Demand Shocks and Open Economy Puzzles

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Standard international real business cycle (IRBC) models with only one source of fluctuations have counterfactual implications for some of the main issues in international macroeconomics. Models with correlated shocks to total factor productivity (TFP) are capable of generating the observed comovements of output and TFP, but fail to account for the fact that the international consumption correlation is smaller than the output correlation (the so called quantity anomaly), as shown in Backus et al. (1992). These models also predict that the real exchange rate (RER) depreciates when domestic consumption increases more than foreign consumption. In contrast, the observed correlations of RER and relative consumption of the home to the foreign country for most pairs of countries are small and mostly negative, as shown in Backus and Smith (1993). This is the so called Backus-Smith puzzle. Models with demand shocks on the other hand are capable of accounting for the quantity anomaly and the Backus-Smith observation, but fail to generate the comovements in output and TFP that we observe.

In this paper, we pose an economy where we introduce good market frictions into an otherwise standard two-country, two-good model. This economy can account *simultaneously* for all these observations with only one shock, a demand shock. Good market frictions make demand shocks work like productivity shocks. When exerting effort, households contribute to measured productivity by extracting more output out of the economy. As a result, TFP responds positively to increases in expenditures. Crucially, this economy looks like a real business cycle model to the eyes of

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NIPA accounting procedures, but it is consistent with the data in all dimensions that are relevant to international finance.

In our economy, households in each country have preference over goods from both countries. Consumption of each good is limited by their costly search effort in addition to the standard budgetary constraints. The search frictions are resolved via competitive search. Firms in each country choose whether to sell their goods in domestic or in foreign markets. In each market, firms post their production, prices, and market tightness, i.e. the average measure of firms per shopper, to maximize their profits. To attract shoppers, firms have to make sure that households receive their reservation values, which are determined in equilibrium. Once a match is formed, shoppers purchase goods produced by firms with the specified price. The probability that a firm matches with a shopper or that a unit of shopping effort matches with a firm is determined by market tightness. The equilibrium has the feature of pricing-to-market, with firms charging different prices at home and foreign markets depending on the market tightness of each country. As shown in Drozd and Nosal (2012), pricing-to-market is important to explain the dynamics of international prices at both aggregate and disaggregate levels.

Our model economy can account for the open economy puzzles. An increase in domestic demand leads to a rise in domestic consumption and consumer prices. The real exchange rate of home consumption in terms of foreign consumption thus appreciates. The model therefore explains the Backus-Smith puzzle. At the same time, due to demand shocks, the correlation of the two countries' consumption is less than that of output. We thus explain the quantity anomaly. So far, the mechanism of our model is similar to that of standard IRBC models under demand shocks. The difference is that our model endogenously produces a procyclical movement in measured productivity. Standard models, however, need an extra productivity shock to get such movement.

Our paper is linked to the literature on international risk sharing.[1] Most work relies on two types of shocks to explain the Backus-Smith puzzle, a productivity shock and a demand-related shock, which is a preference shock in Stockman and Tesar (1995), productivity-induced demand shocks

[1] Kehoe and Perri (2002) and Bai and Zhang (2012) explain the imperfect risk sharing using models with financial frictions.

due to either an endogenous discounting utility function in Corsetti et al. (2008) or an investment specific technology shock in Raffo (2010),[2] and a labor wedge shock in Karabarbounis (2014). Our paper instead only uses one demand shock and has the feature of pricing-to-market.

Our paper is also related to the work on the role of search frictions on international price dynamics, for example Alessandria (2009) and Drozd and Nosal (2012). Alessandria (2009) highlights the importance of search friction as in Burdett and Judd (1983) in generating persistent movement of real exchange rates. Drozd and Nosal (2012) studies a search model with customer capital and slow adjusting in the customer base. Their model explains the co-movement of import and export prices and the co-movement of export prices and real exchange rates. Our search friction is different in that demand shocks in our model have the role of moving productivity. Moreover, neither Alessandria (2009) nor Drozd and Nosal (2012) solves the Backus-Smith puzzle.

I. A Two-Country Model with Shopping Frictions

In this section, we extend the shopping model in Bai et al. (2014) to a two-country-two-good world. In each country, $j = 1, 2$, there is a continuum of firms (trees) with measure one $T = 1$. Each tree yields $F^j = z^j f(n)$ units of fruit every period, where n is the amount of labor used. A standard search friction makes it difficult for households to find trees. To overcome this friction, a household has to make effort d to search for trees. Unmatched fruit perishes.

