

# Trade Adjustment and the Composition of Trade\*

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## Abstract

A striking feature of U.S. trade is that both imports and exports are heavily concentrated in capital goods and consumer durables. However, most open economy general equilibrium models ignore the marked divergence between the composition of trade flows and the sectoral composition of U.S. expenditure, and simply posit import and exports as depending on an aggregate measure of real activity (such as domestic absorption). In this paper, we use a SDGE model (SIGMA) to show that taking account of the expenditure composition of U.S. trade in an empirically-realistic way yields implications for the responses of trade to shocks that are markedly different from those of a “standard” framework that abstracts from such compositional differences. Overall, our analysis suggests that investment shocks, originating from either foreign or domestic sources, may serve as an important catalyst for trade adjustment, while implying a minimal depreciation of the real exchange rate. Moreover, while policy changes that boost investment abroad could serve to significantly improve the U.S. trade balance through an export channel, reforms oriented at stimulating foreign consumption would exert less of a corrective force on the trade balance, and primarily work by restraining real U.S. imports.

*Keywords:* SDGE model, open-economy macroeconomics

*JEL Codes:*

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# 1 Introduction

A striking feature of U.S. trade is that both imports and exports are heavily concentrated in capital goods and consumer durables, with roughly three-quarters of U.S. non-fuel imports and exports appearing to fall into these categories. This contrasts with the relatively low production share of the capital goods and consumer durables sectors in the U.S. economy of under 20 percent. But despite the marked divergence between the composition of trade flows and the sectoral composition of U.S. production, most open economy models simply posit imports and exports as depending on an aggregate measure of activity such as real GDP or domestic absorption (as well as on relative prices).<sup>1</sup>

In this paper, we show that a modeling framework that takes account of the expenditure composition of U.S. trade in an empirically-realistic way yields implications for the responses of trade to shocks that are markedly different from those of a “standard” framework that abstracts from such compositional differences. Our methodology consists in contrasting the implications of alternative versions of an open economy SDGE model (“SIGMA”) that embed different trade specifications.<sup>2</sup> In the version adopting a commonly-used trade specification, the activity variable driving real imports is simply domestic absorption, while exports depend on foreign absorption. We refer to this version as the absorption-based trade (AT) specification. By contrast, our benchmark version of SIGMA posits separate behavioral equations for trade in non-durable consumer goods and for trade in investment goods, where the latter includes both consumer and producer durables (i.e., capital goods). These behavioral equations are derived from underlying production technologies for producing final consumer and investment goods that differ insofar as

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<sup>1</sup>Examples of studies that make imports depend on absorption are: Backus, Kehoe, and Kydland (1994), Chari, Kehoe, and McGrattan (2002), Laxton and Pesenti (2003).

<sup>2</sup>An extended description of the model and its properties with respect to a wide range of shocks is given in Erceg, Guerrieri, and Gust (2005).

they assume that the production of investment goods is much more import-intensive. We refer to this version as the disaggregated trade (DT) specification.

We examine the responses of each model variant to several domestic and foreign shocks. We show that the differences in implications across the alternative trade specifications are particularly large for shocks which exert disparate effects on consumption and investment spending either at home or abroad. Examples include shocks that affect the rate of return on investment (“investment shocks”), and preference shocks for consumption (“consumption shocks”). From an intuitive perspective, the activity variable driving imports and exports in the disaggregated trade specification weights consumption and investment by their share in trade, rather than by their share in production: this implies an effective weight on investment in the import and export demand functions that is several times larger than in the absorption-based trade specification.

A key result derived from our benchmark DI trade specification is that a shock that raises foreign investment by one percentage point of GDP has a much larger effect on the U.S. trade balance than a shock that boosts foreign consumption by one percentage point of GDP. Moreover, the foreign investment shock is associated with a larger export expansion, and much smaller depreciation of the real exchange rate. This contrasts sharply with the implications of the absorption-based trade model, in which the alternative shocks have broadly similar effects on the real exchange rate, the trade balance, and its components.

The reason why the foreign investment and consumption shocks have similar effects in the standard absorption-based trade model is that they have commensurate effects on foreign absorption; although the shocks have very different implications for the composition of absorption between investment and consumption, only total absorption matters for trade flows. Thus, each type of shock boosts U.S. exports significantly through its stimulative effect on foreign absorption, while causing U.S. imports to contract as higher world real interest rates reduce U.S. domestic absorp-

tion. By contrast, in our benchmark DT specification, the foreign investment shock induces a much larger improvement in real exports and the nominal trade balance than the foreign consumption shock. This is attributable to the very high effective weight of foreign investment spending in the U.S. export demand equation. The stronger export stimulus induces domestic real interest rates to rise by more than in the case of the foreign consumption shock, so that the real exchange rate depreciates much less in response to a foreign investment shock than to a foreign consumption shock. While either shock operates to improve the trade balance through a combination of “direct” export stimulus attributable to higher foreign activity, real exchange rate depreciation, and lower imports associated with higher real interest rates, the foreign investment shock generates much more direct stimulus to exports, and is consistent with only a slight deterioration of the real exchange rate.

We show that roughly similar results apply when the investment and consumption shocks emanate from the home rather than the foreign economy. Thus, our benchmark DT specification implies that a shock that raises domestic investment by one percentage point of GDP has a much larger effect on the trade balance than a shock that raises domestic consumption by the same fraction of GDP. This contrasts with the absorption-based trade specification, which implies again that the shocks have roughly commensurate effects on the real exchange rate and trade flows.

Overall, our analysis using a disaggregated trade specification suggests that investment shocks, originating from either foreign or domestic sources, may serve as an important catalyst for facilitating adjustment of the trade balance; moreover, a distinctive feature of this channel is that it may be consistent with a relatively stable exchange value of dollar. The prominent role that we identify for investment shocks in our analysis would seem to complement the interesting empirical work of Freund (2000) and Croke, Kamin, and Leduc (2005). These authors used an event study methodology examining a large number of historical episodes of trade adjustment in industrial countries, and found that trade adjustment has typically been

driven by a large decline in the rate of investment spending, while consumption rates have moved little. In a related vein, our results suggest that while policy changes or reforms that boost foreign investment could serve to significantly improve the U.S. trade balance through an export channel, reforms oriented at stimulating foreign consumption would exert less of a corrective effect on the trade balance, and primarily work by restraining U.S. real imports.

The remainder of this paper is organized as follows. Section 2 presents some stylized facts about the composition of U.S. imports and exports that motivate the trade structure adopted in our benchmark model. These facts are utilized subsequently in the calibration. Section 3 presents our SIGMA model, including the alternative trade specifications, while the calibration and solution methodology is discussed in Section 4. Section 5 contrasts model responses to an array of domestic and foreign shocks across the alternative trade specifications. Section 6 concludes.

## **2 The Composition of U.S. Trade**

Table 1 examines the composition of U.S. nonfuel imports in 2004. The underlying data used to construct the table is from the Bureau of Economic Analysis, although it has been reorganized to correspond more closely to the coarser disaggregation adopted in our theoretical model. In particular, nominal imports are divided into four categories, including consumer nondurable goods, consumer durables, capital goods, and non-energy industrial supplies utilized in producing durable goods (either for households or firms). The major components of the first three categories in Table 1 are derived fairly straightforwardly from the corresponding BEA data, aside from the estimate of non-energy industrial supplies used in producing nondurable consumer goods (item 1d). Our estimate of the latter category is derived by assuming that the share of imports of non-energy industrial goods that are used in producing consumer nondurables is equal to the share of consumer nondurables

in total manufacturing production (of about 40 percent).

The table suggests that nearly three-quarters of U.S. imports consist of either consumer or producer durable goods, or of industrial supplies used in manufacturing such goods. By contrast, only a little over 25 percent of U.S. imports consist of consumer non-durables (including raw materials). While our taxonomy for classifying imports is admittedly imperfect – for example, imports of consumer durables may be somewhat inflated due to extensive cross-border trade in automotive parts – it is unlikely that reasonable alternative breakdowns would markedly affect our results.

Table 2 reports a similar breakdown for U.S. nonfuel exports in 2004. Clearly, capital goods are a noticeably larger fraction of U.S. exports than of U.S. imports, while consumer durables are a somewhat smaller fraction of exports. But notwithstanding these differences, nearly three-quarters of U.S. exports consist of either consumer or producer durable goods, or of industrial supplies used in producing such goods – the same fraction as for U.S. imports. Thus, the composition of U.S. imports and exports is heavily oriented towards durable goods, which in our model we interpret broadly as investment goods.

### **3 The Model**

Our model consists of two countries that may differ in size, but are otherwise isomorphic. Hence, our exposition below focuses on the “home” country. Each country in effect produces a single domestic output good, although we adopt a standard monopolistically competitive framework to rationalize stickiness in the aggregate price level. While household utility depends on consumption of both the domestic output good and imported goods, it is convenient to assume that a competitive distribution sector purchases both inputs, and simply resells them to households.

The two trade specifications that we study differ in the way that the distribution sector combines home and foreign goods to produce final consumption and

investment goods. In our benchmark specification of SIGMA, there are two types of distributors, one for consumption and one for investment, because the technology for producing investment goods differs from that used to produce consumption goods (most noteworthy, the technology for the investment goods requires a higher import content than the technology for the consumption goods). By contrast, in the alternative, absorption-based (AT) trade specification, home and foreign goods are combined to produce a single final good that may be used for either consumption or investment.

