

# Demand Shocks as Productivity Shocks\*

Yan Bai

University of Rochester

José-Víctor Ríos-Rull

University of Minnesota

Federal Reserve Bank of Minneapolis

CAERP, CEPR, and NBER

Kjetil Storesletten

Federal Reserve Bank of Minneapolis and CEPR

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## Abstract

We provide a macroeconomic model where *demand* for goods has a productive role. A search friction prevents perfect matching between potential customers and producers, and larger demand – in the sense of more search – increases output in the economy. Consequently, when viewed through the lens of a standard neoclassical aggregate production function, an increase in demand will appear as an increase in the Solow residual. We estimate the model using standard Bayesian techniques, allowing for business cycles being driven by both demand shocks and true technology shocks. Demand shocks account for more than 95% of the fluctuations in output and the measured Solow residual, whereas true technology shocks account for less than 2% of these fluctuations. Our model also provides a novel theory for important macroeconomic variables such as the relative price of consumption and investment, the stock market, and capacity utilization.

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# 1 Introduction

In the standard neoclassical model, output is a function of inputs such as labor and capital. There is no explicit role for *demand*, in the sense that (Walrasian) prices will adjust so that whatever firms can produce will eventually be utilized. In reality, customers and producers must meet in order for the produced good to be consumed. Consider, for example, a restaurant. According to the standard model, the output of a restaurant should be a function of its employees, building, equipment, and raw material, irrespective of market conditions. However, the restaurant's production takes place only when customers show up to buy meals. Without customers no meals will be served, so the actual value added is zero. The larger the demand for the restaurant's meals, the more customers will be served and the larger the value added will be. Thus, the demand for goods plays a direct role. The spirit of this example extends to many forms of production: car dealers need shoppers, hospitals need patients, all producers need buyers.

This paper provides a theory where *demand* for goods has a productive role. The starting point is that potential customers search for producers, and a standard matching friction prevents neoclassical market clearing in the sense that all productive capacity does translate into value added. Clearly, for households and firms, the acquisition of goods is an active process that involves costs that are not measured in the National Income and Product Accounts (NIPA). Technically, we resolve the search friction by building on the competitive search model. Firms post prices and customers trade off good prices versus congestion when searching for the goods: prices are higher for goods that are easier to find.

Allowing such an explicit role for demand has direct implications for business cycle analysis, especially for our understanding of the driving factors of business cycles.<sup>1</sup> A striking consequence of this type of demand-driven business cycle model is that changes in demand will increase output even if inputs, and the intensity with which they are used, remain constant. If viewed through the lens of a standard neoclassical aggregate production function that ignores demand, an increase in demand would appear as an increase in the total factor productivity (TFP), i.e., shocks to the Solow residual.

Our paper focuses precisely on how the (search-based) model of demand alters the role of productivity shocks in business cycle analysis. Such shocks to TFP feature prominently in both real

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<sup>1</sup>There is a long tradition of attributing a role for demand in business cycle analysis, starting with Keynes' theories and, more recently, in New Keynesian versions of the Dixit-Stiglitz monopolistic competition model. However, in none of these earlier approaches has demand had a directly productive role. This is a key contribution of this paper.

business cycle (RBC) models and in New Keynesian DSGE models. To study the role of shocks to demand and productivity, we embed the search model in an otherwise standard neoclassical growth model. We show how a variety of simple demand shocks (to preferences, to the shopping technology of firms) are capable of generating movements in TFP that mimic those in the data. In fact, we estimate processes for each one of those shocks off the Solow residual in the data. However, the implied business cycle comovements of those univariate economies are not like the ones in the data. But a simple combination of consumption and investment demand shocks generates business cycle statistics that rival and, in fact, beat those generated by standard RBC models without any changes in technologies.

We then proceed to pose an economy where demand shocks coexist with TFP shocks and use Bayesian estimation techniques targeting time series for output, consumption, investment, and the measured Solow residual to tease out the contribution of each of those shocks to the variance of aggregate variables. We consider shocks to consumption and investment demand, to the marginal rate of substitution between consumption and leisure (MRS), and to TFP. Our findings are that demand shocks to consumption and investment account for almost two-thirds of the variance of output, the shock to the MRS for one-third, and the technology shock accounts for only one percent of the variance of output. Yet the Solow residual fluctuates as it does in the data. According to our estimated model, what appears as technology shocks from the perspective of a standard neoclassical growth model are increases in capacity utilization arising from more effective search on the part of consumers and investors.

