Both countries' investment wedges decline over time, but the U.S. investment wedge falls particularly sharply during the 2000-2001 and 2008–2009 recessions. Panel (e) shows the rest of the world's trade wedge. It falls between 2000 and 2002, when the U.S. trade balance and real exchange rate declined together, and then rises when the real exchange rate began to depreciate.

5. Wedge accounting

To evaluate the contributions of the wedges to U.S. trade deficits and the other trends shown in figure 1, I compare my benchmark equilibrium with six counterfactuals. In the no-wedge counterfactual, I hold all five wedges constant to determine how the U.S. trade balance and other variables would have evolved in the absence of the distortions generated by the wedges. This counterfactual includes demographic change and asymmetric productivity growth, however, and so it isolates the combined effects of these exogenous forces. In each of the other five counterfactuals, I isolate the effects of one of the wedges by setting that wedge to its calibrated value in each period and holding the other four wedges constant.

Figures 6–9 present visualizations of the wedge accounting results. Each figure illustrates the contributions of the wedges to the dynamics of one of the variables of interest. Each panel in the figures compares the model outcomes implied by one of the wedges to the outcomes in the no-wedge counterfactual and the data. The red lines with round markers plot the data and the solid blue lines plot model the no-wedge counterfactual. The green lines in each panel plot model outcomes in one of the other five counterfactuals; panel (a) in each figure, for example, shows the model dynamics implied by the U.S. saving wedge.

Table 3 presents numerical comparisons of the counterfactuals and the data that quantify the wedges' effects. The first column of the table reports moments computed from the observed data. The second column compares these moments to the predictions of the no-wedge counterfactual. The remaining columns compare the data to the other counterfactuals, highlighting the effects of each of the wedges in turn.

5.1. Trade balance

The United States ran a trade deficit every year between 1995 and 2011. In the no-wedge counterfactual the United States runs a trade surplus every year. As I demonstrate in section 6.1 below, this is because labor productivity has grown faster—and will continue to grow faster—in the rest of the world than in the United States, leading households in the rest of the world to borrow against their future income to smooth consumption. Gourinchas and Jeanne (2013) obtain a similar result in a small open economy environment; the fact that fast-growing countries typically run trade surpluses, not deficits as theory predicts, is what they call the allocation puzzle. I use the term "cumulative excess deficit" to denote the difference between the cumulative trade deficit in the data and the cumulative trade surplus in the no-wedge counterfactual between 1995 and 2011. The cumulative excess deficit represents the total amount of U.S. foreign borrowing that took place during this period relative to how much the U.S. would have lent in the absence of any distortions.

The results of my wedge accounting analysis clearly indicate that a global saving glut is the primary driver of U.S. trade deficits. Figure 6 shows that the U.S. trade balance implied by the rest of the world's saving wedge fits the data best; in fact, the rest of the world's saving wedge is the only wedge that generates trade deficits rather than trade surpluses. The U.S. saving wedge and the two investment wedges have little impact on the U.S. trade balance. The trade wedge has a larger effect on U.S. trade balance dynamics but it has little impact on the cumulative U.S. trade deficit. As figure 6 shows, the trade wedge boosts the U.S. trade balance in the 1990s, when the U.S. real exchange rate appreciates, and lowers it in the 2000s, when the real exchange rate depreciates. These two effects offset one another, however; the cumulative trade surplus implied by the trade wedge is similar to the no-wedge counterfactual's cumulative surplus.

To measure the wedges' contributions to U.S. trade deficits, I ask: what is the cumulative excess trade deficit (or surplus) implied by each wedge? I find that the rest of the world's saving wedge accounts for 96 percent of the cumulative excess deficit, while the other four wedges each account for less than 5 percent. Thus, a global saving glut is, in fact, the primary cause of U.S. trade deficits.

5.2. *Real exchange rate*

As U.S. trade deficits grew, the U.S. real exchange rate appreciated. My results indicate that a global saving glut is the primary cause of this appreciation as well as U.S. trade deficits. This finding is consistent with my analysis in section 2.3 in which I derived a one-for-one relationship between the rest of the world's saving wedge and the U.S. real exchange rate.

Figure 7 shows that in the no-wedge counterfactual the U.S. real exchange rate depreciates, rather than appreciating because the U.S. runs trade surpluses, not trade deficits. The rest of the world's saving wedge, on the other hand, implies real exchange rate dynamics that track the data closely. As panel (b) of table 3 shows, the rest of the world's saving wedge generates a peak appreciation of 13.45 percent (100/86.55-1) compared to 20.00 percent in the data (79.97/100-1), and accounts for approximately 100 percent of the cumulative excess real exchange rate appreciation (computed in a similar manner to the cumulative excess trade deficit defined above). The other four wedges have little effect on the real exchange rate; in their counterfactuals, the real exchange rate appreciates, rather than depreciating, as in the no-wedge counterfactual.

Interestingly, the trade wedge has little impact on the real exchange rate. Its primary role in the wedge accounting exercise is, instead, to generate the lag between the trade balance and real exchange rate seen in the data, particularly during the 2002–2006 period when the trade deficit continued to rise but the real exchange rate began to depreciate. The rest of the world's saving wedge generates simultaneous movements in the U.S. trade balance and real exchange rate during this period—it generates a recovery in the trade balance starting in 2002 when the real exchange rate begins to depreciate.

5.3. *Investment*

The U.S. investment rate rose during the 1990s as U.S. trade deficits grew before falling during the 2001 recession and plunging again during the Great Recession of 2008–2009. Laibson and Mollerstrom (2010) argue that these dynamics suggest that U.S. trade deficits were driven by domestic forces. They claim that if an increased supply of saving in the rest of the world was the culprit, the U.S. investment rate should have continued to rise throughout the 2000s as U.S. trade deficits continued to grow. KRS, on the other hand, argue that if U.S. trade deficits were driven by domestic distortions, the U.S. investment rate should have fallen, not risen, as the U.S. ran trade deficits. My analysis indicates that both arguments are right.

Figure 8 shows that the rest of the world's saving wedge causes the U.S. investment rate to rise throughout the 2000s until U.S. trade deficits begin to fall, just as Laibson and Mollerstrom (2010) suggest. Other distortions, however, offset this effect—the U.S. investment wedge and trade wedge both reduce the investment rate. Later in the observation period, the U.S. investment and saving wedges play prominent roles in driving U.S. investment dynamics, particularly during the Great Recession. In short, while U.S. trade deficits were driven primarily by a global saving glut, the fluctuations in investment that accompanied these deficits were the net result of domestic and foreign distortions that often offset one another.

To formalize these findings, in panel (c) of table 3 I have computed the wedges' contributions to the cumulative excess investment (computed just like cumulative excess trade deficits and real exchange rate appreciation) during two sub-periods: 1995–2006 and 2007–2011. In the first sub-period, the rest of the world's saving wedge over-explains the cumulative excess investment while the U.S. investment wedge and trade wedge make negative contributions. In the second sub-period, the U.S. investment and saving wedges make positive contributions while the rest of the world's saving wedge and the trade wedge make negative contributions.

5.4. Real interest rate

Bernanke (2005) argued that falling U.S. real interest rates suggest that a global saving glut is the cause of U.S. trade deficits. In section 2 I use a two-period, one-good model to illustrate his logic. I also show, however, that the theoretical relationship between trade deficits and interest rates weakens when domestic and foreign products are not perfectly substitutable, particularly in countries like the United States that consume mostly domestic products. My quantitative analysis indicates that while the rest of the world's saving wedge does account for some of the decline in U.S. real interest rates, the other wedges, especially the U.S. investment wedge, also play important roles.

Figure 9 shows that in the no-wedge counterfactual, the U.S. real interest rate fluctuates around its long-run level of 2.5 percent, exhibiting no downward trend. The two investment wedges and the rest of the world's saving wedge all drive the interest rate downward, but the U.S. investment wedge plays a particularly important role during the Great Recession. Panel (d) of table 3 shows that the interest rate implied by rest of the world's saving wedge has the lowest root mean square error, but the U.S. investment wedge generates the lowest real interest rate and accounts for the largest fraction of the cumulative decline in interest rates between 1995 and 2011. The U.S. saving wedge also depresses the interest rate, but it does so during the 1990s, when interest rates in the data were still relatively high. The trade wedge makes the real interest rate more volatile but does not drive it persistently downward.

Aside from a global saving glut, the literature proposes a variety of explanations for the decline in real interest rates in recent decades, such as secular stagnation (Summers, 2014), demographics (Bean et al., 2015), and a shortage of safe assets (Andolfatto and Williamson, 2015). However, when one looks at the dynamics of the U.S. real interest rate over a longer time horizon, it becomes apparent that interest rates were actually relatively high during the early 1990s and that the decline in recent decades was, at least in part, a return to normal. Between the end of World War 2 and the stagflationary period of the 1970s, U.S. real interest rates averaged about 2 percent per year.[7] They rose dramatically in the early 1980s during the Volker disinflation and have been steadily falling

[7]The average ex-post real interest rate between 1954 and 1972, as measured by the yield on 10-year Treasury bonds less CPI-U inflation, is 1.8 percent.

toward their pre-stagflation average since then. My findings indicate that this decline was driven by waning investment distortions as well as an increased supply of saving in the rest of the world. Yi and Zhang (2016) report similar results, arguing that "forces leading to lower investment demand have been relatively more important than those leading to higher desired saving... in addition to a saving glut, there must have been forces that reduced global investment demand, and these forces must have been more important." My findings are also consistent with estimates of Warnock and Warnock (2009) and Krishnamurthy and Vissing-Jorgensen (2007), who find that foreign lending has reduced U.S. interest rates by no more than 80 basis points.