### 3.1 Firms and Price Setting

*Production of Domestic Intermediate Goods.* There is a continuum of differentiated intermediate goods (indexed by  $i \in [0, 1]$ ) in the home country, each of which is produced by a single monopolistically competitive firm. As in Betts and Devereux (1996), intermediate goods firms charge different prices at home and abroad (i.e., they practice local currency pricing). In the home market, firm  $i$  faces a demand function that varies inversely with its output price  $P_{Dt}(i)$  and directly with aggregate demand at home  $Y_{Dt}$ :

$$Y_{Dt}(i) = \left[ \frac{P_{Dt}(i)}{P_{Dt}} \right]^{\frac{-(1+\theta_p)}{\theta_p}} Y_{Dt}, \quad (1)$$

where  $\theta_p > 0$ , and  $P_{Dt}$  is an aggregate price index defined below. Similarly, in the foreign market, firm  $i$  faces the demand function:

$$X_t(i) = \left[ \frac{P_{Mt}^*(i)}{P_{Mt}^*} \right]^{\frac{-(1+\theta_p)}{\theta_p}} M_t^*, \quad (2)$$

where  $X_t(i)$  denotes the foreign quantity demanded of home good  $i$ ,  $P_{Mt}^*(i)$  denotes the price that firm  $i$  sets in the foreign market (denominated in foreign currency),  $P_{Mt}^*$  is the foreign import price index, and  $M_t^*$  is aggregate foreign imports (we use an asterisk to denote foreign variables).

Each producer utilizes capital services  $K_t(i)$  and a labor index  $L_t(i)$  (defined below) to produce its respective output good. The production function is assumed

to have a constant-elasticity of substitution (CES) form:

$$Y_t(i) = \left( \omega_K^{\frac{\rho}{1+\rho}} K_t(i)^{\frac{1}{1+\rho}} + \omega_L^{\frac{\rho}{1+\rho}} (Z_t L_t(i))^{\frac{1}{1+\rho}} \right)^{1+\rho}. \quad (3)$$

The production function exhibits constant-returns-to-scale in both inputs, and technological progress  $Z_t$  is given by:

$$Z_t = \exp(g_z t + z_t), \quad (4)$$

where  $z_t$  is a country-specific shock to the level of technology and  $g_z$ , the deterministic rate of technological growth, is assumed to be the same in both countries. Firms face perfectly competitive factor markets for hiring capital and labor. Thus, each firm chooses  $K_t(i)$  and  $L_t(i)$ , taking as given both the rental price of capital  $R_{K_t}$  and the aggregate wage index  $W_t$  (defined below). Firms can costlessly adjust either factor of production. Thus, the standard static first-order conditions for cost minimization imply that all firms have identical marginal cost per unit of output,  $MC_t$ .

We assume that the home and foreign prices of the intermediate goods are determined by Calvo-style staggered contracts (see Calvo (1983)). In each period, a firm faces a constant probability,  $1 - \xi_p$ , of being able to reoptimize its price at home ( $P_{Dt}(i)$ ) and  $1 - \xi_{p,x}$  probability of being able to reoptimize its price abroad ( $P_{Mt}^*(i)$ ). These probabilities are assumed to be independent across firms, time, and countries. If a firm is not allowed to optimize its prices, we follow Christiano, Eichenbaum, and Evans (2001) and assume the firm must reset its home price based on lagged aggregate inflation. Prices are updated according to  $P_{Dt}(i) = \pi_{t-1} P_{Dt-1}(i)$  where  $\pi_t = P_{Dt}/P_{Dt-1}$ .<sup>3</sup> Similarly, in foreign markets, if a firm cannot reoptimize its price, the price is changed according to the rule,  $P_{Mt}^*(i) = \pi_{Mt-1}^* P_{Mt-1}^*(i)$  where

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<sup>3</sup>In alternative calibrations of SIGMA, we also consider the specification used by Yun (1996) and Erceg, Henderson, and Levin (2000) where  $P_{Dt}(i) = \pi P_{Dt-1}(i)$  so that  $V_{Dt+j} = \pi^j$  in the profit functional defined below. For this alternative calibration, prices are updated according to  $P_{Mt}(i) = \pi^* P_{Mt-1}(i)$  in foreign markets.



$\pi_{Mt}^* = P_{Mt}^*/P_{Mt-1}^*$ . This form of lagged indexation is a mechanism for introducing inflation inertia into the key price-setting equations.

*Production of the Domestic Output Index.* Because households have identical Dixit-Stiglitz preferences, it is convenient to assume that a representative aggregator combines the differentiated intermediate products into a composite home-produced good  $Y_{Dt}$ :

$$Y_{Dt} = \left[ \int_0^1 Y_{Dt}(i)^{\frac{1}{1+\theta_p}} di \right]^{1+\theta_p}. \quad (5)$$

The aggregator chooses the bundle of goods that minimizes the cost of producing  $Y_{Dt}$ , taking the price  $P_{Dt}(i)$  of each intermediate good  $Y_{Dt}(i)$  as given. The aggregator sells units of each sectoral output index at its unit cost  $P_{Dt}$ :

$$P_{Dt} = \left[ \int_0^1 P_{Dt}(i)^{\frac{-1}{\theta_p}} di \right]^{-\theta_p}. \quad (6)$$

We also assume a representative aggregator in the foreign economy who combines the differentiated home products  $X_t(i)$  into a single index for foreign imports:

$$M_t^* = \left[ \int_0^1 X_t(i)^{\frac{1}{1+\theta_p}} di \right]^{1+\theta_p}, \quad (7)$$

and sells  $M_t^*$  at price  $P_{Mt}^*$ :

$$P_{Mt}^* = \left[ \int_0^1 P_{Mt}^*(i)^{\frac{-1}{\theta_p}} di \right]^{-\theta_p}. \quad (8)$$

*Production of Consumption and Investment Goods.* We consider two alternative specifications for the production of consumption and investment goods. In our benchmark specification of SIGMA, there are different technologies for the production of final consumption and investment goods. Because this leads to a specification in which import demand for consumption purposes may differ from import demand for investment purposes, we call this the disaggregated (DT) trade specification. In our alternative specification, we assume that the technology for producing final consumption and investment goods is the same. We call this alternative the

absorption-based trade (AT) specification, because import demand depends on the sum of private consumption and investment (i.e., private absorption).

We begin by describing our benchmark version of the model which uses the DT specification. In this case, we assume that final consumption goods are produced by a representative consumption good distributor, and investment goods are produced by a representative investment goods distributor. Letting  $V_t \in \{C_t, I_t\}$  be the good each type of distributor produces, a representative distributor's production technology is given by:

$$V_t = \left( \omega_V^{\frac{\rho_V}{1+\rho_V}} V_{Dt}^{\frac{1}{1+\rho_V}} + (1 - \omega_V)^{\frac{\rho_V}{1+\rho_V}} (\varphi_{Vt} M_{Vt})^{\frac{1}{1+\rho_V}} \right)^{1+\rho_V}, \quad (9)$$

where  $V_{Dt} \in \{C_{Dt}, I_{Dt}\}$  is a distributor's demand for the index of domestically-produced goods,  $M_{Vt} \in \{M_{Ct}, M_{It}\}$  is a distributor's demand for the index of foreign-produced goods, and  $\rho_V$  is parameter determining the substitutability of home and foreign goods. The quasi-share parameter  $\omega_V$  may be interpreted as determining a household's preference for home relative to foreign goods, or equivalently the degree of home-bias in private consumption or investment. Because  $\omega_V$  can differ depending on whether the final good is a investment or consumption good, this specification allows the import-content of consumption and investment to differ. The term  $\varphi_{Vt}$  reflects a cost to adjusting imports, which are assumed to be quadratic:

$$\varphi_{Vt} = \left[ 1 - \frac{\varphi_{M_V}}{2} \left( \frac{\frac{M_{Vt}}{V_{Dt}}}{\frac{M_{Vt-1}}{V_{Dt-1}}} - 1 \right)^2 \right]. \quad (10)$$

This adjustment cost implies that it is costly to change the share of imports of consumer goods relative to domestically-produced consumer goods, or of imports of investment goods relative to domestically-produced investment goods. It has the attractive feature that the import share for either consumption or investment goods is relatively unresponsive in the short-run to changes in the relative price of imported goods, even while allowing the level of imports to jump costlessly in

response to changes in overall consumption or investment demand.<sup>4</sup> Thus, these adjustment costs influence the short-run elasticity of substitution between home and foreign goods. In steady state, these adjustment costs are zero and the elasticity of substitution between home and foreign goods is governed exclusively by  $\rho_V$ .

Given the presence of adjustment costs, each type of representative distributor chooses a contingency plan for  $V_{Dt}$  and  $M_{Vt}$  to minimize its discounted expected costs of producing the final good  $V_t \in \{C_t, I_t\}$ :

$$\begin{aligned} \min_{V_{Dt}, M_{Vt}} \quad & \tilde{\mathbb{E}}_t \sum_{k=0}^{\infty} \psi_{t,t+k} (P_{Dt+k} V_{Dt+k} + P_{Mt+k} M_{Vt+k}) \\ & + P_{Vt} \left[ V_t - \left( \omega_V^{\frac{\rho_V}{1+\rho_V}} V_{Dt}^{\frac{1}{1+\rho_V}} + (1 - \omega_V)^{\frac{\rho_V}{1+\rho_V}} (\varphi_{Vt} M_{Vt})^{\frac{1}{1+\rho_V}} \right)^{1+\rho_V} \right]. \end{aligned} \quad (11)$$

The distributor sells  $V_t$  to households at a price  $P_{Vt} \in \{P_{Ct}, P_{It}\}$  so that there is a different price for consumption and investment, reflecting the different technologies for aggregating these goods.

