Pricing to Habits and the Law of One Price

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A long-standing puzzle in open economy macroeconomics is the fact that prices of the same good across countries, expressed in the same currency, differ widely and persistently over the business cycle. The observed deviations from the law of one price hold even for individual goods that are actively traded internationally, and even in the absence of tariffs or quotas (see Pinelopi K. Goldberg and Michael M. Knetter 1997; and Mario J. Crucini and Mototsugu Shintani 2006).

In this paper, we propose a novel approach to explaining the observed violations in the law of one price. We embed the deep habit mechanism due to Ravn, Schmitt-Grohé, and Uribe (2006a) into a two-country dynamic general equilibrium model. We show that when habits are formed at the level of individual goods, as opposed to at the level of aggregate consumption goods, firms have an incentive to lower markups in markets where aggregate demand is strong and to raise markups in markets where demand is weak. In equilibrium, firms price discriminate across markets exhibiting different ratios of current to habitual demand. We refer to this type of price discrimination as pricing to habits. Our pricing-to-habit formulation is in the tradition of models displaying pricing to market due to customer switching costs, as in Kenneth A. Froot and Paul D. Klemperer (1989).

Under pricing to habits, an expansionary domestic demand shock induces a decline in prices in the domestic country but not abroad, leading to a departure from the law of one price. In addition, the pricing-to-habit mechanism gives rise to two important predictions. Namely, in response to a positive domestic demand shock, the real exchange rate, defined as the ratio of foreign to domestic CPI indices expressed in the same currency, depreciates and private consumption expands. These predictions of the pricing-to-habit model are consistent with recent empirical evidence on the effects of government expenditure shocks on international relative prices and aggregate demand (e.g., Tommaso Monacelli and Roberto Perotti 2006).

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I. A Two-Country Model with Deep Habits

The economy consists of two countries: the home country and the foreign country. Each country specializes in the production of a set of differentiated goods. We denote the set of goods produced by the home country by a, and the set of goods produced by the foreign country by b. All goods are internationally traded. To emphasize the transmission mechanism invoked by deep habits, we abstract from a number of important frictions that are common elements of the related literature, such as sticky prices and wages, distribution costs, nontraded goods, rule-of-thumb consumers, nonseparabilities of preferences across consumption and leisure, incomplete international asset markets, tariffs, quotas, and other trade barriers. In what follows, we keep the presentation of the model and the characterization of equilibrium concise. A separate Technical Appendix (Ravn, Schmitt-Grohé, and Uribe 2006b) contains a detailed derivation.

We describe the household problem in the domestic economy. The foreign counterpart is a mirror image. The domestic economy is populated by a large number of identical households with preferences defined over consumption of a composite good, x_t, and labor effort, h_t, and described by the utility function $E_0 \sum_{t=0}^{\infty} \beta^t [\phi \ln(x_t) + (1 - \phi)\ln(1 - h_t)]$, with $\phi \in (0, 1)$. The variable x_t is a composite defined as $x_t = \left[\omega x_{a,t}^{c\ 1-1/\xi} + (1 - \omega) x_{b,t}^{c\ 1-1/\xi}\right]^{1/(1-1/\xi)}$, where $\omega \in (0, 1)$ and $\xi > 0$. The variable $x_{a,t}^c$ denotes a habit-adjusted composite consumption good of varieties of goods of type a. The variable $x_{b,t}^c$ denotes a habit-adjusted composite consumption good of varieties of goods of type b.