5.5. Interpreting the wedges

Gourinchas and Jeanne (2013) point out that one should not interpret wedges as causal explanations for the data they are constructed to account for—further investigation is needed to determine the policies or frictions that the wedges represent. Chari et al. (2007) provide several examples of how one can map wedges to explicitly-modeled frictions. My results indicate that a global saving glut is the primary driver of U.S. trade deficits, so this investigation should focus on understanding the behavior of the rest of the world's saving wedge.

As figure 5 illustrates, the rest of the world's saving wedge rose throughout the 1990s and 2000s as U.S. trade deficits grew. In the model, a rising saving wedge manifests as an increasing saving subsidy or borrowing tax. One potential explanation for the increase in the rest of the world's saving wedge is that governments in the countries that make up the rest of the world implemented more stringent capital controls. Another version of this explanation is that countries with strict capital controls—China, for example—grew faster than other countries in the rest of the world, so that the rest of the world's aggregate capital account openness fell. Panel (a) in figure 10, which plots a measure of the rest of the world's capital account openness alongside the U.S. trade balance, supports this sort of explanation. I measure the rest of the world's capital account openness using the Chinn and Ito (2006) dataset, applying the same aggregation to this data that I apply to the labor productivity and demographic series; the rest of the world's capital account opennness is the average of its consituent countries' openness, weighted by the constituents' time-varying shares of the rest of the world's output. A deeper look into the Chinn and Ito (2006) data suggests that the second version of this explanation is the right one. Capital account openness increased in almost every country in the dataset between 1995 and 2011—China, whose capital account remained closed, is a notable exception—so the decline in the rest of the world's openness is due to the shift in weight towards less-open countries.

Another related explanation for the behavior of the rest of the world's saving wedge is that domestic financial markets in the rest of the world became less developed or, more likely, that constituent countries with underdeveloped domestic financial markets grew fastest. Caballero et al. (2008) and Mendoza et al. (2009) illustrate how domestic financial market frictions like poor contract enforcement can lead to capital outflows, rather than inflows as standard theory predicts. Gourinchas and Jeanne (2013) argue that domestic financial frictions could also manifest as investment distortions. The rest of the world's investment wedge falls throughout the observation period as its saving wedge rises, suggesting that this explanation, too, may hold water. Panel (a) in figure 10, plots a measure of domestic financial development in the rest of the world, provides further corroboration. This measure is constructed using data on constituent countries' private credit/GDP ratios from the Beck et al. (2000) database. Again, most constituent countries' financial sectors became more developed during this period, so the decline in the rest of the world's aggregate financial development is due to a shift in weight towards less-developed countries.

The U.S. investment wedge plays an important role in accounting for the dynamics of U.S. investment and the U.S. real interest rate, so further investigation of the source of this wedge's behavior is also warranted. The sharp drop in 2008–2009 is consistent with Eaton et al. (2016), who find that shocks to investment efficiency, which are isomorphic to the investment wedge in my model, explain a significant fraction of the macroeconomic downturn and trade collapse that occurred during the Great Recession. The most likely explanation for the behavior of the U.S. investment wedge during this episode is the financial crisis itself. The sharp increase in the corporate bond spread that resulted from the crisis maps directly to the investment wedge, which represents the gap between the real interest rate and the marginal product of capital. A similar, but less pronounced, drop in the U.S. investment wedge also occurs during the 2000-2001 recession.

The trade wedge, which helps account for the J-curve dynamics of the U.S. trade balance and real exchange rate, particularly during the 2002–2006 period, stands in for a number of frictions and adjustment costs. Alessandria and Choi (2018), Ruhl (2008), Ramanarayanan (2017), and others have shown how sunk costs of exporting or importing reduce the sensitivity of trade flows to short-run price changes. Alessandria and Choi (2018), in particular, show that these frictions can account for the U.S. J-curve. Other researchers have highlighted the roles of durable goods (Engel and Wang, 2011), destination-specific marketing capital (Drozd and Nosal, 2012), and barriers to forming supplier relationships (Lim, 2017).

6. Sensitivity analysis

I have conducted a wide range of additional experiments with the model and have found that my main conclusion—that a global saving glut is the primary driver of U.S. trade deficits—is robust.[8] In this section, I present the results of two sets of sensitivity analyses that provide useful context for my findings. First, I explore the roles of demographic change and productivity growth in driving U.S. trade deficits. Second, I study how the joint dynamics of the U.S. trade balance and real exchange rate shape the results of the wedge accounting analysis. Table 4 summarizes the wedge accounting results for the U.S. trade balance in each of these analyses.

6.1. Demographic change and productivity growth

In addition to the five wedges, the model includes two exogenous driving forces that are taken from external data sources: demographic change and labor productivity growth. As figure 4 shows, the United States population grows more slowly and becomes younger than the rest of the world's, and U.S. labor productivity grows more slowly. These forces are present in the no-wedge counterfactual, in which the United States lends to, instead of borrowing from, the rest of the world. Here, I ask: what are the roles of demographic change and productivity growth—and differences in these

[8]The appendix contains the results of sensitivity analyses in which I vary assigned parameters like elasticities of substitution and adjustment costs.

trends between the United States and the rest of the world—in determining what U.S. trade balance dynamics would have been in the absence of saving, investment, or trade distortions? How do demographic change and productivity growth determine the distortions' contributions to U.S. trade deficits?

To answer these questions, I repeat the wedge accounting analysis in two alternative calibrations. In the first, there is no demographic change within or across countries: the demographic parameters $\bar{n}_{i,t}$ and $\bar{\ell}_{i,t}$ are constant over time. In the second, labor productivity growth is constant and symmetric: each country's labor productivity, $\bar{\gamma}_{i,t}$, always grows at the long-run rate of 2 percent per year. Panel (a) of figure 11 plots U.S. trade balance dynamics in the no-wedge counterfactual in these two sensitivity analyses against the baseline results, and panel (b) shows the contribution of the rest of the world's saving wedge.

Without demographic change, the United States lends more to the rest of the world than in the baseline analysis. This is consistent with Sposi (2017), who finds that the United States would have run smaller trade deficits but for demographic change. The intuition for this result follows permanent-income logic. As the United States grows relatively younger over time it produces relatively more output per adult equivalent. All else equal, this leads the the United States to borrow in the 1990s and 2000s, when it is relatively old, to smooth adult-equivalent consumption. Consequently, the U.S. trade balance is higher in the version of the analysis without demographic change. In the no-demographics version of the wedge accounting analysis, the rest of the world's saving wedge accounts for a smaller fraction of U.S. trade deficits—82 percent of the cumulative excess deficit compared to 96 percent in the baseline—while the U.S. saving wedge accounts for a larger fraction. This indicates that the U.S. saving wedge takes up the slack left by demographic change; in the baseline analysis demographic change explains a portion of U.S. borrowing, and the no-demographic version of the analysis assigns the bulk of this portion to the U.S. saving wedge.

Without differences in labor productivity growth, the United States borrows in the no-wedge counterfactual, rather than lending. This, too, follows permanent income logic. As in Gourinchas and Jeanne (2013), relatively rapid labor productivity growth in the rest of the world creates a permanent-income motive for households in the rest of the world to borrow from the United States. The rest of the world's saving wedge plays an even stronger role in driving U.S. trade deficits in the symmetric-growth version of the wedge accounting analysis; in fact, it over-explains the cumulative excess deficit, and the U.S. saving wedge acts as a countervailing force. This analysis also highlights the importance of China's growth in accounting for U.S. trade deficits. If one were to construct the rest of the world's labor productivity series using constant weights—constituent countries' 1995 GDPs— instead of time-varying weights, productivity would grow at almost the same rate in the rest of the world as in the United States. The difference between productivity growth in the United States and the rest of the world is due in large part to the growing importance of China in the world economy.

These results highlight the important roles of demographics and productivity growth in driving U.S. trade deficits, but they also illustrate why the no-wedge counterfactual is the right benchmark from which to assess the wedges' contributions to these deficits. Comparing the extent of U.S. borrowing in the one-wedge counterfactuals to the data does not tell the whole story because U.S. trade would not have been balanced in the absence of saving, investment, and trade distortions. The cumulative excess deficit represents the total amount of U.S. foreign borrowing that occurred as a result of these distortions, and measuring the wedges' contributions to the cumulative excess deficit is, in my view, the right way to quantify the wedges' effects.