In the alternative AT specification, there is effectively only one final good ( $A_t$ ) that may be used for consumption or investment, (i.e.,  $A_t \equiv C_t + I_t$ , noting that  $A_t$  can be interpreted as private absorption). Accordingly, there is only one type of distributor which combines its purchases of the domestically-produced goods with imported goods to produce final goods  $A_t$  according to

$$A_t = \left( \omega_A^{\frac{\rho_A}{1+\rho_A}} A_{Dt}^{\frac{1}{1+\rho_A}} + (1 - \omega_A)^{\frac{\rho_A}{1+\rho_A}} (\varphi_{At} M_t)^{\frac{1}{1+\rho_A}} \right)^{1+\rho_A}, \quad (12)$$

where  $A_{Dt}$  denotes the distributor's demand for the domestically-produced good and  $M_t$  denotes the distributor's demand for imports. The quasi-share parameter  $\omega_A$  determines the degree of home bias in private absorption, and  $\rho_A$  determines the elasticity of substitution between home and foreign goods in the long run. In the

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<sup>4</sup>Hooper, Johnson, and Marquez (2000) find that the short-run trade price elasticity is significantly smaller than the long-run elasticity in their study using aggregate data. This is qualitatively consistent with the results of industry studies as surveyed by McDaniel and Balistreri (2003).

short run, this elasticity is lower, because we allow for adjustment costs  $\varphi_{At}$ :

$$\varphi_{At} = \left[ 1 - \frac{\varphi_{MA}}{2} \left( \frac{\frac{M_t}{A_{Dt}}}{\frac{M_{t-1}}{A_{Dt-1}}} - 1 \right)^2 \right]. \quad (13)$$

Note that the adjustment costs in this case depend on the ratio of total consumption to total absorption, rather than depending on each of the components of absorption separately.

Distributors of  $A_t$  solve an intertemporal cost minimization problem analogous to the consumption and investment distributors of the DT specification. The distributor sells its good to households at price  $P_{At}$  which may be interpreted as the price of consumption or investment, since in this case  $P_{At} = P_{Ct} = P_{It}$ .

### 3.2 Households and Wage Setting

We assume a continuum of monopolistically competitive households (indexed on the unit interval), each of which supplies a differentiated labor service to the intermediate goods-producing sector (the only producers demanding labor services in our framework). It is convenient to assume that a representative labor aggregator (or “employment agency”) combines households’ labor hours in the same proportions as firms would choose. Thus, the aggregator’s demand for each household’s labor is equal to the sum of firms’ demands. The aggregate labor index  $L_t$  has the Dixit-Stiglitz form:

$$L_t = \left[ \int_0^1 (\zeta_t N_t(h))^{\frac{1}{1+\theta_w}} dh \right]^{1+\theta_w}, \quad (14)$$

where  $\theta_w > 0$  and  $N_t(h)$  is hours worked by a typical member of household  $h$ . Also,  $\zeta_t$  is the size of a household of type  $h$  and evolves according to  $\zeta_t = g_n \zeta_{t-1}$  (effectively,  $\zeta_t$  and  $g_n$  determine the size and growth rate of the population). The aggregator minimizes the cost of producing a given amount of the aggregate labor index, taking each household’s wage rate  $W_t(h)$  as given, and then sells units of the

labor index to the production sector at their unit cost  $W_t$ :

$$W_t = \left[ \int_0^1 W_t(h)^{\frac{-1}{\theta_w}} dh \right]^{-\theta_w}. \quad (15)$$

It is natural to interpret  $W_t$  as the aggregate wage index. The aggregator's demand for the labor services of a typical member of household  $h$  is given by

$$N_t(h) = \left[ \frac{W_t(h)}{W_t} \right]^{-\frac{1+\theta_w}{\theta_w}} L_t / \zeta_t. \quad (16)$$

The utility functional of a representative member of household  $h$  is

$$\begin{aligned} \tilde{\mathbb{E}}_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma} \left( C_{t+j}(h) - \varkappa \frac{C_{t+j-1}}{\zeta_{t+j-1}} - \nu_{ct} \right)^{1-\sigma} + \right. \\ \left. \frac{\chi_0 Z_{t+j}^{1-\sigma}}{1-\chi} (1 - N_{t+j}(h))^{1-\chi} + \frac{\mu_0}{1-\mu} \left( \frac{MB_{t+j+1}(h)}{P_{C_{t+j}}} \right)^{1-\mu} \right\}, \quad (17) \end{aligned}$$

where the discount factor  $\beta$  satisfies  $0 < \beta < 1$ . As in Smets and Wouters (2003), we allow for the possibility of external habits, where each household member cares about its consumption relative to lagged aggregate consumption per capita. The period utility function depends on an each member's current leisure  $1 - N_t(h)$ , his end-of-period real money balances,  $\frac{MB_{t+1}(h)}{P_{C_t}}$ , and a preference shock,  $\nu_{ct}$ . We allow for preferences over leisure to shift with the level of technology so that the model is consistent with balanced growth, even if the subutility function over consumption is not logarithmic.<sup>5</sup>

We assume that there are two types of households: households that make intertemporal consumption, labor supply, and capital accumulation decisions in a forward-looking manner by maximizing utility subject to an intertemporal budget constraint (FL households, for "forward-looking"); and the remainder that simply

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<sup>5</sup>This statement is only strictly true in the absence of permanent country-specific technology shocks. In this case, a permanent increase in technology in the home country that does not occur abroad will be associated with a permanent deterioration in the home country's terms of trade that moves the home economy off its balanced growth path.

consume their after-tax disposable income (HM households, for “hand-to-mouth” households). The latter type receive no capital rental income or profits, and choose to set their wage to be the average wage of optimizing households. Given that households of each type grow at the same rate, the share of each type of household in the population is fixed. We denote the share of FL households by  $\varsigma$  and the share of HM households by  $1 - \varsigma$ .

We consider first the problem faced by FL households. Household  $h$  faces a flow budget constraint in period  $t$  which states that its combined expenditure on goods and on the net accumulation of financial assets must equal its disposable income:

$$\begin{aligned}
& P_{Ct}C_t(h) + P_{It}I_t(h) + MB_{t+1}(h) - g_n^{-1}MB_t(h) + \int_s \xi_{t,t+1}B_{Dt+1}(h) \\
& - g_n^{-1}B_{Dt}(h) + P_{Bt}B_{Gt+1} - g_n^{-1}B_{Gt} + \frac{e_t P_{Bt}^* B_{Ft+1}(h)}{\phi_{bt}} - g_n^{-1}e_t B_{Ft}(h) \\
& = (1 - \tau_{Nt})W_t(h)N_t(h) + \Gamma_t(h) + TR_t(h) - T_t(h) + (1 - \tau_{Kt})g_n^{-1}R_{Kt}K_t(h) + \\
& P_{It}\tau_{Kt}\delta g_n^{-1}K_t(h) - P_{Dt}\phi_{It}(h).
\end{aligned} \tag{18}$$

The presence of the population growth parameter  $g_n$  in the household’s budget constraint reflects that equation (18) is expressed in per capita terms as well as the assumption that new household members are born without any initial holdings of bonds, capital, or money. Final consumption goods are purchased at a price  $P_{Ct}$ , and final investment goods at a price  $P_{It}$ . Investment in physical capital augments the per capita capital stock  $K_{t+1}(h)$  according to a linear transition law of the form:

$$K_{t+1}(h) = (1 - \delta)g_n^{-1}K_t(h) + I_t(h), \tag{19}$$

where  $\delta$  is the depreciation rate of capital.

Financial asset accumulation of a typical member of FL household  $h$  consists of increases in nominal money holdings ( $MB_{t+1}(h) - g_n^{-1}MB_t(h)$ ) and the net acqui-

sition of bonds. We assume that agents within a country can engage in frictionless trading of a complete set of contingent claims, while trade in international assets is restricted to a non-state contingent nominal bond. The term  $P_{Bt}B_{Gt+1} - g_n^{-1}B_{Gt}$  represents each household member's net purchases of domestic government bonds, while  $\int_s \xi_{t,t+1}B_{Dt+1}(h) - g_n^{-1}B_{Dt}(h)$  are net purchases of state-contingent domestic bonds. We denote  $\xi_{t,t+1}$  as the price of an asset that will pay one unit of domestic currency in a particular state of nature at date  $t + 1$ , while  $B_{Dt+1}(h)$  represents the quantity of such claims purchased by a typical member of household  $h$  at time  $t$ . Thus, the gross outlay on new state-contingent domestic claims is given by integrating over all states at time  $t + 1$ , while  $B_{Dt}(h)$  indicates the value of the household's existing claims (on a per capita basis) given the realized state of nature.

In equation (18),  $B_{Ft+1}(h)$  represents the quantity of a non-state contingent bond purchased by a typical member of household  $h$  at time  $t$  that pays one unit of foreign currency in the subsequent period,  $P_{Bt}^*$  is the foreign currency price of the bond, and  $e_t$  is the exchange rate expressed in units of home currency per unit of foreign currency. We follow Turnovsky (1985) and assume there is an intermediation cost  $\phi_{bt}$  paid by households in the home country for purchases of foreign bonds, which ensures that net foreign assets are stationary in the model.<sup>6</sup> More specifically, the intermediation costs depend on the ratio of economy-wide holdings of net foreign assets to nominal output and are given by:

$$\phi_{bt} = \exp\left(-\phi_b\left(\frac{e_t B_{Ft+1}}{P_{Dt} Y_t}\right) + \nu_{bt}\right). \quad (20)$$

In the above,  $\nu_{bt}$  is a mean-zero stochastic process, which we interpret as a risk-premium shock or shock to the uncovered interest-rate parity condition. Abstracting from this shock, if the home economy has an overall net lender position internationally, then a household will earn a lower return on any holdings of foreign bonds. By contrast, if the economy has a net debtor position, a household will pay a higher

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<sup>6</sup>This intermediation cost is asymmetric, as foreign households do not face these costs. Rather, they collect profits on the monopoly rents associated with these intermediation costs.

return on any foreign debt.