Following Ravn, Schmitt-Grohé, and Uribe (2006a), we introduce deep habits. Specifically, we assume that habits form at the level of each individual variety of goods instead of at the level of the aggregate consumption good. Habits are external to the individual household (i.e., we model catching up with the Joneses good by good). Formally, $x^c_{a,t}$ is given by $x^c_{a,t} = \left[\int_0^1 (c_{i,a,t} - \theta s^c_{i,a,t-1})^{1-1/\eta}\, di\right]^{1/(1-1/\eta)}$. Here, $c_{i,a,t}$ denotes consumption of variety i of goods belonging to the set a in period t. The variable $s^c_{i,a,t}$ denotes the stock of external habit in consumption of variety i of good a. This habit stock is assumed to evolve according to the following law of motion—$s^c_{i,a,t} = \rho s^c_{i,a,t-1} + (1 - \rho)\tilde{c}_{i,a,t}$,—where $\tilde{c}_{i,a,t}$ denotes the average per capita consumption of variety i of good a in the domestic country. That is, $\tilde{c}_{i,a,t}$ is the integral of $c_{i,a,t}$ over all domestic households. The parameter $\theta \in [0, 1)$ measures the intensity of deep external habits. When θ is equal to zero, preferences display no deep habit formation. The parameter $\eta > 0$ represents the intratemporal elasticity of substitution across varieties, and the parameter $1 - \rho \in (0, 1]$ denotes the rate at which the stock of external habits depreciates over time. Similarly, $x^c_{b,t}$ is given by $x^c_{b,t} = \left[\int_0^1 (c_{i,b,t} - \theta s^c_{i,b,t-1})^{1-1/\eta}\, di\right]^{1/(1-1/\eta)}$, with $s^c_{i,b,t} = \rho s^c_{i,b,t-1} + (1 - \rho)\tilde{c}_{i,b,t}$. For simplicity, we assume that the deep-habit parameter θ is common across varieties and types of goods.

It can be shown that this preference structure implies the following demand functions for individual varieties of goods $c_{i,a,t} = (P_{i,a,t}/P_{a,t})^{-\eta} x^c_{a,t} + \theta s^c_{i,a,t-1}$ and $c_{i,b,t} = (P_{i,b,t}/P_{b,t})^{-\eta} x^c_{b,t} + \theta s^c_{i,b,t-1}$, where $P_{a,t}$ and $P_{b,t}$ are defined by $P_{a,t} = \left[\int_0^1 (P_{j,a,t})^{1-\eta}\, dj\right]^{1/(1-\eta)}$ and $P_{b,t} = \left[\int_0^1 (P_{j,b,t})^{1-\eta}\, dj\right]^{1/(1-\eta)}$, respectively. Note that the demand for each variety of good a, say, is decreasing in its relative price, $P_{i,a,t}/P_{a,t}$, increasing in the level of habit-adjusted consumption of the composite good of type a, $x^c_{a,t}$, and increasing in the stock of habit of the variety in question $s^c_{i,a,t-1}$.

We assume that real government expenditures, denoted by g_t, are exogenous and stochastic and follow a univariate first-order autoregressive process of the form $\ln(g_t/\bar{g}) = \rho_g \ln(g_{t-1}/\bar{g}) + \varepsilon^g_t$, where the innovation ε^g_t distributes i.i.d. with mean zero and standard deviation σ_{ε^g}. Public spending is financed by lump-sum taxation. The government aggregates individual varieties of domestic and foreign goods to produce two intermediate composite goods denoted $x^g_{a,t}$ and $x^g_{b,t}$, using the same aggregator function as the private sector. Like households, the government forms habits on consumption of individual varieties of goods. This assumption is important for understanding the transmission of government purchase shocks in the context of our model. It is less important in driving the transmission of other types of demand disturbances, such as preference shocks. We motivate the deep-habit formulation in public spending by assuming that private households value public goods in a way that is separable from private consumption and leisure, and that households derive habits from consumption of government-provided goods. Alternatively, one can assume that the government forms procurement relationships that create a tendency for it to favor transactions with sellers that supplied public goods in the past. We treat government habits as external. Conceivably, government habits could be treated as internal to the government even if they are external to their beneficiaries, namely households. This alternative is, however, less tractable, and is therefore not pursued here.

The public demand functions for individual varieties of goods a and b are of the form $g_{i,a,t} = (P_{i,a,t}/P_{a,t})^{-\eta} x^g_{a,t} + \theta s^g_{i,a,t-1}$ and $g_{i,b,t} = (P_{i,b,t}/P_{b,t})^{-\eta} x^g_{b,t} + \theta s^g_{i,b,t-1}$.

Each individual variety of goods (of type a or b) is assumed to be produced by a monopolist. Each good $i \in (0, 1)$ is manufactured using labor as the sole input with a linear production technology, $y_{i,a,t} = h_{i,a,t}$, where $y_{i,a,t}$ denotes output of variety i of good a in period t, and $h_{i,a,t}$ denotes labor input in producing variety i of good a.