6.2. Joint dynamics of the U.S. trade balance and real exchange rate

U.S. trade deficits have been accompanied by large fluctuations in the U.S. real exchange rate. As the U.S. trade deficit grew during the 1990s and early 2000s, the U.S. real exchange rate appreciated by more than 20 percent. This follows standard Marshall-Lerner logic: the United States substituted towards foreign goods and services as they became cheaper. When the real exchange rate began to depreciate in 2002, however, the U.S. trade deficit continued to grow four more years. In my quantitative analysis, I used a trade wedge to ensure that my model could generate these J-curve dynamics. I have found that the trade wedge is not a significant driver of cumulative U.S. trade deficits or U.S. real exchange rate appreciation, but that it does play a role in the timing of U.S. deficits. Here, I ask: How does the requirement that the model match the U.S. real exchange rate affect the wedges' contributions to U.S. trade balance and cumulative U.S. foreign borrowing? What would equilibrium real exchange rate dynamics look like in the absence of this requirement?

To answer these questions, I conduct a version of the wedge accounting analysis without a trade wedge that targets only the U.S. trade balance, both countries' investment rates, and the real interest rate. Panel (a) of figure 12 shows that while the no-trade-wedge version of the analysis still matches closely the extent of U.S. real exchange rate appreciation, it no longer matches the timing. In this version, the real exchange rate continues to appreciate until 2006, when the trade deficit peaks, before beginning to depreciate. The rest of the world's saving wedge still accounts for the bulk of real exchange rate movements in this version of the model, however, as in KRS.

As table 4 shows, the paper's main result is unchanged in this version of the analysis: the rest of the world's saving wedge still accounts for 96 percent of cumulative excess trade deficits. The table also shows, though, that the rest of the world's saving wedge accounts for a larger portion of U.S. trade balance fluctuations in this version of the analysis; the root mean squared error in the counterfactual with only this wedge is lower in this version than in the baseline. Panel (b) of figure 12 illustrates why: the rest of the world's saving wedge does a better job of capturing the timing of U.S. trade deficits in the no-trade-wedge analysis; the largest trade deficit in the one-wedge counterfactual for the rest of the world's saving wedge now occurs in 2006, just as in the data, instead of in 2002.

The results of this analysis confirm that a global saving glut is the primary driver of both U.S. trade deficits and the real exchange rate appreciation that accompanied them. The trade wedge creates a lag trade between the real exchange rate and the trade balance, allowing the U.S. trade deficit to continue to grow between 2002 and 2006 even as the real exchange rate depreciates, but plays almost no role in the cumulative extent of U.S. foreign borrowing or real exchange rate appreciation.

7. Concluding remarks

In this paper I have used a calibrated dynamic general equilibrium model of the United States and the rest of the world to conduct a wedge accounting analysis of the causes of U.S. trade deficits between 1995 and 2011. I have found that increased supply of saving in the rest of the world—a global saving glut—explains 96 percent of cumulative U.S. trade deficits in excess of those that would have occurred naturally as a result of productivity growth and demographic change.

Contrary to widespread belief, however, a global saving glut is not the primary cause of declining real interest rates. Investment distortions (both domestic and foreign) are also important drivers of this trend. I have used a simple two-period model to demonstrate analytically that when domestic and foreign products are imperfectly substitutable, a global saving glut can have more impact on the real exchange rate than on the real interest rate, particularly in countries like the United States in which domestic products account for the bulk of aggregate consumption expenditures. My quantitative analysis corroborates this result; I find that a global saving glut is also responsible for the substantial real exchange rate appreciation that has accompanied U.S. trade deficits.

My results highlight the roles of productivity growth and demographic change—and differences in these trends between the United States and the rest of the world—in driving U.S. trade balance dynamics and in shaping the results of the wedge accounting analysis. Productivity has grown more rapidly in the rest of the world than in the United States, creating a permanent-income motive for the rest of the world to borrow (Gourinchas and Jeanne, 2013). At the same time, the United States has grown younger, creating a permanent-income motive for the United States to borrow (Sposi, 2017). Together, these motives imply that the United States would have run trade surpluses, not trade deficits, but for saving, investment, and trade distortions. Thus, the wedge accounting exercise must explain a large excess trade deficit—the difference between the observed U.S. trade deficit and the trade surplus in the no-wedge counterfactual.

Further investigation into the underlying sources of a global saving glut points to decreases in capital account openness and domestic financial development in the rest of the world. While many of the countries that comprise the rest of the world became more open and more financially developed in recent decades, less-open and less-developed emerging economies like China grew rapidly, and so aggregate openness and financial development in the rest of the world fell relative to the United States. These declines are highly correlated with saving distortions in the rest of the world and with U.S. trade deficits. Correspondingly, as emerging economies' productivity growth slows and their financial markets develop in the future, the global saving glut will wane and U.S. trade will rebalance.

Acknowledgements

I thank Michael Sposi, seminar participants at the North American Econometric Society 2016 Summer Meeting, and two anonymous referees for helpful comments. I would also like to thank the editor, Matthias Doepke, for his guidance. I acknowledge the Connaught Fund (grant number 497045) for financial support.

Appendix A. Supplementary material

Supplementary material related to this article can be found online at https://www.economics.utoronto.ca/steinberg/files/gsg_dsd_supplement.zip.

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Table 1: 1995 input-output table (U.S. GDP = 100)

		Intermediate inputs						Final demand			
		USA			ROW			USA		ROW	
		Goods	Srvcs	Const	Goods	Srvcs	Const	Cons	Inv	Cons	Inv
USA	Goods	19.11	8.34	2.01	3.03	0.92	0.23	9.54	5.03	1.31	1.28
	Srvcs	10.36	31.56	1.99	1.11	1.58	0.14	70.04	3.42	0.62	0.07
	Const	-	-	-	-	-	-	-	7.90	-	-
ROW	Goods	3.50	1.16	0.26	87.28	28.47	12.16	2.36	2.15	56.76	22.13
	Srvcs	0.40	0.81	0.07	41.62	76.76	7.85	0.52	0.04	159.74	11.28
	Const	-	-	-	-	-	-	-	-	-	36.64
VA		17.42	79.01	3.57	83.19	191.36	16.26				
GO		50.80	120.89	7.90	216.22	299.09	36.64				

Table 2: Assigned parameters and initial conditions

Parameter	Meaning	Value	Source or target
β	Discount factor	1.003	Long-run interest rate = 2.5%
δ	Depreciation rate	0.06	Standard
α	Capital share	0.33	Standard
ϕ_i	Consumption utility share	(0.39,0.36)	Long-run leisure time = 2/3
φ	Capital adjustment cost	0.8	Sposi (2017)
$1/(1-\psi)$	Intertemporal elasticity	0.5	Standard
$1/(1-\zeta^1)$	Intermediate goods Armington elasticity	3.0	KRS
$1/(1-\zeta^2)$	Intermediate services Armington elasticity	1.0	KRS
$1/(1-\sigma^1)$	Final goods Armington elasticity	2.0	KRS
$1/(1-\sigma^2)$	Final services Armington elasticity	1.0	KRS
$1/(1-\eta)$	Value added-intermediates elasticity	0.03	Atalay (2017)
$1/(1-\kappa)$	Goods-services intermediates elasticity	0.05	Atalay (2017)
$1/(1-\rho)$	Goods-services consumption elasticity	0.65	Atalay (2017)
$b_{i,0}$	Initial bondholdings	(-7.2,7.2)	Lane and Milesi-Feretti (2007)
$k_{i,0}$	Initial aggregate capital	(281.3,890.6)	Penn World Tables