Each member of FL household  $h$  earns after-tax labor income,  $(1 - \tau_{Nt})W_t(h) N_t(h)$ , where  $\tau_{Nt}$  is a stochastic tax on labor income. The household leases capital to firms at the after-tax rental rate  $(1 - \tau_{Kt})R_{Kt}$ , where  $\tau_{Kt}$  is a stochastic tax on capital income. The household receives a depreciation writeoff of  $P_{It}\tau_{Kt}\delta$  per unit of capital. Each member also receives an aliquot share  $\Gamma_t(h)$  of the profits of all firms and a lump-sum government transfer,  $TR_t(h)$  and pays a lump-sum tax  $T_t(h)$ . We follow Christiano, Eichenbaum, and Evans (2005) in assuming that households bear a cost of changing the level of gross investment from the previous period, so that the acceleration in the capital stock is penalized:

$$\phi_{I_t}(h) = \frac{1}{2}\phi_I \frac{(I_t(h) - g_z g_n I_{t-1}(h))^2}{I_{t-1}(h)}. \quad (21)$$

In every period  $t$ , each member of FL household  $h$  maximizes the utility functional (17) with respect to its consumption, investment, (end-of-period) capital stock, money balances, holdings of contingent claims, and holdings of foreign bonds, subject to its labor demand function (16), budget constraint (18), and transition equation for capital (19). In doing so, a household takes as given prices, taxes and transfers, and aggregate quantities such as lagged aggregate consumption and the aggregate net foreign asset position.

Forward-looking (FL) households set nominal wages in staggered contracts that are analogous to the price contracts described above. In particular, with probability  $1 - \xi_w$ , each member of a household is allowed to reoptimize its wage contract. If a household is not allowed to optimize its wage rate, we assume each household member resets its wage according to:

$$W_t(h) = \omega_{t-1}W_{t-1}(h), \quad (22)$$

where  $\omega_t = W_t/W_{t-1}$  and in steady state  $\omega = \pi g_z$ .<sup>7</sup> Each member of household  $h$  chooses the value of  $W_t(h)$  to maximize its utility functional (17).

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<sup>7</sup>In alternative specifications, we also consider  $W_t(h) = \omega W_{t-1}(h)$ .



Finally, we consider the determination of consumption and labor supply of the hand-to-mouth (HM) households. A typical member of a HM household simply equates his nominal consumption spending to his current after-tax disposable income, which consists of labor income plus net lump-sum transfers from the government:

$$P_{Ct}C_t(h) = (1 - \tau_{Nt})W_t(h)N_t(h) + TR_t(h) - T_t(h). \quad (23)$$

The HM households set their wage to be the average of the forward-looking households. Since HM households face the same labor demand schedule as the forward-looking households, each HM household works the same number of hours as the average for forward-looking households.

### 3.3 Monetary Policy

We assume that the central bank follows an interest rate reaction function similar in form to the historical rule estimated by Orphanides and Wieland (1998) over the Volcker-Greenspan period. Thus, the short-term nominal interest rate is adjusted so that the *ex post* real interest rate rises when inflation exceeds its constant target value, or when output *growth* rises above some target value. With some allowance for interest rate smoothing, monetary policy is described by the following interest rate reaction function:

$$i_t = \gamma_i i_{t-1} + \bar{r} + \bar{\pi}_t + \gamma_\pi (\pi_t^{(4)} - \bar{\pi}_t) + \gamma_y (y_t - y_{t-4} - g_y) + \epsilon_{it}. \quad (24)$$

In the above,  $i_t$  is the annualized nominal interest rate,  $\pi_t^{(4)}$  is the four-quarter inflation rate of the GDP deflator (i.e.,  $\pi_t^{(4)} = \sum_{j=0}^3 \pi_{t-j}$ ),  $\bar{r}$  and  $\bar{\pi}$  are the steady-state real interest rate and the central bank's constant inflation target (both expressed at annual rate). Also,  $y_t - y_{t-4}$  is the four-quarter growth rate of output, and  $g_y$  is its corresponding steady state value.

### 3.4 Fiscal Policy

Some of the domestically-produced good is purchased by the government. Government purchases ( $G_t$ ) are assumed to have no direct effect on the utility of a household.<sup>8</sup> We also assume that government purchases as a fraction of output,  $g_t = G_t/Y_t$ , follow an exogenous stochastic process.

The government can issue debt  $B_{Gt+1}$  to finance a deficit so that its budget constraint is given by:

$$P_{Bt}B_{Gt+1} - B_{Gt} = P_{Dt}G_t + TR_t - T_t - \tau_{Nt}W_tL_t - (\tau_{Kt}R_{Kt} - \delta P_{It})K_t - (MB_{t+1} - MB_t). \quad (25)$$

In equation (25), we have aggregated the capital stock, money and bond holdings, and transfers and taxes over all households so that, for example,  $T_t = \zeta_t \int_0^1 T_t(h)dh$ . As noted above, labor and capital taxes are determined exogenously, while we assume that real transfers as a fraction of domestic output,  $tr_t = \frac{TR_t}{P_{Dt}Y_t}$ , evolve according to a exogenous stochastic process. Given that the central bank uses the nominal interest rate as its policy instrument, the level of seignorage revenues are determined by nominal money demand.

Lump-sum taxes are adjusted in a manner that the government satisfies an intertemporal solvency constraint, requiring that the present discounted value of the government debt stock tends toward zero in the long run. In particular, we assume that the real lump-sum tax rate,  $\tau_t = \frac{T_t}{P_{Dt}Y_t}$ , is determined according to the following reaction function:

$$\tau_t = \nu_0\tau_{t-1} + \nu_1(b_{Gt+1} - b_G) + \nu_2(b_{Gt+1} - b_{Gt}), \quad (26)$$

where  $b_{Gt+1} = \frac{B_{Gt+1}}{P_{Dt}Y_t}$  and  $b_G$  is the government's target value for the ratio of government debt to nominal output.

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<sup>8</sup>We could have assumed instead that government purchases enter separably in the utility function. This would not alter the model's dynamics but would have different welfare consequences.

### 3.5 Resource Constraint and Net Foreign Assets

In the DT specification, the home economy's aggregate resource constraint can be written as:

$$Y_t = C_{Dt} + I_{Dt} + G_t + M_t^* + \phi_{It}, \quad (27)$$

where  $M_t^* = M_{Ct}^* + M_{It}^*$ ,  $\phi_{It}$  are the adjustment costs on capital and investment aggregated across all households, and  $G_t$  is government consumption. In the AT specification, the resource constraint assumes the slightly modified form:

$$Y_t = A_{Dt} + G_t + M_t^* + \phi_{It}, \quad (28)$$

recalling that  $A_{Dt}$  represents domestically-produced goods used as inputs into the production of final consumption and investment goods.

The evolution of net foreign assets can be expressed as:

$$\frac{e_t P_{B,t}^* B_{F,t+1}}{\phi_{bt}} = e_t B_{F,t} + e_t P_{Mt}^* M_t^* - P_{Mt} M_t. \quad (29)$$

This expression can be derived from the budget constraint of the FL households after imposing the government budget constraint, the consumption rule of the HM households, the definition of firm profits, and the condition that domestic bonds ( $B_{Dt+1}$ ) are in zero net supply.<sup>9</sup>

Finally, we assume that the structure of the foreign economy (the “rest of the world”) is isomorphic to that of the home country.

## 4 Solution Method and Calibration

Because the levels of technology and the population are non-stationary, real variables (including output and the expenditure components of GDP) are also non-stationary.

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<sup>9</sup>The derivation of the evolution of net foreign assets also requires that  $P_{Ct}C_t = P_{Dt}C_{Dt} + P_{Mt}M_{Ct}$  and  $P_{It}I_t = P_{Dt}I_{Dt} + P_{Mt}M_{It}$ . It is possible to show that these conditions are satisfied even in the presence of the adjustment costs on imported goods.

Accordingly, prior to solving the model, we scale real variables in the home country by the level of home technology  $Z_t$  and the population size,  $\zeta_t$ , and the real variables in the foreign country by  $\exp(g_z t)$  and  $\zeta_t^*$ . Nominal variables are scaled to account both for growth in the corresponding real variables, and for the steady state inflation rate. By construction, the model is stationary in the transformed variables provided that home and foreign economies have the same steady-state population and technological growth rates.

We solve the model by log-linearizing the equations (specified in terms of the transformed variables) around the steady state associated with common growth rates of technology and population in the two countries. To obtain the reduced-form solution of the model, we use the numerical algorithm of Anderson and Moore (1985), which provides an efficient implementation of the method proposed Blanchard and Kahn (1980).

## 4.1 Calibration of Parameters

The model is calibrated at a quarterly frequency. Structural parameters are set at identical values for each of the two countries, except for the parameters determining population size (as discussed below). We assume that the discount factor  $\beta = .997$  and the rate of technological growth  $g_z = 1.0037$ . These values are consistent with a steady-state annualized real interest rate  $\bar{r}$  of about 3 percent.

The utility functional parameter  $\sigma$  is set equal to 2, while the parameter determining the degree of habit persistence in consumption  $\varkappa = 0.8$ . We set  $\chi = 10$ , implying a Frisch elasticity of labor supply of  $1/5$ , which is considerably lower than if preferences were logarithmic in leisure, but well within the range of most empirical estimates. The utility parameter  $\chi_0$  is set so that employment comprises one-third of the household's time endowment, while the parameter  $\mu_0$  on the subutility function for real balances is set an arbitrarily low value (so that variation in real balances has a negligible impact on other variables). We choose  $\varsigma = 0.5$  so that 50 percent

of households are Ricardian FL agents and the rest are HM agents.