The demand function faced by the producer of variety i of good a has a domestic and a foreign component given by:

$$d_{i,a,t} = \left(\frac{P_{i,a,t}}{P_{a,t}}\right)^{-\eta} x_{a,t} + \theta s_{i,a,t-1},$$

and

$$d^*_{i,a,t} = \left(\frac{P^*_{i,a,t}}{P^*_{a,t}}\right)^{-\eta} x^*_{a,t} + \theta s^*_{i,a,t-1},$$

respectively, where $d_{i,a,t} \equiv c_{i,a,t} + g_{i,a,t}$ and $d^*_{i,a,t} \equiv c^*_{i,a,t} + g^*_{i,a,t}$ denote the domestic and

foreign aggregate demands for variety i of good a in period t, respectively. The variables $s_{i,a,t} \equiv s^c_{i,a,t} + s^g_{i,a,t}$ and $s^*_{i,a,t} \equiv s^{c^*}_{i,a,t} + s^{g^*}_{i,a,t}$ denote the domestic and foreign aggregate stocks of habit for variety i of good a, respectively. And the variables $x_{a,t} = x^c_{a,t} + x^g_{a,t}$, and $x^*_{a,t} = x^{c^*}_{a,t} + x^{g^*}_{a,t}$ denote domestic and foreign measures of habit-adjusted aggregate demands for the composite good a in period t, respectively.

A number of important implications for the model's predictions regarding deviations from the law of one price are evident from inspection of the demand functions above. First, the demand function for an individual variety of goods is the sum of a price-elastic component and a price-inelastic component. The price-elastic component has price elasticity η and is proportional to a measure of current aggregate demand ($x_{a,t}$ in the domestic market and $x^*_{a,t}$ in the foreign market). The price-inelastic term is purely habitual in nature. It follows that the price elasticity of demand is a weighted average of η and 0, with the weight on η given by the relative importance of the price-elastic, non-habitual demand component in total demand. An increase in aggregate demand enlarges the importance of the price elastic component of demand increasing the price elasticity. In other words, the price elasticity of demand is procyclical. Second, the fact that the price elasticity is procyclical opens the possibility for markups to move countercyclically in equilibrium. Third, because the price elasticity of demand can, in principle, be different in the domestic and the foreign markets, it follows that firms have an incentive to charge different markups (via price discrimination) domestically and abroad. We refer to this incentive for price discrimination as "pricing to habits," as it originates from the presence of a habitual demand for individual varieties of goods. More importantly, pricing to habits gives rise to deviations from the law of one price over the business cycle at the level of individual goods traded across borders. Finally, because firms understand that the stock of habit is a weighted average of all past sales, their profit-maximization problem is dynamic in nature. Thus, customer-market and brand-switching cost considerations in the spirit of Edmund S. Phelps and Sidney G. Winter (1970) and Froot and Klemperer (1989) will endogenously emerge in the pricing behavior of firms, affecting the size and persistence of deviations from the law of one price.

II. Deviations from the Law of One Price

In a symmetric equilibrium, all firms producing varieties of good a for the domestic market will charge the same price. That is, $P_{i,a,t} = P_{a,t}$ for all i. Similarly, all firms producing varieties of good a for the foreign market will charge the same price, or $P^*_{i,a,t} = P^*_{a,t}$ for all i. The same will be true for foreign firms producing good b, that is, $P_{i,b,t} = P_{b,t}$ and $P^*_{i,b,t} = P^*_{b,t}$ for all i.

We now examine a few equilibrium conditions that are insightful for communicating the potential of the pricing-to-habit theory to predict persistent and volatile deviations from the law of one price in international goods markets. For the complete set of equilibrium conditions, see Ravn, Schmitt-Grohé, and Uribe (2006b). To simplify the exposition, we consider the case in which all stocks of habit depreciate completely after one period ($\rho = 0$).