The frictions in the good markets are resolved via a competitive search protocol.[3] Households in country j search for both home and foreign goods that we denote as in traditional international parlance by the j and j^* goods, in specific locations that are indexed by price, market tightness, and firms' production. In competitive search environments, households of different types shop in different markets. Consequently, any particular market will be indexed by the country where the

[2] Raffo (2010) uses a model with endogenous capacity utilization via varying intensity of input usage. Such model amplifies the effects of shocks. Its implications of endogenous productivity are related to, although different from, those in our shopping model.

[3] This feature has the potential to yield Pareto optimal allocations and it alleviates the need for additional bargain parameters.

customers are from, by the country that produces the good, and by the particular tuple of price, market tightness, and production that it is associated with. To avoid cumbersome notation, we refer to a generic market or location as i.

The aggregate amount of fruits sold in location i is given by a Cobb-Douglas matching function $Y^i = A(D^i)^{\alpha}(T^i)^{1-\alpha}z^i f(n^i)$ where α is the share of shopping effort, A the shopping efficiency, D^i is the total search effort allocated to this location, and T^i is the number of firms that search in location i. Market tightness Q^i at this location is defined as the average measure of firms per shopper $Q^i = T^i/D^i$. Once a match is formed, the good is traded at the posted price p^i. The rate at which shopping effort is successful at matching with selling firms is $\Psi_d(Q^i) = A(Q^i)^{\alpha-1}$. The probability that a firm will be found is $\Psi_T(Q^i) = A(Q^i)^{-\alpha}$.

Agents have standard preferences for the goods produced in each country and disutility from working and from exerting search effort. Their utility is also subject to shocks θ^j that are perfectly correlated among all agents in a country and may be correlated across countries. We write $u\left[G(c,c^*), n, d+d^*, \theta\right]$ to denote the within period utility function where $G(c,c^*)$ is the final consumption good assembled using intermediate goods from both domestic country c and from foreign country c^*. Households have to send out shoppers d to domestic markets and d^* to foreign markets to purchase these intermediate goods.

We explore two versions of this economy. The first version has incomplete markets where agents of both countries can trade with each other intertemporally, but they cannot sign contracts that are contingent on the realization of the preference shocks. We implement the intertemporal trades via purchases and sales of shares on a world mutual fund that owns all firms in the world economy. The other version has complete markets. Its equilibrium allocation can be found by solving an equal weight social planner problem.[4] The allocation with complete markets can be implemented via state contingent sales on shares of the world mutual fund, which is a trivial extension of the market structure that we pose below and that we omit for brevity. We normalize the number of shares of the world mutual fund as two and its price as one (our numeraire). The aggregate state

[4]We just assume the appropriate initial distribution of wealth and initial shocks.

is then $S = (B, \theta^1, \theta^2)$, where B is the number of shares held by citizens of country 1, and θ^j is the shock faced by country j.

Country j households receive labor income $w^j(S)\, n^j$ and stock market returns $[1+R(S)]b$, which they can use to purchase new shares b' and home and foreign goods. They also choose how much to work and in which markets to exert their search efforts among those that are available. We denote the set of available markets by $\Gamma^{j\ell}$ for $\ell = \{1,2\}$. It is convenient to decompose the problem of a household into two phases, a phase to choose shopping markets and a phase to choose allocations. In particular, we write

$$V^j(S,b) = \max_{\left\{\{p^{j\ell},Q^{j\ell},F^{j\ell}\}\in\Gamma^{j\ell}\right\}_{\ell=j}^{j^*}} v^j\left(S,b;\{p^{j\ell},Q^{j\ell},F^{j\ell}\}_{\ell=j}^{j^*}\right)$$

where $v^j\left(S,b;\{p^{j\ell},Q^{j\ell},F^{j\ell}\}_{\ell=j}^{j^*}\right)$ is the value of households in country j when shopping at home market (p^{jj}, Q^{jj}, F^{jj}) and foreign market $(p^{jj^*}, Q^{jj^*}, F^{jj^*})$, i.e.