The depreciation rate of capital  $\delta = .025$  (consistent with an annual depreciation rate of 10 percent). The price and wage markup parameters  $\theta_p = \theta_w = 0.20$ , similar to the estimated values obtained by Rotemberg and Woodford (1998) and Amato and Laubach (2003). We set  $\xi_p$  and  $\xi_w$  to be consistent with four-quarter contracts (subject to full indexation). The parameter  $\xi_{p,x}$  is chosen to be consistent with two-quarter contracts. We set the steady state inflation rate  $\pi$  to yield an annual inflation rate of four percent.

The parameter  $\rho$  in the CES production function of the intermediate goods producers is set to -2, implying an elasticity of substitution between capital and labor of 1/2. Thus, capital and labor are less substitutable than the unitary elasticity case implied by the Cobb-Douglas specification. The quasi-capital share parameter  $\omega_K$  is chosen to imply a steady state investment to output ratio of 25 percent, reflecting our inclusion of consumer durables as part of investment. The private consumption to output ratio is 57 percent, while government consumption is 18 percent of steady state output. We set the cost of adjusting investment parameter  $\phi_I = 3$ , slightly below the value used by Christiano, Eichenbaum, and Evans (2001).

For both specifications of import demand, the steady-state ratio of aggregate imports to GDP is 0.12. In the AT specification we choose  $\omega_A = 0.15$  to be consistent with this import share. In the DT specification, we set  $\omega_C = 0.052$  and  $\omega_I = 0.36$ , so that roughly five percent of consumption goods and 36 percent of investment goods are comprised of imports. These choices for  $\omega_C$  and  $\omega_I$  are consistent with the evidence presented in Table 1. We choose the initial population levels  $\zeta_0$  and  $\zeta_0^*$  so that the home country constitutes about 25 percent of world output. This implied an import (or export) share of output of the foreign country of about 3 percent. Because the foreign country is assumed identical to the home country except in its size, in the AT specification,  $\omega_A^* = 0.05$ . In the DT specification we set  $\omega_C^* = 0.01$  and  $\omega_I^* = 0.07$  both consistent with the evidence presented in Table 2.

We assume that the trade-price elasticities of import demand are the same across the two specifications. In particular, we set  $\rho_C = \rho_I = \rho_A = 2$ , consistent with a long-run price elasticity of demand for imported consumption and investment goods of 1.5. While this is higher than most empirical estimates using macro data, we emphasize that the presence of adjustment costs translates into a much lower relative price sensitivity in the short to medium-term. In particular, we set the adjustment cost parameters  $\varphi_{MC} = \varphi_{MI} = \varphi_{MA} = 10$ , implying a price-elasticity near unity after four quarters. We choose a small value (0.001) for the financial intermediation cost  $\phi_b$ , which is necessary to ensure the model has a unique steady state.

We estimated the parameters of the monetary policy rule using U.S. data from 1983:1-2003:4.<sup>10</sup> Our estimates implied  $\gamma_\pi = 0.6$ ,  $\gamma_y = 0.28$ , and  $\gamma_i = 0.8$ . For the tax rate reaction function, we choose  $\nu_0 = 1$ ,  $\nu_1 = 0.1$ ,  $\nu_2 = 0.001$ , and  $b_G = 0.6$ . We set the steady state capital and labor tax rates equal to 0.3 and 0.2, respectively.

## 5 Simulations

### 5.1 A Foreign Investment Demand Shock

Figure 1 shows the effects of a rise in foreign investment demand under the two alternative trade specifications. The underlying shock is a highly persistent decline in the foreign capital income tax rate  $\tau_{Kt}^*$ , although it can be interpreted more broadly as a shock that boosts the expected rental rate on capital abroad.<sup>11</sup> For each trade specification, the shock is scaled so that the foreign investment rate at its maximum rises 1 percentage point above steady state.

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<sup>10</sup>We estimated the rule using instrumental variables with lags of inflation and output growth as instruments.

<sup>11</sup>As suggested by this broader interpretation, the simulations abstract from the direct effects of lower capital tax rates on government revenue (although this is inconsequential for our results, because the fiscal rule prescribes very slow adjustment of taxes to government debt).

We begin by focusing on the AT specification. To understand the channels through which the foreign investment shock affects the home economy, it is helpful to consider the log-linearized equation determining the home country's export demand (abstracting from adjustment costs for simplicity):

$$\tilde{X}_t = \tilde{M}_t^* = \tilde{A}_{Dt}^* - \frac{1 + \rho_A}{\rho_A} (\tilde{P}_{Mt}^* - \tilde{P}_t^*) \quad (30)$$

$$= \left(\frac{C^*}{A^*}\right) \tilde{C}_{Dt}^* + \left(\frac{I^{**}}{A^*}\right) \tilde{I}_{Dt}^* + \frac{1 + \rho_A}{\rho_A} (\tilde{P}_{Mt}^* - \tilde{P}_t^*), \quad (31)$$

where tildes indicate the logarithmic percentage deviation of a variable from steady state (steady state shares appear without time subscripts). As can be inferred from Equation 30, domestic real exports rise both due to a rise in foreign absorption ( $\tilde{A}_{Dt}^*$ ), and because home goods become relatively cheaper in the foreign market (i.e.,  $\tilde{P}_{Mt}^* - \tilde{P}_t^*$  declines). The relative price effect is driven by a decline in the home country's real exchange rate, reflecting that foreign real interest rates rise relative to domestic real interest rates.

Notwithstanding this change in interest rate spreads, domestic real interest rates rise as the export stimulus boosts domestic real GDP, and pushes up price inflation. Higher real rates in turn reduce domestic consumption and investment spending (with the decline in investment particularly pronounced, due to its greater interest sensitivity). Thus, real imports are depressed as the effects of weaker domestic absorption are reinforced by the real exchange rate decline (which raises import prices).

Given that pass-through of exchange rate changes to import prices is complete after a couple of quarters in our model, changes in the relative price of imports nearly coincide with the changes in the real exchange rate. With real imports falling 2.5 percent at their trough and the real exchange rate depreciating 1.5 percent over the same interval, nominal imports decline by only 1 percent. Hence, the improvement in the trade balance of about 0.5 percentage point of GDP is mostly explained by the 3 percent increase in real exports.

It is clear from Figure 1 that the qualitative effects of the foreign investment shock on the home country's trade and real exchange rate are identical under the DT specification (using essentially the same logic as described above). Thus, the interesting issue is to explain the larger quantitative effects on exports and the nominal trade balance under the DT specification, and also the somewhat smaller real exchange rate depreciation. To facilitate this comparison across specifications, it is useful to examine the log-linearized export demand function faced by the home economy under the DT specification:

$$\tilde{X}_t = \tilde{M}_t^* = \left(\frac{M_C^*}{M^*}\right) \tilde{M}_{Ct}^* + \left(\frac{M_I^*}{M^*}\right) \tilde{M}_{It}^* - \frac{1 + \rho_A}{\rho_A} \left(\tilde{P}_{Mt}^* - \tilde{P}_t^*\right) \quad (32)$$

$$= \left(\frac{M_C^*}{M^*}\right) \tilde{C}_{Dt}^* + \left(\frac{M_I^*}{M^*}\right) \tilde{I}_{Dt}^* - \frac{1 + \rho_A}{\rho_A} \left(\tilde{P}_{Mt}^* - \tilde{P}_t^*\right). \quad (33)$$

As seen in equation 33, the foreign activity variable relevant in determining domestic exports under the DT specification is an average of foreign consumption and investment that weights each component by its share in foreign imports (i.e., the foreign activity variable is associated with the first two terms in equation 33). This contrasts sharply with the foreign activity variable in the corresponding AT specification (equation 31), in which foreign consumption and investment are instead weighted by their share in foreign private absorption. Using our calibration, foreign investment receives a weight of 3/4 under the DT specification, which is more than three times the weight it receives under the AT specification.

Given that the underlying shock has much larger stimulative effects on foreign investment than foreign consumption (which actually declines slightly under either trade specification), the effects on home exports arising from the foreign activity channel are much larger under the DT specification.<sup>12</sup> This accounts for the larger export response shown in Figure 1. Interestingly, the greater export stimulus under

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<sup>12</sup>The foreign activity channel in either specification is identified with variables that shift the export demand function while holding relative prices constant, e.g. foreign absorption in the AT specification.



the DT specification coming from the activity channel is partly offset by a smaller depreciation of the real exchange rate. Because the foreign shock stimulates domestic external demand to a greater degree, domestic real interest rates rise by more under the DT specification. This reduces the magnitude of real depreciation of the home currency relative to the AT specification.

The larger export export improvement under the DT specification translates into a more substantial improvement in the nominal trade balance (of about 0.75 percentage point of GDP, relative to 0.5 percentage point under the AT specification). Thus, our DT specification implies that a foreign investment shock has a bigger effect on the domestic trade balance than the AT specification, even while generating a smaller depreciation of the domestic currency.

## 5.2 A Foreign Consumption Demand Shock

Figure 2 displays the effects of a foreign consumption demand shock under both trade specifications. This shock is modeled as a preference shift  $\nu_{ct}^*$  that has a highly persistent effect on the foreign marginal utility of consumption. The shock is scaled so that the ratio of foreign private consumption to output rises 1 percentage point above steady state at its peak.