In equilibrium, the markup of price over marginal cost charged on varieties of good a in the domestic market, which we denote by $\mu_{a,t}$, must satisfy

$$\mu_{a,t} = \left[1 - \frac{1}{\eta(1 - \theta d_{a,t-1}/d_{a,t})} + \theta \Omega_{a,t}\right]^{-1},$$

where $\Omega_{a,t}$ is the present discounted value of a sale in the domestic market in period $t + 1$. Note that in the absence of deep habits ($\theta = 0$), the markup is constant and equal to $1/(1 - 1/\eta)$. Under deep habits, the markup falls in response to expansions in aggregate demand for good a, $d_{a,t}/d_{a,t-1}$. This is the price elasticity effect of deep habits, originating from the fact that when demand increases, the relative importance of the price-inelastic (or habitual) component of demand falls. In addition, the markup is decreasing in the present discounted value of a future sale, $\Omega_{a,t}$. This is the intertemporal effect of deep habits explained in detail in Ravn, Schmitt-Grohé, and Uribe (2006a). When the present value of a future sale increases, it pays for the firm to invest in market share today by lowering current markups.

In the foreign market for good a , domestic firms charge a markup $\mu^*_{a,t}$ given by:

$$\mu^*_{a,t} = \left[1 - \frac{1}{\eta(1 - \theta d^*_{a,t-1}/d^*_{a,t})} + \theta\Omega^*_{a,t}\right]^{-1}.$$

Comparing the expressions for the domestic and foreign markups for good a conveys intuition for the central result of this paper, namely, that pricing to habits can lead to deviations from the law of one price over the business cycle. In effect, any disturbance that produces an asymmetric response in aggregate demand across countries (i.e., any disturbance that produces variations in $d_{a,t-1}/d_{a,t}$ relative to $d^*_{a,t-1}/d^*_{a,t}$) will induce divergence in prices for the same good across countries. In the same way, shocks that affect the present value of future sales asymmetrically across countries will bring about deviations from the law of one price for individual goods.

Given that the marginal cost of producing variety i of good a is the same regardless of whether the good is sold in the domestic or the foreign market, the ratio of foreign to domestic markups for a particular good equals the real exchange rate for that particular good. Formally, letting $e_{a,t} \equiv P^*_{a,t}/P_{a,t}$ denote the real exchange rate for goods of type a, we have that $e_{a,t} = \mu^*_{a,t}/\mu_{a,t}$. It follows from this expression that, to the extent that it can predict cyclical differences in markups across countries, the pricing-to-habit theory will succeed in generating cyclical deviations from the law of one price.

III. International Adjustment to Demand Shocks

To illustrate the role of the pricing-to-habit mechanism in propagating aggregate shocks, we study the equilibrium response of our model economy to an innovation in domestic government purchases. The reason for our focus on the effects of demand shocks is twofold. First, a fast-growing empirical literature argues that demand shocks are a major source of business-cycle fluctuations in the United States and Europe (see Jordi Galí and Pau Rabanal 2005). Second, recent empirical work has estimated the international transmission of a particular identified demand shock, namely innovations in government purchases (see Monacelli and Perotti 2006, and references cited therein), providing a benchmark to gauge the qualitative success of our model.

We calibrate the model as follows: $\beta = 0.99$, $\phi = 0.15$, $\omega = 0.75$, $\xi = 1.5$, $\eta = 6$, $\theta = 0.6$, $\rho = 0.85$, $\overline{g} = 0.0622$, and $\rho_g = 0.87$. We note that if the habit parameter θ is set close to unity, equilibria in which expectations are self-fulfilling may arise. We provide more discussion on calibration in the expanded version of this paper (Ravn, Schmitt-Grohé, and Uribe 2006b).

Figure 1 shows impulse response functions to a 1 percent increase in domestic government spending. The model displays significant pricing to habits. In effect, as shown in the top two panels of the figure, domestic markups on both domestically and foreign produced goods ($\mu_{a,t}$ and $\mu_{b,t}$) fall, whereas foreign markups on both goods ($\mu^*_{a,t}$ and $\mu^*_{b,t}$) increase. The difference in markup movements across borders is due to the fact that aggregate demand in the home country, where the innovation in public spending originates, increases, whereas aggregate demand in the foreign country contracts slightly.