Table 3: Wedge accounting results for U.S. quantities and prices

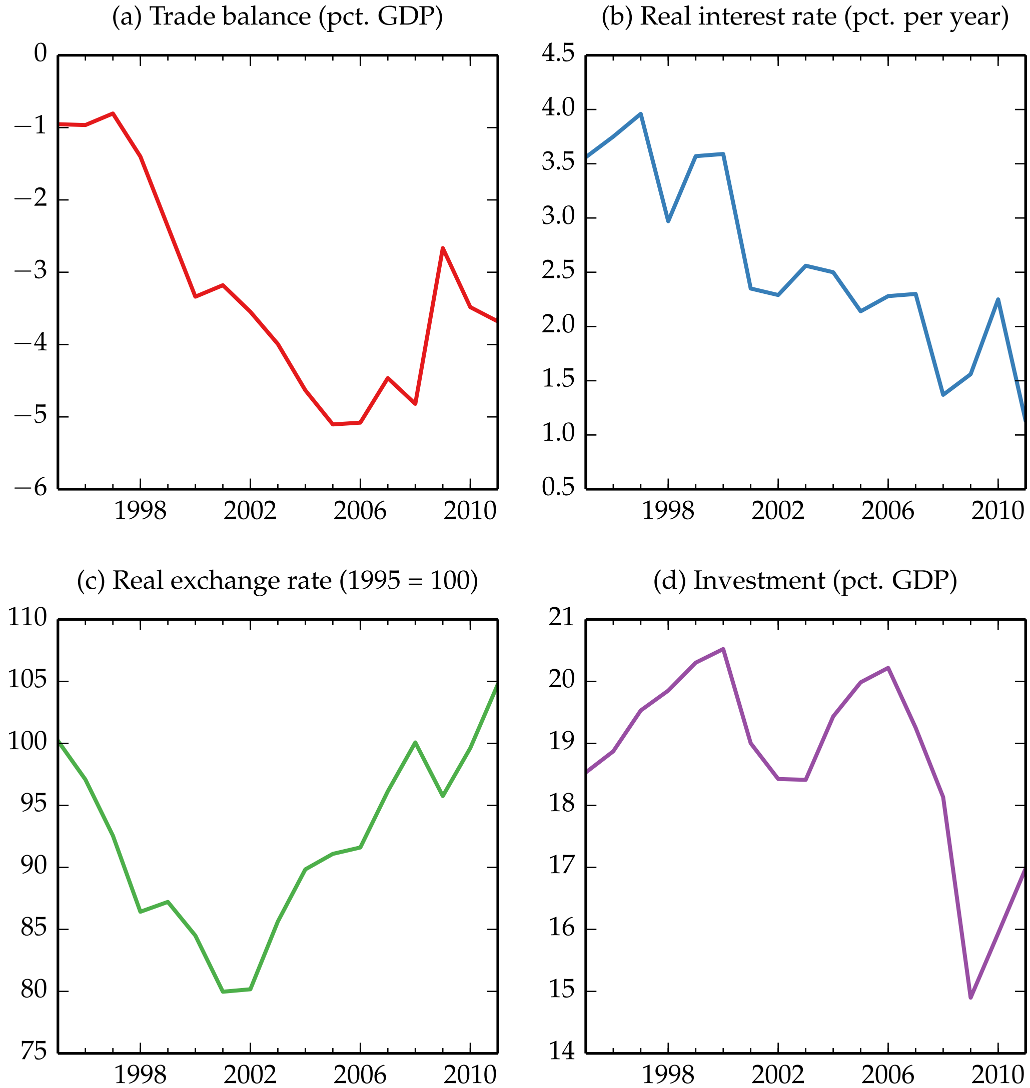
			United States		Rest of the world		
Measure	Data	No wedges	Saving wedge	Inv. wedge	Saving wedge	Inv. wedge	Trade wedge
(a) Trade balance (percent GDP)							
Minimum	-5.10	3.87	3.07	4.15	-4.33	2.55	-0.61
Average	-3.20	4.86	4.58	5.32	-2.90	4.46	5.14
RMSE from data	0.00	8.21	7.89	8.73	1.90	7.80	8.86
Fraction CED explained	1.00	0.00	0.03	-0.06	0.96	0.05	-0.03
(b) Real exchange rate (1995 data = 100)							
Minimum	79.97	116.02	112.20	115.14	86.55	117.95	116.03
Average	91.92	125.35	124.67	125.83	92.02	125.40	124.19
RMSE from data	0.00	34.82	34.59	35.47	4.63	34.15	33.19
Fraction CEA explained	1.00	0.00	0.02	-0.01	1.00	-0.00	0.03
(c) Investment rate (percent GDP)							
RMSE from data	0.00	1.90	1.16	2.37	2.63	2.05	2.83
Fraction CEI explained (1995–2006)	1.00	0.00	0.37	-0.48	1.26	0.19	-0.51
Fraction CEI explained (2007–2011)	1.00	0.00	0.64	2.25	-1.48	-0.02	-0.77
(d) Real interest rate (percent per year)							
Minimum	1.13	1.96	1.51	1.39	1.78	1.79	0.02
Average	2.60	2.81	2.57	2.74	2.80	2.92	2.85
RMSE from data	0.00	1.23	1.25	0.97	0.80	0.92	2.01
Fraction decline explained	1.00	-0.46	-0.73	0.47	0.17	-0.04	-0.69

Notes: The second column reports counterfactual model outcomes when all wedges are set to one. Columns 3–7 report counterfactual model outcomes with one wedge set to its calibrated value in each period and all other wedges held constant. Fraction of CED explained calculated as (cumulative difference between trade balance in model and no wedge counterfactual) divided by (cumulative difference between trade balance in data and no-wedge counterfactual). Fraction of cumulative excess RER appreciation (CEA) and cumulative excess investment (CEI) computed analogously.

Table 4: Wedge accounting for U.S. trade balance in baseline model and sensitivity analyses

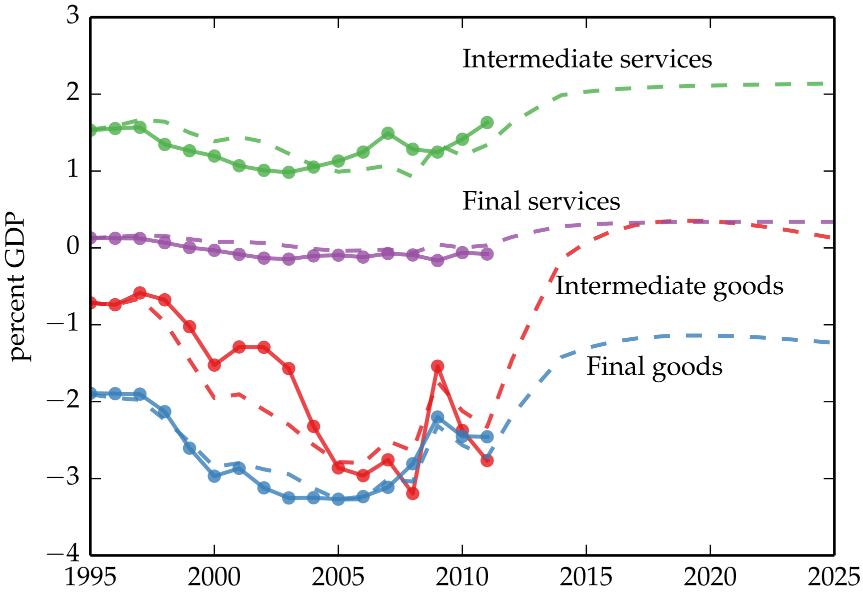
		United States		Rest of the world		
Model	No wedges	Saving wedge	Inv. wedge	Saving wedge	Inv. wedge	Trade wedge
(a) RMSE from data						
Baseline	8.21	7.89	8.73	1.90	7.80	8.86
No demographic change	9.12	7.49	9.45	2.25	8.78	9.50
Symmetric growth	2.67	2.98	3.18	1.79	2.69	3.18
No trade wedge	8.21	8.03	8.78	1.14	7.52	-
(b) Fraction of CED explained						
Baseline	0.00	0.03	-0.06	0.96	0.05	-0.03
Symmetric growth	0.00	-0.21	-0.17	1.39	-0.02	-0.15
No demographic change	0.00	0.18	-0.03	0.82	0.04	0.01
No trade wedge	0.00	0.02	-0.06	0.96	0.07	-

Notes: The second column reports counterfactual model outcomes when all wedges are set to one. Columns 3–7 report counterfactual model outcomes with one wedge set to its calibrate value in each period and all other wedges held constant. Fraction of CED explained calculated as (cumulative difference between trade balance in model and no wedge counterfactual) divided by (cumulative difference between trade balance in data and no-wedge counterfactual).



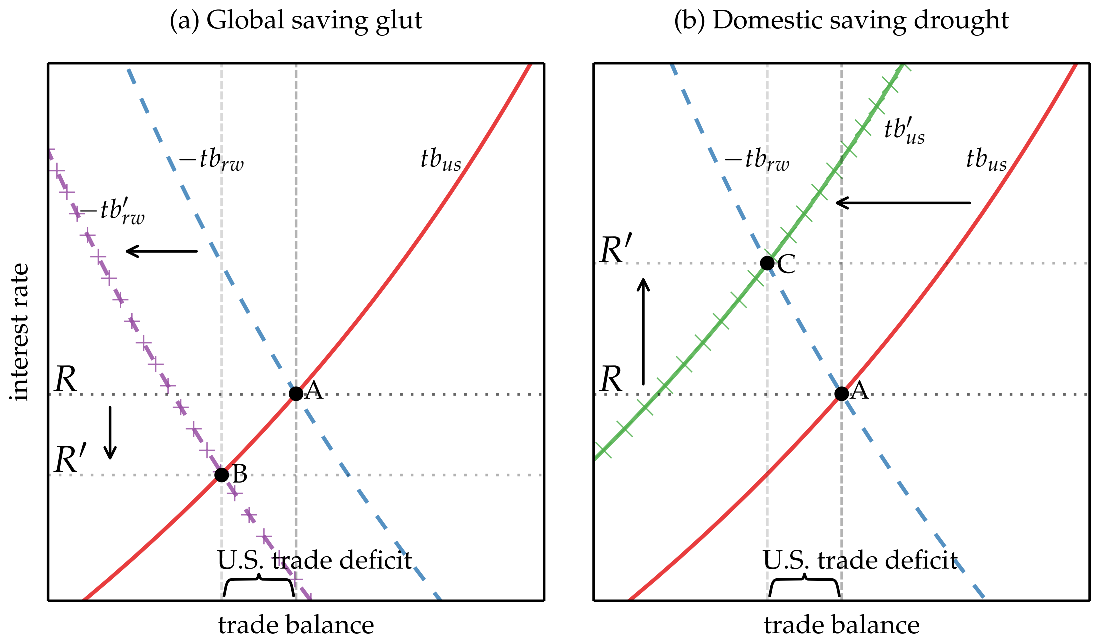
Notes: The data source for panels (a) and (d) is the World Input Output Database (WIOD). In panel (b), the real interest rate is calculated using the yield on 10-year Treasury bonds and the realized rate of CPI-U inflation. The source for panel (c) is the International Monetary Fund's International Financial Statistics (IFS) database.