$$(1) \qquad v^j\left(S,b;\{p^{j\ell},Q^{j\ell},F^{j\ell}\}_{\ell=j}^{j^*}\right) = \max_{c^{\cdot\cdot},n^j,d^{\cdot\cdot},b'} u\left[G(c^{jj},c^{jj^*}),n^j,d^{jj}+d^{jj^*},\theta\right] + \beta E\left\{V^j(S',b')|\theta\right\}$$

subject to the budget constraint,

$$(2) \qquad \sum_{\ell=j}^{j^*} p^{j\ell}(S)\, c^{j\ell} + b' = [1+R(S)]\, b + w^j(S)\, n^j,$$

the shopping constraint for goods from both countries,

$$(3) \qquad c^{j\ell} = d^{j\ell}\Psi_d\left(Q^{j\ell}\right)F^{j\ell}, \quad \text{for } \ell = j, j^*,$$

and the law of motion of aggregate state $S' = G(S)$.

Firms in each country choose which country's households to serve and in which market of (p,Q,F) to sell their good. Firms hire enough labor to produce the promised quantity of goods F in case they are matched with a shopper. To determine the actual set of markets that are opened, we specify that firms choose the market such that households in country ℓ receive at least the reservation value $V^{\ell}(S, B^{\ell})$. Specifically, firms in country j solve

$$\Pi^{j}(S) = \max \left\{\Pi^{j\ell}(S)\right\}_{\ell=j}^{j^*} \qquad \text{with} \qquad \Pi^{j\ell}(S) = \max_{p,Q,F,n} \; p\,\Psi_T(Q)\,F - w^{j}(S)\,n, \tag{4}$$

subject to $F \leq z^{j} f(n)$ and the households' participation constraint

$$v^{\ell}\left[S, B^{\ell}; p, Q, F, p^{\ell j^*}(S), Q^{\ell j^*}(S), F^{\ell j^*}(S)\right] \geq V^{\ell}\left(S, B^{\ell}\right). \tag{5}$$

A competitive equilibrium consists of a set of decision rules, $\{C^{j\ell}(S),\ D^{j\ell}(S),\ N^{j}(S),\ B_j'(S)\}$, value functions $V^{j}(S), v^{j}\left(S, b; \{p^{j\ell}, Q^{j\ell}, F^{j\ell}\}_{\ell=j}^{j^*}\right)$, a tuple of $\left(p^{j\ell}(S), Q^{j\ell}(S), F^{j\ell}(S)\right)$, and a rate of return $R(S)$ such that (i) The decision rules $\{C^{j\ell}(S),\ D^{j\ell}(S),\ N^{j}(S)\}\ B_j'(S)\}$, and the value functions solve each country's problem (1) with $b = B^{j}$; (ii) Firms choose $\left(p^{j\ell}(S), Q^{j\ell}(S), F^{j\ell}(S)\right)$ to solve their problem (4), where the market tightness is $Q^{j\ell} = T^{j\ell}/D^{j\ell}$; (iii) Market clearing conditions: $C^{j\ell}(S) = A(D^{j\ell})^{\alpha}(T^{j\ell})^{1-\alpha} z^{\ell} f(N^{\ell})$ and $B_j'(S) + B_{j^*}'(S) = 2$.

II. Backus-Smith Puzzle

Backus and Smith (1993) highlights that, in a standard two-country model with perfect financial markets, the real exchange rate is perfectly correlated with the relative consumption of the home and the foreign country. This is at odds with the data where the correlations of these two variables for most pairs of countries are small and mostly negative.

To illustrate the intuition of how the shopping friction with demand shocks overturns the implications of the standard IRBC model, we consider a stylized version of our model with complete markets and no labor input. In particular, firms in country j produce z^{j} each period. Furthermore, let's assume that preferences of households are given by $u\left[G, d + d^*, \theta\right] = \theta \log(G) - (d + d^*)$ and the final good consumption is given by $G = c^{\mu}(c^*)^{1-\mu}$ where μ captures the home bias, $\mu > \frac{1}{2}$. Let P be a price index of final consumption goods. The real exchange rate of a country on the basis of consumption goods is defined as $RER = P^{*}/P$.