Under the AT specification, the foreign consumption shock induces very similar effects on the home country as the foreign investment shock described above: in fact, the quantitative effects of each shock are nearly identical, as can be seen by comparing Figure 2 to Figure 1. The similar quantitative effects reflect that while the foreign consumption and investment shocks have disparate effects on the components of foreign absorption, they have nearly identical implications for total foreign absorption. Given that only total foreign absorption enters as the activity variable in the domestic export equation (equation 30 or 31), the stimulus to domestic exports arising from the foreign activity channel is nearly identical in response to either shock; as a consequence, the shocks have similar effects on the real exchange

rate, trade balance, and its components.

Returning to Figure 2, it is clear that the foreign consumption shock has considerably different effects under the DT specification than under the AT specification. In particular, real exports improve by less under the DT specification, real imports fall by more, and the real exchange rate exhibits a more pronounced depreciation. The divergence reflects that the direct stimulus to domestic exports arising from the foreign activity channel is virtually negligible under the DT specification. This is because the foreign consumption shock causes foreign investment to contract, and foreign investment has a high weight (of  $3/4$ ) in the foreign activity measure in the domestic export equation (recalling the discussion after equation 33). Thus, while the foreign activity measure in equation 31 rises 0.8 percent under the AT specification in response to the foreign consumption shock, it rises only 0.1 percent under the DT specification.

With a smaller "direct" stimulus to exports under the DT specification, the foreign consumption shock induces a smaller increase in domestic real interest rates, which in turn accounts for the larger depreciation of the real exchange rate apparent in Figure 2. Accordingly, even though the effects on the nominal trade balance are only slightly smaller under the DT specification, the adjustment of the components is quite different. In particular, the rise in exports under the DT specification is almost wholly attributable to real exchange rate depreciation (rather than stronger foreign activity, as under the AT specification), while the much deeper import contraction under the DT specification is also attributable to the larger exchange rate depreciation.

Finally, it is useful to explicitly compare the effects foreign investment and consumption shocks under the DT specification using Figures 1 and 2. While we have observed that these shocks have very similar effects under the AT specification, it is clear that under the DT specification that the foreign investment shock exerts a much larger effect on domestic real exports and the trade balance, while implying

much less exchange rate depreciation. As our analysis above indicates, this reflects that the foreign investment shock imparts a much larger external stimulus to the domestic economy through a direct activity channel than the foreign consumption shock.

### 5.3 A Domestic Investment Demand Shock

Figure 3 shows the effects of a fall in home investment demand under the two trade specifications. The underlying shock is a highly persistent decline in the domestic capital income tax rate  $\tau_{Kt}$ , and is scaled so that the investment rate decreases 1 percentage point below steady state at its trough.

Under the AT specification, the fall in investment demand induces a decrease in domestic real interest rates, stimulating consumption. With the increase in consumption only partially offsetting lower investment, domestic absorption falls, reducing domestic import demand. The effect of lower domestic absorption on imports is reinforced by a depreciation of the real exchange rate. The real exchange rate depreciation occurs because domestic real interest rates fall by more than foreign rates. Home exports rise both due to the real depreciation, and because foreign interest rate cuts (in response to weak external demand) stimulate foreign absorption.

While the qualitative implications of the shock are similar under the DT specification, there are substantial quantitative differences: notably, the contraction in real imports is much larger under the DT specification, and the trade balance improvement larger, despite a smaller depreciation of the real exchange rate. Reinterpreting equation 33 to apply to domestic imports, real imports fall by more under the DT specification because imports are mainly driven by variation in domestic investment (i.e., investment receives a weight of 3/4 in the activity variable affecting imports under the DT specification). Interestingly, because exports drop more sharply in the foreign economy under the DT specification, foreign interest rates fall by more than under the AT specification, which mainly accounts for the smaller depreciation of

the real exchange rate in the former case. Thus, as in the case of the foreign investment shock, more of the trade adjustment under the DT specification is attributable to an activity rather than to a relative price channel.

## 5.4 A Domestic Consumption Demand Shock

Figure 4 shows the response of key variables to a preference shock  $\nu_{ct}$  that temporarily reduces consumption as a share of GDP by 1 percentage point at its trough.

Under the AT specification, the consumption shock induces very similar quantitative effects on the home country as the investment shock just described. Both shocks have commensurate effects on total domestic absorption, which is the activity variable that drives imports in the AT specification; as a consequence, the shocks have nearly the same effects on the real exchange rate, trade balance, and its components.

The effects of the consumption shock under the DT specification are markedly different than under the AT specification, as the former implies a smaller contraction in imports, despite a noticeably larger exchange rate depreciation. The smaller import contraction reflects that the impetus from the activity measure in the domestic import equation is negligible, as domestic investment actually rises somewhat (and receives a high weight under the DT specification). The larger real exchange rate depreciation under the DT specification reflects a much sharper fall in domestic relative to foreign interest rates. Foreign interest rates fall less because the consumption shock exerts a less contractionary impact on foreign exports (which are heavily concentrated in investment goods under the DT specification). Thus, given that the foreign country fails to cushion the impact of the shock on the home country by lowering its interest rates as much as under the AT specification (which in that case boosts absorption abroad, and home exports), more of the adjustment must occur through real depreciation of the home currency.

In comparing the effects of domestic investment and consumption shocks under

the DT specification, it is clear that the investment shocks induce a significantly larger adjustment of the trade balance, exert larger effects on real imports, and are associated with much less exchange rate depreciation than consumption shocks. The larger effects reflect both that the home country's imports are heavily investment-intensive, and that domestic investment shocks exert comparatively larger effects on the foreign economy (which translates into larger foreign interest rate cuts, and more stimulus to domestic exports).

## **5.5 A Technology Shock**

Figure 5 shows the effects of a technology shock that boosts the level of real GDP by 1 percent in the long run. The effects of the shock are qualitatively similar under either trade specification. In particular, because the technology shock pushes up the marginal product of capital, investment increases faster than output. Consumption also rises, though much less than output due to the restraining effect of higher real interest rates. The rise in absorption boosts imports under either trade specification, and causes the trade balance to deteriorate. However, given that the shock has a disproportionately large effect on investment spending, imports exhibit a more pronounced rise under the DT specification, and the trade balance deterioration is somewhat larger.

## **5.6 A Persistent Rise in Foreign Activity**

We conclude with two simulations that involve simple dynamic extensions of the earlier experiments of one-time innovations to foreign investment and consumption. In particular, Figure 6 considers the effects of a sequence of foreign investment innovations that gradually raises the foreign investment share by 1.5 percentage points above baseline (the foreign investment innovations are identified with negative innovations to the foreign capital tax rate, as described in the first simulation). The 1.5 percentage point rise in the investment rate is calibrated to reverse the

estimated decline in the investment rate that has occurred in major U.S. OECD trading partners since the late 1990s. We compare the implications of a rise in foreign investment of this magnitude to the effects that would arise if the foreign consumption rate increased by a similar percentage of GDP. Both simulations are conducted using our preferred DT specification.

As suggested by our analysis of the foreign investment and consumption shocks above, the foreign investment shock exerts a considerably larger effect on the U.S. trade balance than the foreign consumption shock, even while implying a much smaller depreciation of the real exchange rate. Thus, while the trade balance improves by nearly 1.0 percentage point of GDP after 5 years and the real exchange rate depreciates less than one percent, the trade balance improves only 0.6 percentage point in response to the foreign consumption shock, while the real exchange rate depreciates over 4 percent. Moreover, while the foreign investment shock induces a sizeable response of real exports and comparatively small import contraction, the foreign consumption shock is associated with a much weaker rise in exports, and larger import decline.

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Table 1: **Composition of U.S. Non-energy Imports in 2004**

	Billions of \$US	Percent of imports
<b>TOTAL NON-ENERGY IMPORTS</b>	<b>1209</b>	<b>100</b>
<b>1. Consumer Nondurable Goods</b>	<b>335</b>	<b>28</b>
a. Foods, feeds, beverages	62	
b. Manufactured consumer goods	174	
c. Nonmanufactured consumer goods	18	
d. Non-energy industrial supplies used in nondurable consumer goods	81	
<b>2. Consumer Durable Goods</b>	<b>389</b>	<b>32</b>
a. Automotive less trucks, buses	208	
b. Manufactured durables	181	
<b>3. Capital Goods</b>	<b>364</b>	<b>30</b>
a. Non-auto capital goods	343	
b. Trucks, buses, etc.	21	
<b>4. Non-energy industrial supplies used in producing durables</b>	<b>121</b>	<b>10</b>

Table 2: Composition of U.S. Non-energy Exports in 2004

	Billions of \$US	Percent of exports
<b>TOTAL NON-ENERGY EXPORTS</b>	<b>759</b>	<b>100</b>
<b>1. Consumer Nondurable Goods</b>	<b>186</b>	<b>25</b>
a. Foods, feeds, beverages	57	
b. Manufactured consumer goods	49	
c. Nonmanufactured consumer goods	8	
d. Non-energy industrial supplies used in nondurable consumer goods	72	
<b>2. Consumer Durable Goods</b>	<b>123</b>	<b>16</b>
a. Automotive less trucks, buses	77	
b. Manufactured durables	46	
<b>3. Capital Goods</b>	<b>343</b>	<b>45</b>
a. Non-auto capital goods	331	
b. Trucks, buses, etc.	12	
<b>4. Non-energy industrial supplies used in producing durables</b>	<b>107</b>	<b>14</b>