The asymmetric response of markups for the same type of good across countries, together with the fact that all goods of the same variety are produced at the same marginal cost, independently of their final destination, implies that prices in the domestic country fall relative to prices abroad. That is, the government spending shock triggers deviations from the law of one price across all goods. The panels in the second row of Figure 1 show that the good-specific real exchange rates ($e_{a,t} \equiv P^*_{a,t}/P_{a,t}$ and $e_{b,t} \equiv P^*_{b,t}/P_{b,t}$) depreciate, indicating that both types of goods become relatively cheaper domestically than abroad.

The generalized fall in domestic prices (of both importable and exportable goods) leads to a depreciation of the CPI real exchange rate denoted $e_t \equiv P^*_t/P_t$, where $P_t \equiv \gamma P_{a.t} + (1 - \gamma)P_{b,t}$ and $P^*_t \equiv (1 - \gamma)P^*_{a,t} + \gamma P^*_{b,t}$ denote, respectively, the domestic and foreign consumer price indices, and where γ denotes the steady-state share of domestic absorption of good a in total domestic absorption. (See Ravn, Schmitt-Grohé, and Uribe 2006b for more detail on the construction of consumer price indices under deep habits.) The left panel in the third

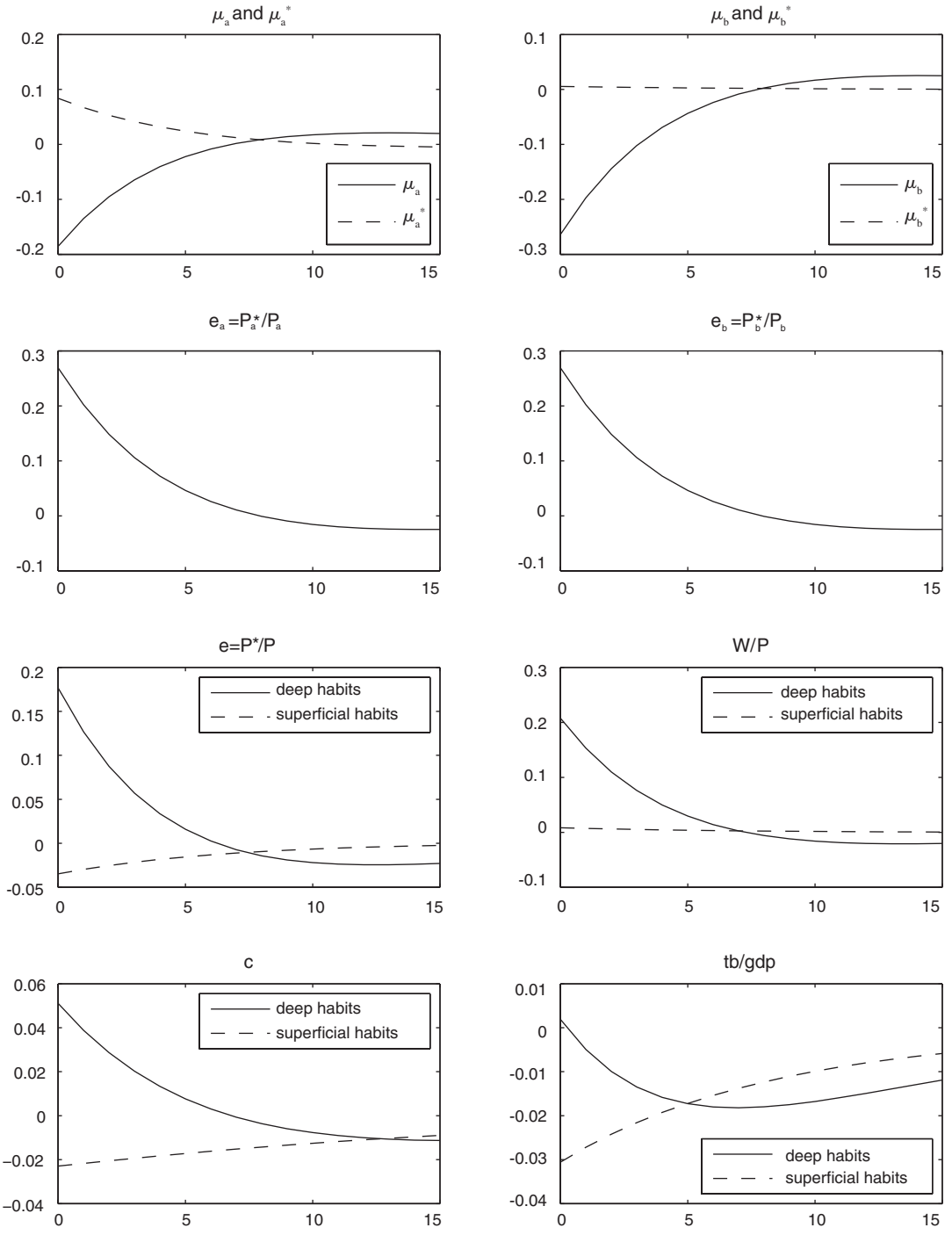

FIGURE 1. IMPULSE RESPONSE TO A 1-PERCENT INCREASE IN DOMESTIC GOVERNMENT PURCHASES

Note: All responses are expressed in percent deviations from steady state with the exception of the trade-balance-to-GDP ratio, which is expressed in level deviations from steady state.

row of Figure 1 shows that the real exchange rate depreciates (i.e., e_t increases), making consumption in the domestic country relatively less expensive than in the foreign country.

The predicted real depreciation in response to an expansion in domestic government spending is consistent with recent empirical evidence reported in Monacelli and Perotti (2006). These authors use a structural VAR model to identify innovations to government spending. Monacelli and Perotti, using data from four developed countries (the United States, the United Kingdom, Canada, and Australia) since the breakdown of Bretton Woods, find that an exogenous increase in government spending leads to a protracted depreciation of the real exchange rate.

The domestic real wage rate increases with the expansion in government spending, as shown with a solid line in the right panel of the third row of Figure 1. The reason for this increase in wages is as follows. An increase in (unproductive) government spending makes consumers poorer, creating a tendency for agents to consume less and work more. At the same time, the implied decline in domestic markups, which has the same effect on the demand for labor as an increase in total factor productivity, causes the demand for labor to expand in the domestic country. This increase in the demand for labor is sufficiently strong to cause the real wage to increase following the innovation in government spending.