Let $\hat{x}$ denote the percentage deviation from steady state $\bar{x}$ for variable x, $\hat{x} = (x - \bar{x})/\bar{x}$. The percentage deviation of output or TFP in the home country is given by

$$\widehat{TFP} = \hat{z} + \alpha \left[\mu \, \hat{\theta} + (1-\mu) \, \hat{\theta}^{*}\right]. \tag{6}$$

Note that demand shocks $(\hat{\theta}, \hat{\theta}^{*})$ have a productivity role as the TFP of the home country increases with both domestic and foreign demand shocks. The logic is that a demand shock induces households to pose a greater search effort, and thus to find more fruit.

The real exchange rate after linearization takes the form of

$$\widehat{RER} = -(2\mu-1)^{2}(1-\alpha)(\hat{\theta}-\hat{\theta}^{*}) + (2\mu-1)(\hat{z}-\hat{z}^{*}). \tag{7}$$

RER appreciates when the home country experiences a positive demand shock or a negative productivity shock relative to the foreign country. The final consumption of the home country relative to that of the foreign country increases with both demand shocks and productivity shocks,

$$\hat{G} - \hat{G}^{*} = \left[1-(2\mu-1)^{2}(1-\alpha)\right](\hat{\theta}-\hat{\theta}^{*}) + (2\mu-1)(\hat{z}-\hat{z}^{*}). \tag{8}$$

Proposition 1 *Under productivity shocks, the real exchange rate and relative consumption of the home to the foreign country are perfectly positively correlated. The relative TFP and relative consumption are also positively correlated.*

From equations (6)-(8), it is easy to see that under productivity shocks $\widehat{RER} = \widehat{G} - \widehat{G}^{*}$ and $\widehat{TFP} - \widehat{TFP}^{*} = \frac{1}{2\mu-1}(\widehat{G} - \widehat{G}^{*})$, which reproduces the Backus-Smith puzzle. The model with productivity shocks, however, generates the observed comovement between TFP and consumption.

Proposition 2 *Under demand shocks, the real exchange rate and relative consumption are perfectly negatively correlated. The relative TFP and relative consumption are positively correlated if and only if there exist search frictions, i.e.* $\alpha > 0$.

The proof is straightforward using equations (6)-(8) under demand shocks and $\mu > 1/2$. Thus, with demand shocks and shopping frictions $\alpha > 0$, our model can generate both the negative correlation between RER and relative consumption and the positive correlation between relative TFP and relative consumption. Without search frictions, i.e. $\alpha = 0$, the model has constant relative TFP but variable relative consumption.

III. Putting the Model to Use

In this section, we show the business cycle predictions of the model. We assume a separable utility function, $u(G,d,n,\theta) = \theta \frac{G^{1-\sigma}}{1-\sigma} - d - \chi \frac{n^{1+\frac{1}{\nu}}}{1+\frac{1}{\nu}}$ where σ is the risk-aversion parameter, χ the disutility parameter from working, and ν the Frisch elasticity. The function of final good consumption G is a CES aggregator $G(c,c^*) = \left[\mu(c)^{\frac{\eta-1}{\eta}} + (1-\mu)(c^*)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$ where μ is the home advantage and η is the elasticity of substitution between home and foreign goods. We assume firms have a decreasing-return Cobb-Douglas production function $f(n) = n^{\gamma_n}$.

Calibration Table 1 reports the targets and the parameters that are most closely associated with each target. The targets are defined in yearly terms even though the model period is a quarter. The first group of parameters is set independently of the equilibrium allocation. The risk aversion parameter is 2 and the real rate of return is 4 percent, as commonly used in the literature. The Frisch elasticity is chosen to be 0.72, based on Heathcote et al. (2010). The Armington elasticity of substitution between home and foreign goods is 3, consistent with the work by Ruhl (2008). The share of shopping effort α is 0.23 to match the price dispersion in the data, see Bai et al. (2014) for details. We calibrate the following five parameters jointly: $\{\chi, \mu, \bar{z}, \gamma_n, A\}$, to match five moments: normalization of output, labor share, working hours, capacity utilization, and import share of US. In particular, we take the U.S. capacity utilization series published by the Federal Reserve Board and calculate the average, 81 percent.