Figure 1: A Foreign Investment Demand Shock

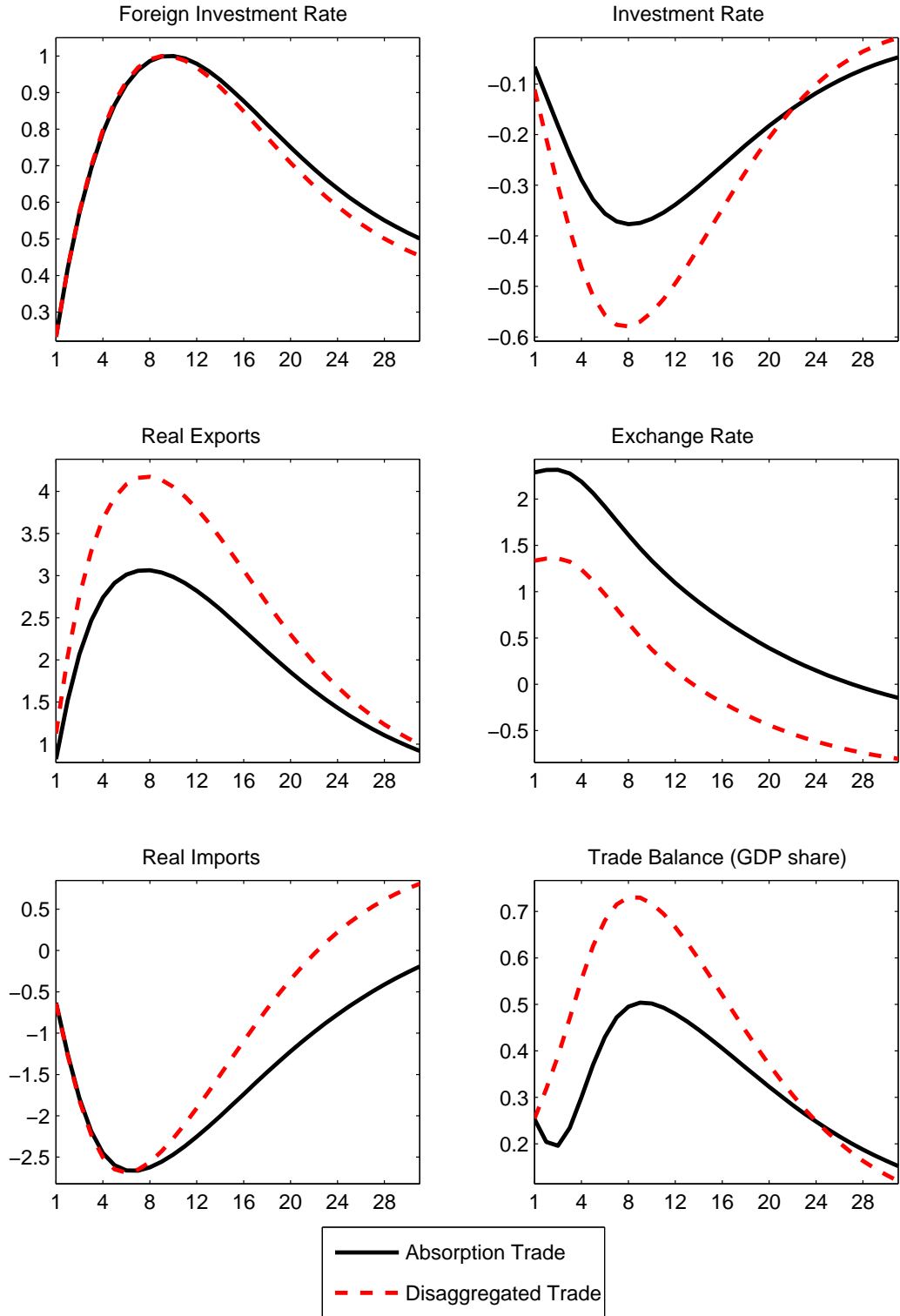


Figure 2: A Foreign Consumption Demand Shock

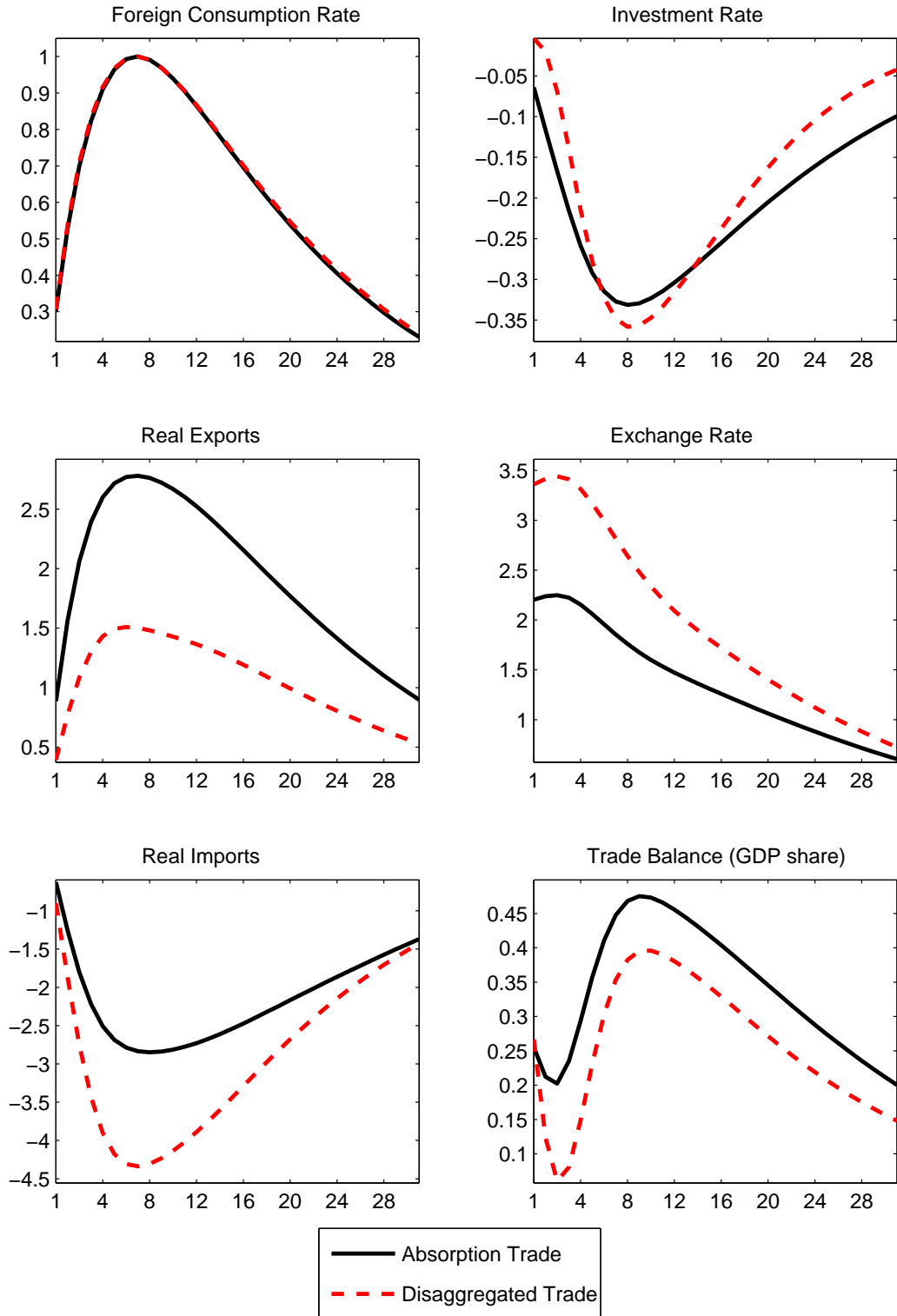


Figure 3: A Domestic Investment Demand Shock

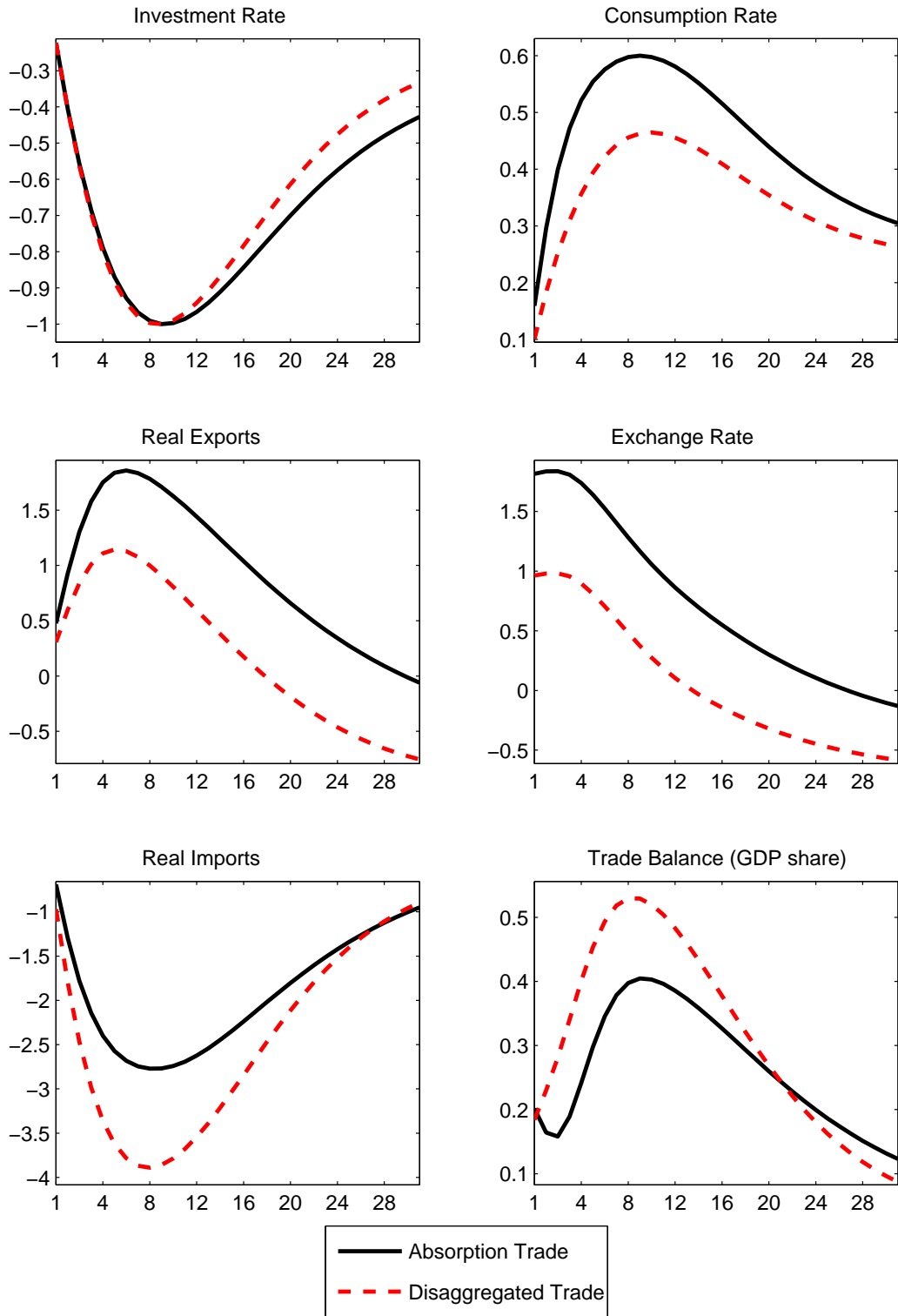