Figure 1: Dynamics of the U.S. trade balance and other key variables during 1995–2011



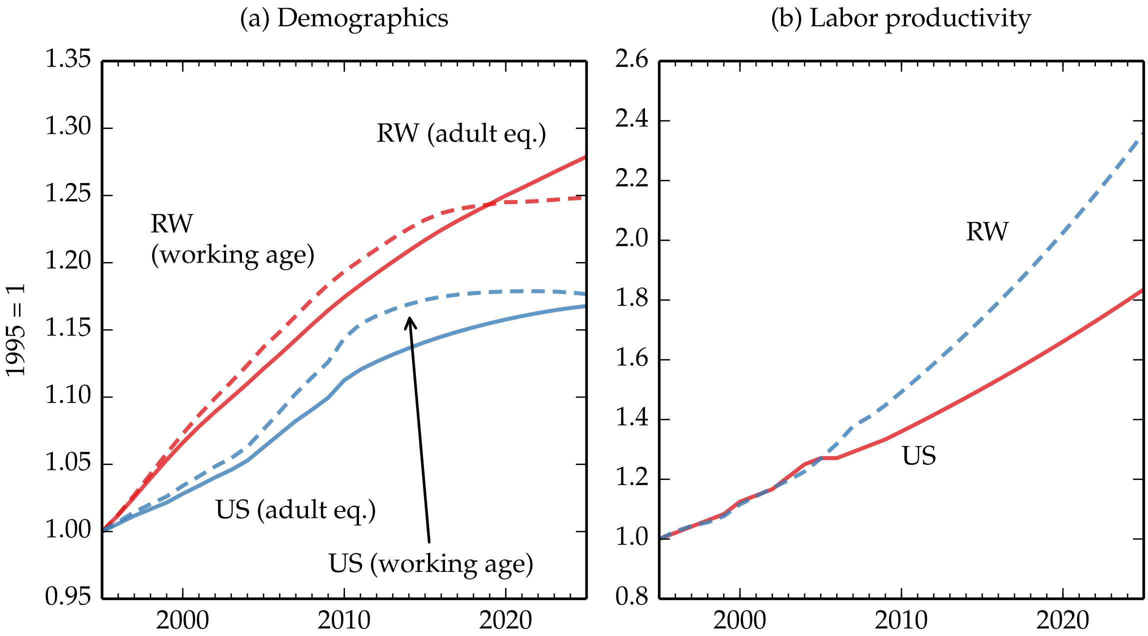
Notes: Colors denote trade categories (blue = final goods, red = intermediate goods,purple = final services, green = intermediate services). Data are represented by solid lines with round markers. Model results are represented by dashed lines.

Figure 2: Disaggregated U.S. trade balance



Notes: Panel (a) illustrates the effects of an increase in the rest of the world's saving wedge on the U.S. trade balance and real interest rate. The line tb_{us} denotes the U.S. trade balance curve. $-tb_{rw}$ denotes the rest of the world's initial trade deficit curve. $-tb'_{rw}$ denotes the rest of the world's trade deficit curve after its saving wedge rises. Point A denotes the initial equilibrium and point B denotes the equilibrium after the wedge rises. Panel (b) illustrates the effects of a decrease in the U.S. saving wedge using similar notation. Point C denotes the equilibrim after the U.S. saving wedge falls.

Figure 3: A global saving glut and domestic saving drought in the two-period model



Notes: Panel (a) plots the demographic time series parameters. The U.S. demographic data is shown in blue and the rest of the world's data is shown in red. Solid lines plot adult-equivalent populations and dashed lines plot working-age populations. Panel (b) plots the labor productivity parameters. U.S. labor productivity is a solid red line and the rest of the world's labor productivity is a dashed blue line.

Figure 4: Demographic and labor productivity time series parameters

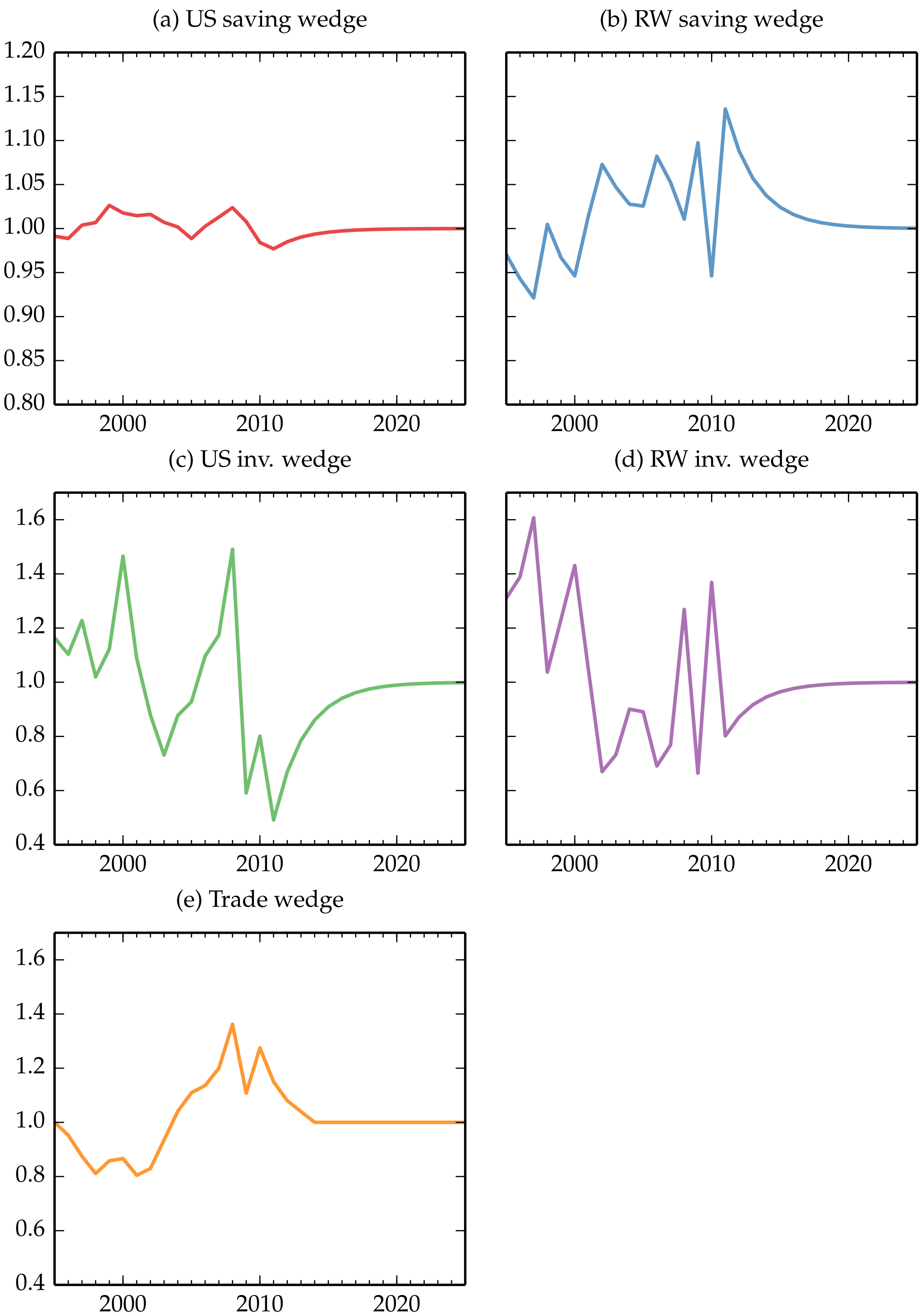
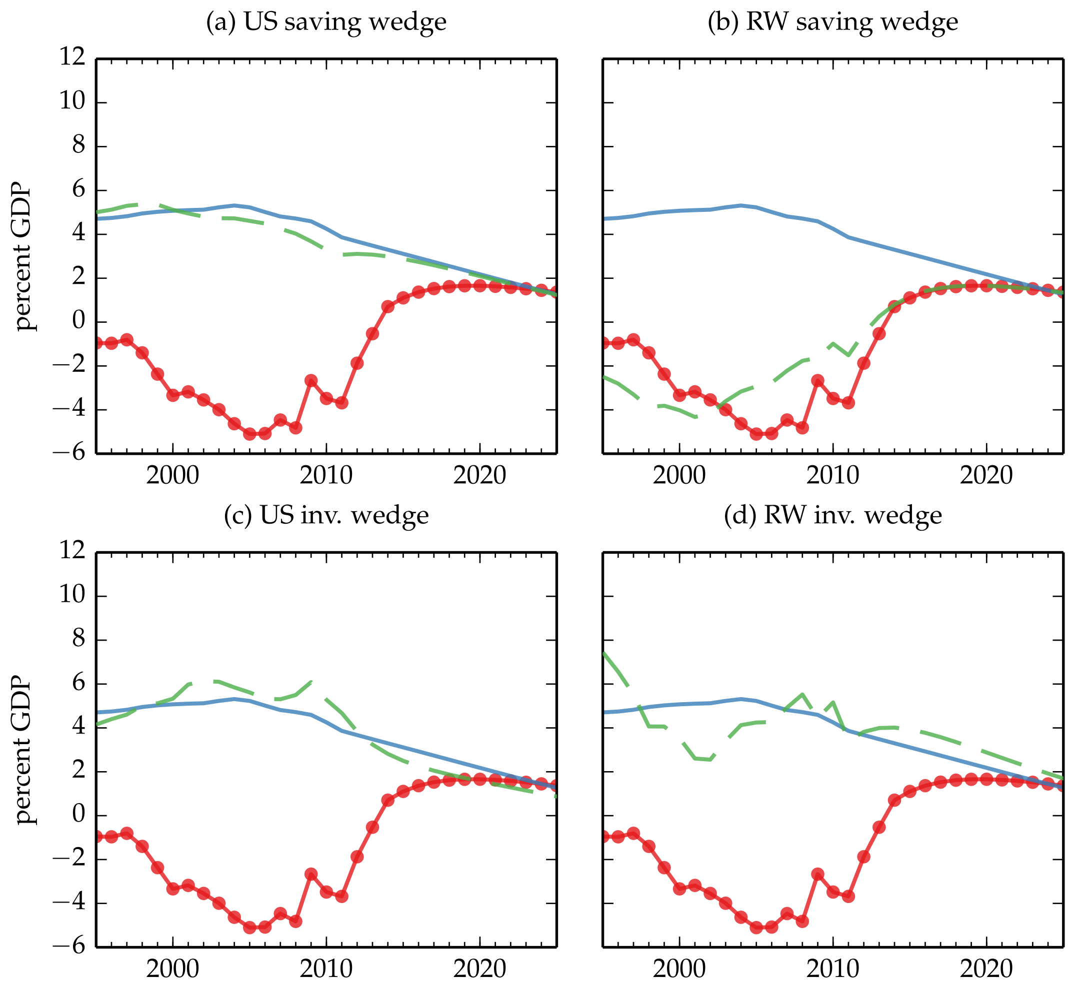
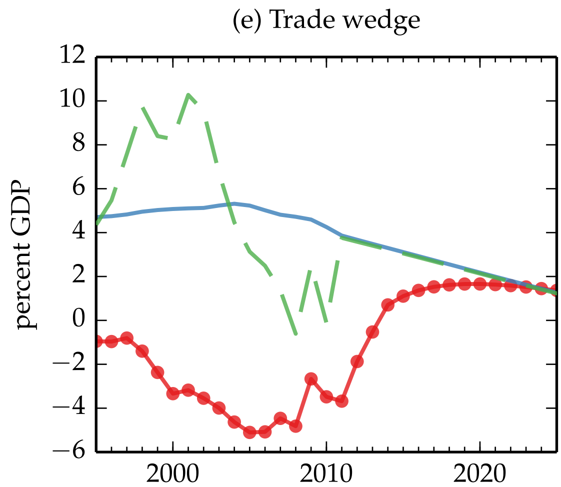