Table 1: Calibration Targets, Implied Aggregates, and (Quarterly) Parameter Values

Targets	Value	Parameter	Value
First Group: Parameters Set Exogenously			
Risk aversion	2	σ	2.
Real interest rate	4%	β	0.99
Frisch elasticity	0.72	ν	0.72
Armington elasticity	3	η	3
Shopping parameter	0.23	α	0.23
Second Group: Parameters Calibrated Jointly			
Fraction of time spent working	30%	χ	16.62
Labor share of income	0.67	γ_n	0.50
Steady-state output	1	$\bar{z}$	2.26
Import share	0.10	μ	0.58
Capacity utilization	0.81	A	0.98

Quantitative Results Table 2 presents the business cycle statistics for the data, our shopping model, and the standard IRBC model with labor as input. In this version markets are incomplete, there are no state-contingent markets.[5]

We study the implications of two types of shocks, demand shocks and productivity shocks. In both case, we assume the shocks follow an AR(1) process with correlated innovations across countries. We choose the correlation between the two innovations to match the international co-movement of consumption. All persistence parameters are 0.95.

We take the data from Drozd and Nosal (2012) for the U.S. and 15 countries from EU (EU15). In the data, consumption and employment are about three-fourths as volatile as output. TFP is pro-cyclical and net exports are countercyclical. Both output and consumption are positively correlated across the U.S. and EU15 countries. Moreover, the cross-country consumption correlation is lower than the output correlation. The real exchange rate is negatively correlated with the ratio of home to foreign consumption.

The IRBC model has counterfactual implications. A positive productivity shock in the home country leads to a reduction in the relative price of home goods (an increase in the real exchange

[5]Whether there are state-contingent markets or not makes little quantitative difference. We choose incomplete markets as our baseline because of the lack of evidence for the existence of state-contingent markets for aggregate shocks, despite the popularity of market completeness due to the simplicity of its computation. The results with complete markets are available by request.

rate) and to an increase in home consumption due to home bias. This is the Backus-Smith puzzle. The productivity shock and the tools to smooth consumption available to both countries imply that consumption is more correlated than output internationally.[6] The IRBC model with demand shocks can fix these correlations, as well as the countercyclicality of net exports. However, it is unable to generate any movements in TFP. So one shock alone cannot deliver both features of the data.

Our shopping model with demand shocks accounts for the Backus-Smith puzzle and the quantity anomaly. In addition, the demand shocks alone can produce procyclical movements in TFP and countercyclical net exports. The correlation between the real exchange rate and consumption ratio is -0.98, close to the observed correlation, -0.71. In addition, our model with demand shocks also successfully predicts that consumption is less correlated than output, and that net exports are countercyclical. The shopping model with productivity shocks matches the data poorly. It fails to solve the Backus-Smith puzzle, both consumption and labor are too smooth, and the cross-country correlation in output and TFP are negative, opposite to the data.

Table 2: Quantitative Result

Data: for US and EU15					
Quantities	Data	Standard IRBC		Shopping model	
		z	θ	z	θ
A. Puzzles of international economics					
$corr(RER, C/C^*)$	-0.71	1.00	-1.00	0.99	-0.98
$corr(Y, Y^*)$	0.40	-0.86	0.97	-0.88	0.92
$corr(C, C^*)$	0.25	0.25	0.25	0.25	0.25
$corr(TFP, Output)$	0.45	0.99	0.00	0.99	1.00
B. Co-movement within a country					
NX/output, Output	-0.49	0.97	-0.22	0.96	-0.13
C. Volatility relative to GDP					
TFP	0.60	0.80	0.00	0.78	0.14
Consumption	0.74	0.11	1.67	0.10	1.55
Employment	0.81	0.05	2.23	0.06	0.83
Net exports	0.29	0.48	0.41	0.50	0.26

Note: Y denotes output, C consumption, *RER* the real exchange rate, *NX* net exports, all variables with $*$ are for foreign countries. *corr* denote correlation.

[6] Complete markets would ensure perfect comovement of consumption. Savings allows for almost the same thing.

IV. Conclusion

We pose a shopping model structure a la Bai et al. (2014) on top of an otherwise standard two-country international real business cycle model. Shopping for goods takes effort, which prevents perfect matching between potential customers and producers. An increase in search effort implies increased measured productivity. Thus, demand shocks act as productivity shocks. Larger demand in one country leads to an increase in its consumption for both home and foreign goods, and an appreciation of the real exchange rate. Demand shocks under our shopping model can solve two important open economy puzzles: the Backus-Smith puzzle and the quantity anomaly. It also generates procyclical TFP and countercyclical net exports. In contrast, a standard IRBC model either fails to account for open economy puzzles or generates no movement in TFP.

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