Figure 4: A Domestic Consumption Demand Shock

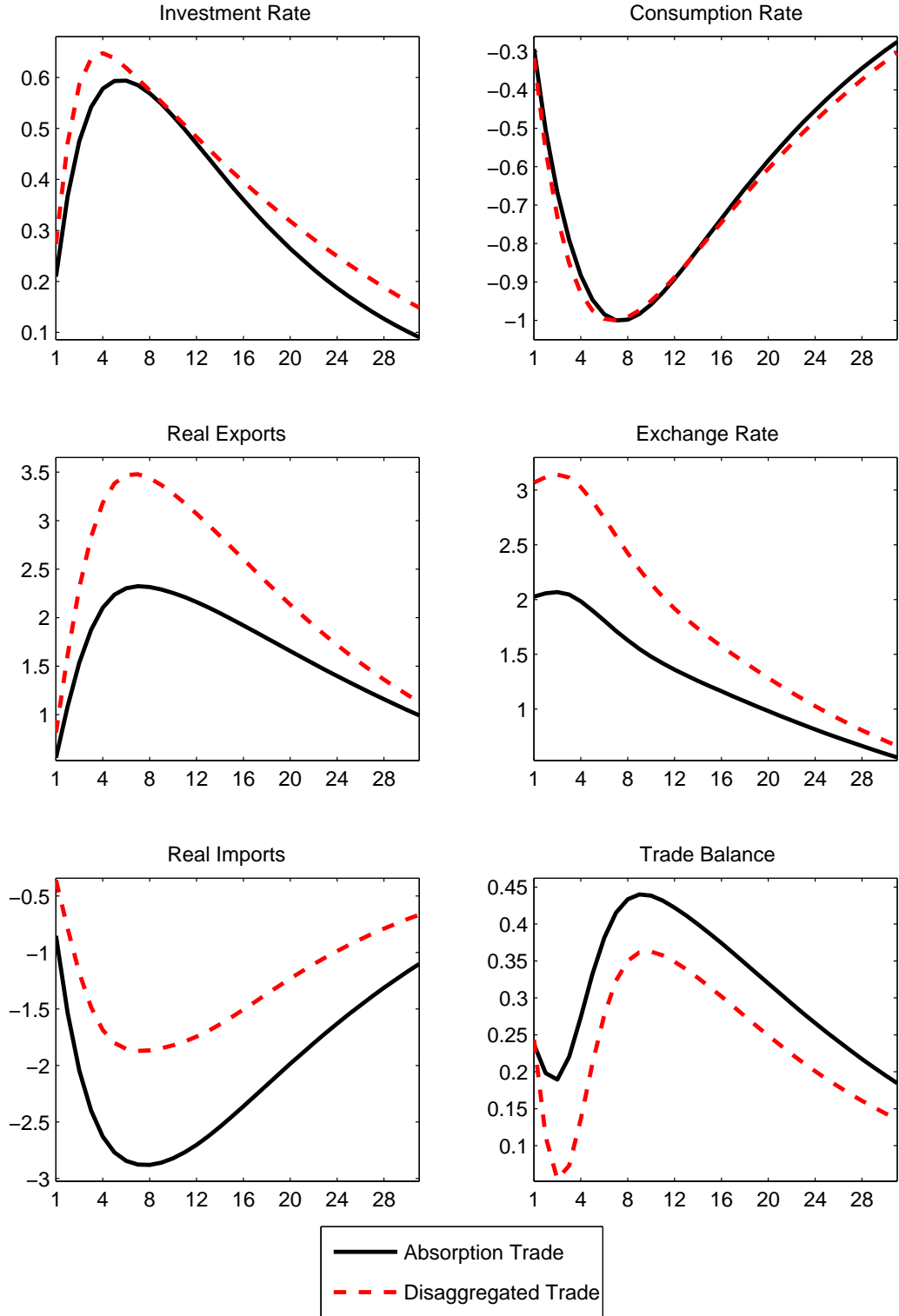


Figure 5: A Technology Shock that Boosts Real GDP by 1% in the Long Run

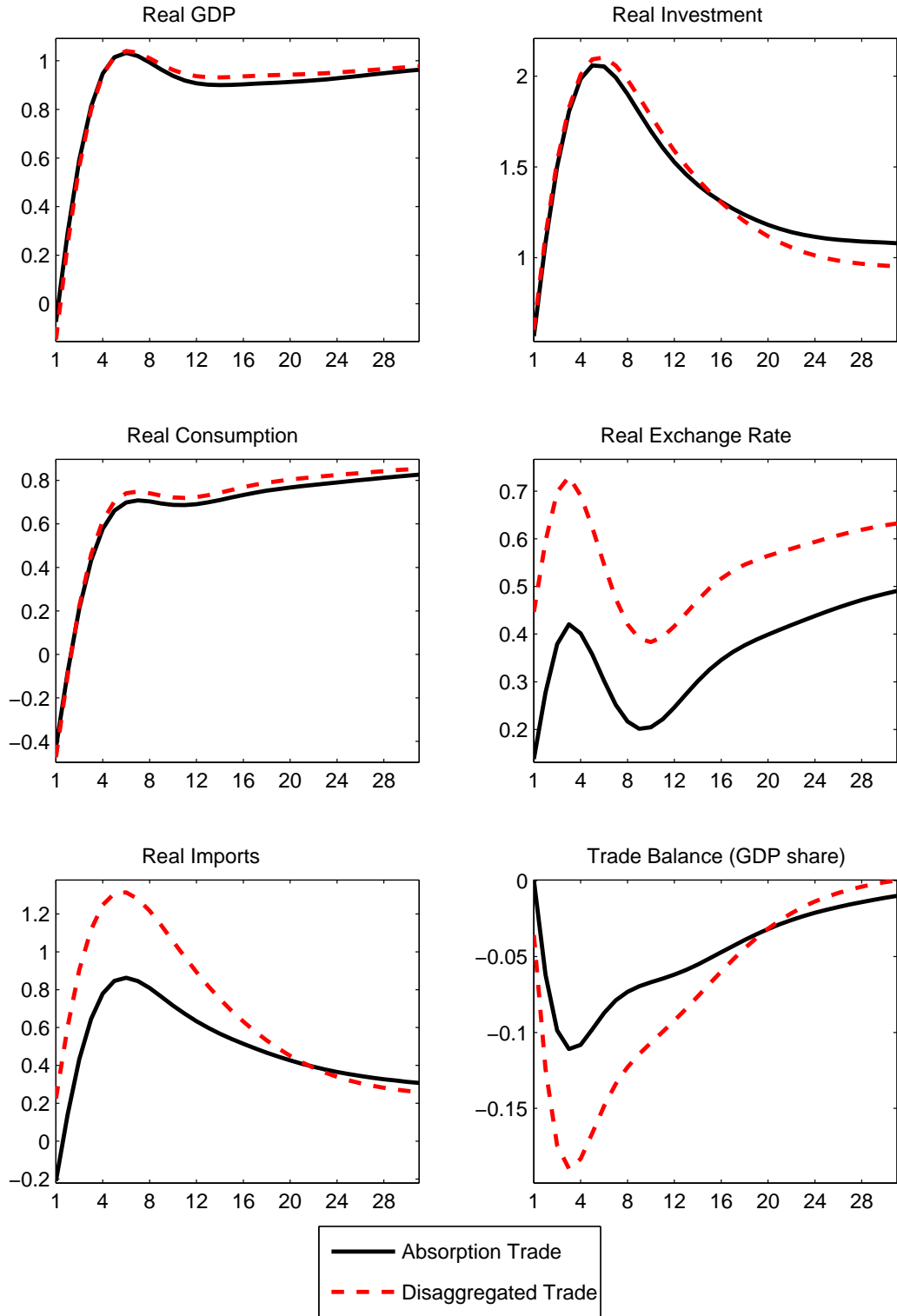


Figure 6: A Persistent Increase in Foreign Demand (Disaggregated Trade Specification)