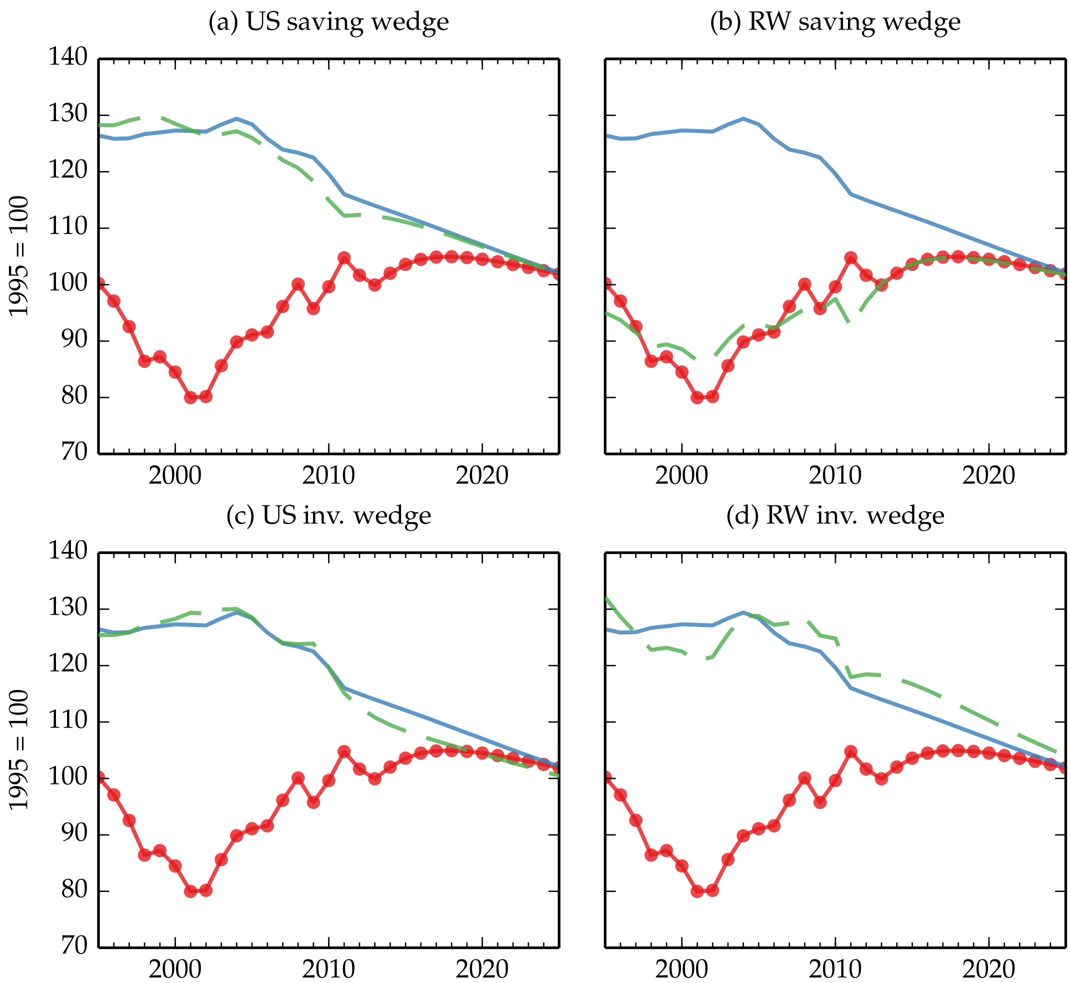
Figure 5: Calibrated wedges

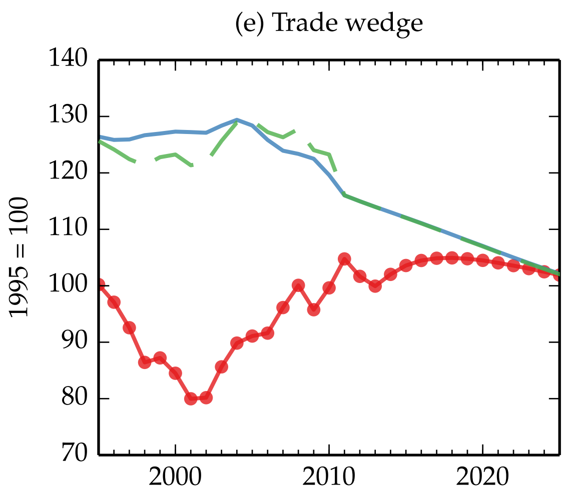




Notes: Each panel shows the effect of one wedge. Solid red lines marked with circles show the data (and projections from the model with all wedges). Blue lines show the no-wedge counterfactual. Dashed green lines plot counterfactual outcomes with the relevant wedge set to its calibrated value in each period holding all other wedges constant.