In turn, the rise in wages induces workers to substitute consumption for leisure. This substitution effect dominates the negative wealth effect associated with higher government spending, resulting in an increase in consumption in equilibrium, as shown with a solid line in the bottom-left panel of Figure 1. The increase in consumption predicted by the model is consistent with the empirical evidence presented in the studies by Galí, David López-Salido, and Javier Vallés (forthcoming), and Monacelli and Perotti (2006).

The implied expansion in aggregate domestic absorption triggered by the increase in public spending causes a deterioration in the trade balance. As shown in the bottom-right panel of Figure 1, the trade-balance-to-GDP ratio is little changed on impact, but then falls and remains below trend throughout the transition. Again, this prediction of the pricing-to-habits model is in line with the empirical regularities documented in Monacelli and Perotti.

To highlight the role of pricing to habits in shaping the international transmission of government spending shocks, we compare the dynamics of the deep habit model with those of a model in which habits are formed at the level of the composite goods a and b, as opposed to at the level of each individual variety of goods. We refer to this standard habit-formation formulation as superficial habits. Under superficial habits, the problem of the firm ceases to be dynamic, as the demand for each individual variety of good no longer depends on past consumption of that variety. As a result, firms face isoelastic demand functions domestically and abroad. It follows that firms set constant markups, which implies the absence of variations in deviations from the law of one price on a good-by-good basis over the business cycle. In particular, the good-specific real exchange rates $e_{a,t} \equiv P^*_{a,t}/P_{a,t}$ and $e_{b,t} \equiv P^*_{b,t}/P_{b,t}$ are constant over time when habits take the standard superficial form.

Rows three and four of Figure 1 plot, using dashed lines, the response of the real exchange rate, wages, consumption, and the trade-balance-to-GDP ratio under superficial habits. There are several important differences between the predictions of the models with deep and superficial habits. Specifically, the superficial-habit model has the counterfactual implications that the real exchange rate appreciates and that consumption falls following an expansionary government spending shock. We conclude that in the context of our model, deep habits are essential in generating responses in relative prices and aggregate absorption that are qualitatively in line with the available empirical evidence.

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