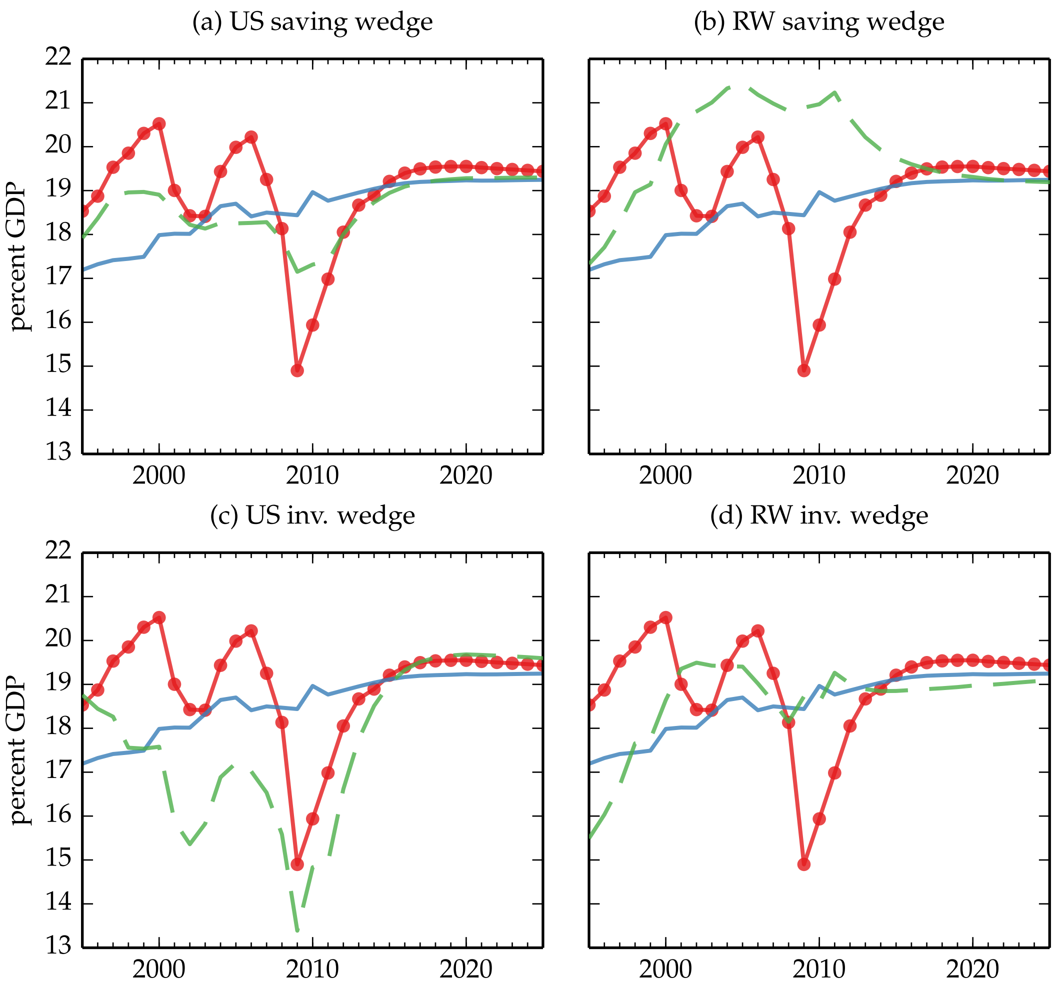
Figure 6: Wedge accounting results for U.S. trade balance

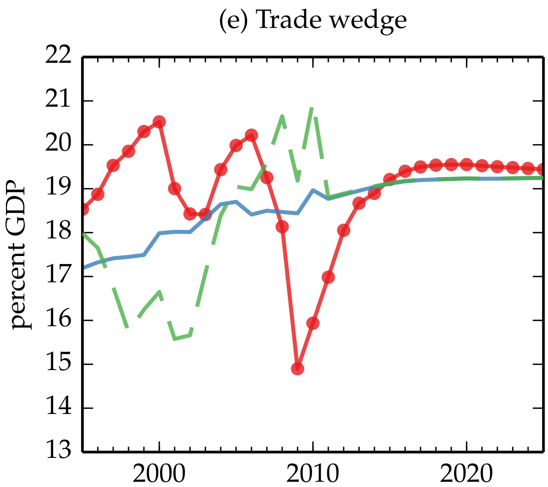




Notes: Each panel shows the effect of one wedge. Solid red lines marked with circles show the data (and projections from the model with all wedges). Blue lines show the no-wedge counterfactual. Dashed green lines plot counterfactual outcomes with the relevant wedge set to its calibrated value in each period holding all other wedges constant.

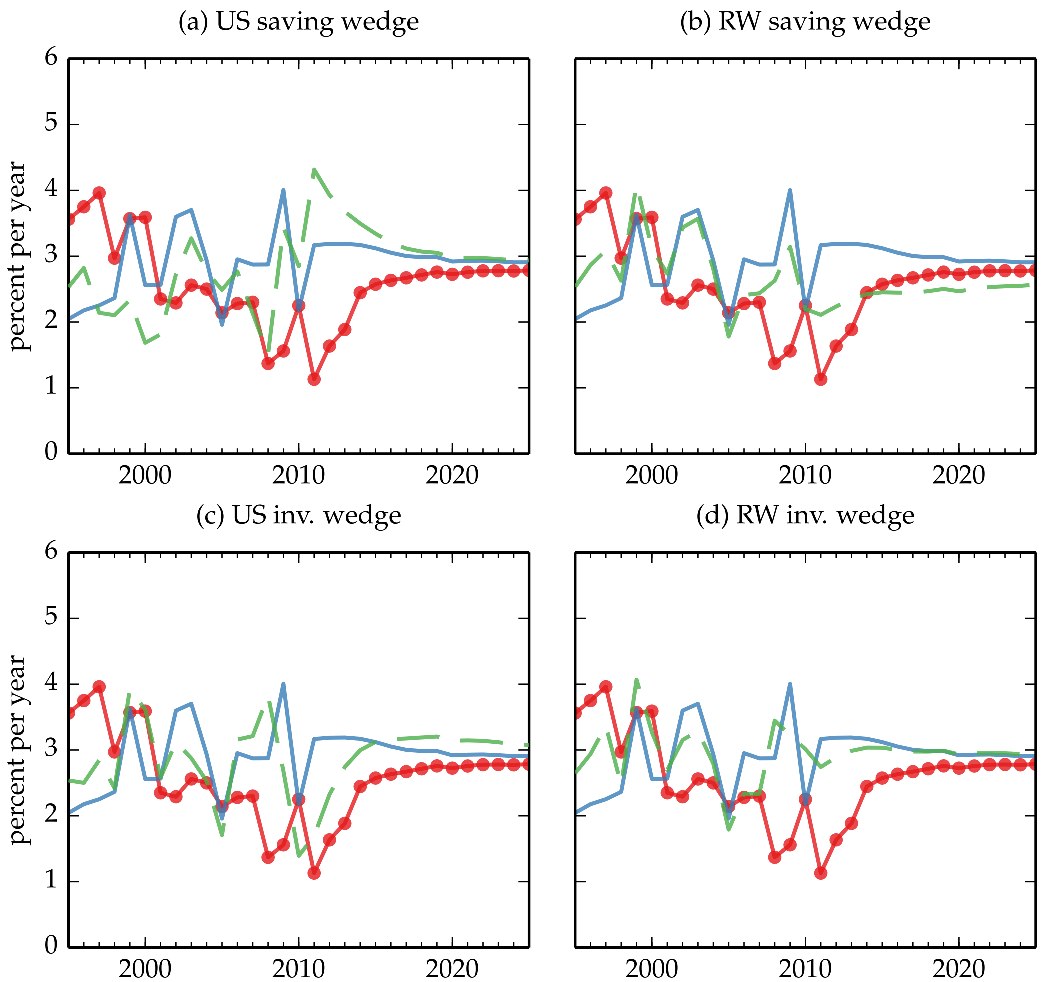
Figure 7: Wedge accounting results for U.S. real exchange rate

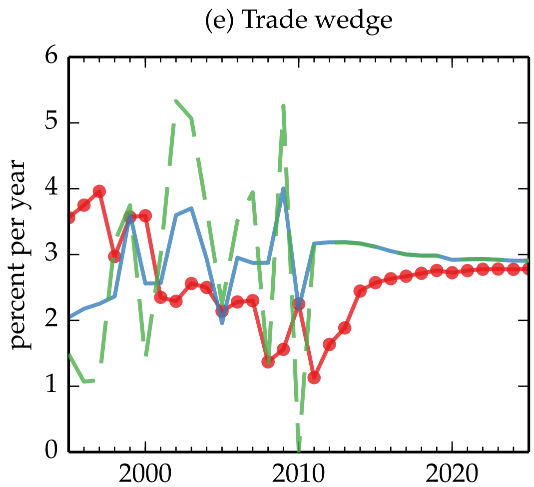




Notes: Each panel shows the effect of one wedge. Solid red lines marked with circles show the data (and projections from the model with all wedges). Blue lines show the no-wedge counterfactual. Dashed green lines plot counterfactual outcomes with the relevant wedge set to its calibrated value in each period holding all other wedges constant.

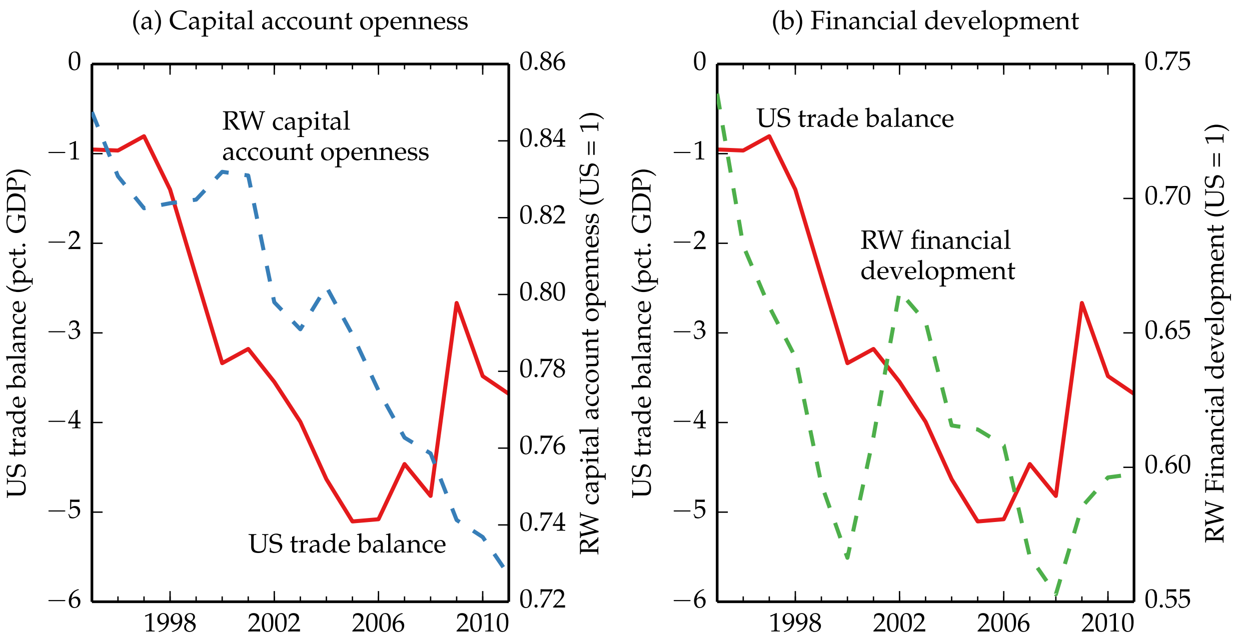
Figure 8: Wedge accounting results for U.S. investment rate





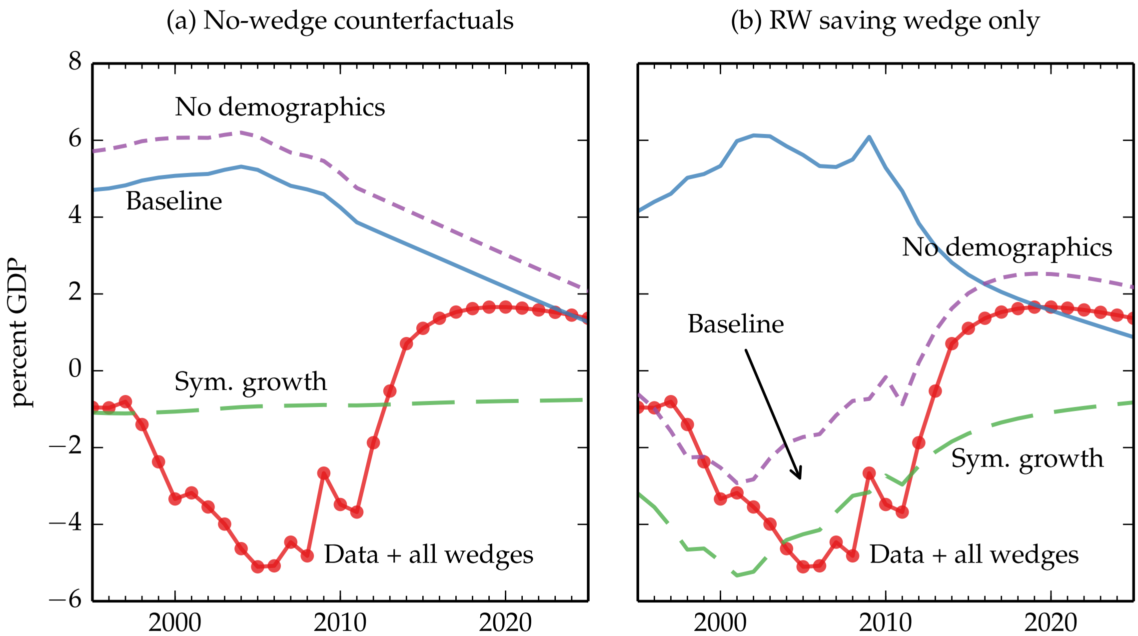
Notes: Each panel shows the effect of one wedge. Solid red lines marked with circles show the data (and projections from the model with all wedges). Blue lines show the no-wedge counterfactual. Dashed green lines plot counterfactual outcomes with the relevant wedge set to its calibrated value in each period holding all other wedges constant.

Figure 9: Wedge accounting results for U.S. real interest rate



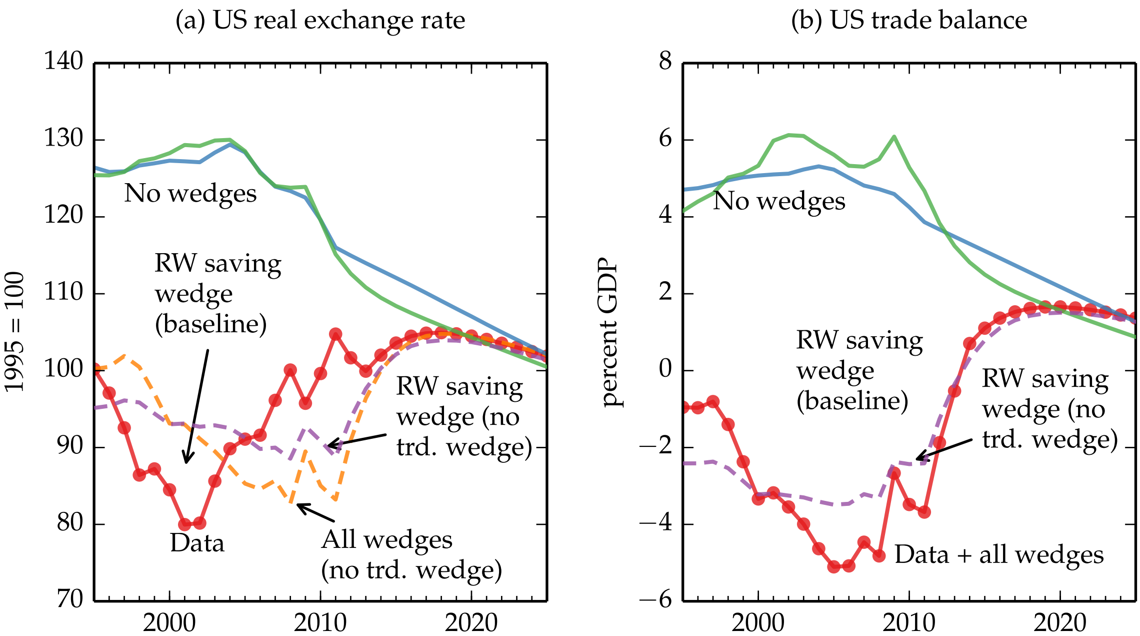
Notes: Solid red lines in both panels plot the U.S. trade balance as a fraction of U.S. GDP (left axis). Dashed lines in panels (a) and (b), respectively, plot the rest of the world's capital account openness and financial development relative to those of the United States (right axes). The former is based on the *KAOPEN* variable from the Chinn and Ito (2006) dataset, while the latter is based on *PCRDBOFGDP* from the Beck et al. (2000) dataset.

Figure 10: U.S. trade balance vs. capital account openness and financial development in the rest of the world



Notes: Both panels plot the observed U.S. trade balance (and future projections from the model with all wedges) in red with round markers. Panel (a) plots the U.S. trade balance in the no-wedge counterfactual for three versions of the analysis: baseline (solid line), symmetric productivity growth (long dashes), and without demographics (short dashes). Panel (b) plots the counterfactual outcomes implied by the rest of the world's saving wedge using the same line style scheme.

Figure 11: U.S. trade balance dynamics with symmetric TFP growth and without demographics



Notes: Panel (a) plots the observed U.S. real exchange rate (solid red), the exchange rate with no wedges (solid blue), the exchange rate in the no-trade-wedge version of the analysis (dashed yellow), the exchange rate implied by the rest of the world's saving wedge in the baseline (solid green) and no-trade-wedge (dashed purple) versions of the analysis. Panel (b) presents a similar plot for the U.S. trade balance; both versions of the model match the trade balance data exactly, however, so there is one less line.

Figure 12: U.S. trade balance and real exchange rate dynamics without trade wedges