In addition to these findings, the mechanics of our model relate a lot more closely to the popular notions of what makes business *go well*: that there is high demand for the product and not that there is a technological improvement. All these findings taken together, we think, makes a strong case for demand sources being a major source of economic fluctuations while being within the most complete neoclassical orthodoxy.

In our model the role for demand is intrinsic to the process of production and is not arbitrarily imposed: markets clear, and no agent has incentives to deviate. Although New Keynesian models generate demand-induced shocks, they do so by making agents trade at prices that are not equilibrium prices, in the sense that agents would, *ex post*, prefer to change the prices and quantities in order to achieve better allocations. In this paper there is no involuntary trade and the equilibrium allocation is efficient. We see our paper pursuing Keynes' central idea of the role of demand. However, this is done neither in the fixed-price tradition of the New Keynesian literature nor in the coordination-problem tradition that sees a recession as a bad outcome within environments

susceptible to multiple equilibria. Instead, our model follows a tradition where failures of demand generate recessions via infrautilization of productive capacity. In our environment “animal spirits,” modeled as shocks to agents’ forecasts, can generate recessions.

We have posed demand shocks in the most simple fashion – as shocks to preferences and to shopping ability – because we wanted to illustrate their ability to generate fluctuations in as stark a manner as possible. It is straightforward to extend our environment to contexts where the demand shocks are generated by financial frictions, government expenditures, and foreign demand shocks. Moreover, it is also straightforward to embed our structure within the New Keynesian and Mortensen-Pissarides approaches to fluctuations, which assume frictions in either price setting or labor markets to generate large fluctuations in output and hours worked. Ultimately, these two traditions build on technology shocks as a major source of fluctuations. Our theory provides a rationale for substituting productivity shocks for demand shocks in these models. We view demand shocks as a more desirable theory of business cycles because it provides as good or better quantitative fit than productivity shocks and because it rings more true as a driving factor.

**Additional contributions** Besides the proposal of a novel model of aggregate demand to study aggregate fluctuations, our work has other contributions. First, it shows how in models with production and competitive search, achieving optimality requires indexing markets, not only by price and market tightness but also by the quantity of the good traded. Second, we provide a theory of the cyclical changes of the relative price between investment and consumption goods that is not based on exogenous technology shocks<sup>2</sup>. Third, we provide a theory of endogenous capacity utilization, different from the early capacity utilization literature (see below for further discussion). Fourth, we also provide a theory of stock market movements that are associated not with capital adjustment costs or shocks to productivity or production costs, but rather with aggregate demand and with how well firms can match up with customers.

**Literature** Our exercise of exploring endogenous sources of fluctuations in the Solow residual is related to the capacity utilization literature. For example, [Greenwood, Hercowitz, and Huffman \(1988\)](#), [Basu \(1996\)](#), and [Licandro and Puch \(2000\)](#) consider variable capital utilization, and [Burnside, Eichenbaum, and Rebelo \(1993\)](#) introduce variable worker utilization in the form of labor hoarding during periods of low aggregate activity. In periods during which productivity and/or profits are high, firms will use the input factors more intensively, and this will drive a wedge between

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<sup>2</sup>See, for example, [Krusell, Ohanian, Ríos-Rull, and Violante \(2000\)](#) and [Fisher \(2006\)](#) for papers that use exogenous technical shocks as the source of changes in the relative price of investment.

“true” technology shocks and the measured Solow residual.<sup>3</sup> A key insight is that through varying capacity utilization, true technology shocks magnify the shocks to the Solow residual. Moreover, [Wen \(2004\)](#) argues that with variable capacity utilization, preference shocks that change the desired timing of consumption will cause changes in the utilization of input factors and, hence, changes in the measured Solow residual. Our theory provides a source of fluctuations in capacity utilization fundamentally different from and a complement to this former literature.

Our paper is also related to [Petrosky-Nadeau and Wasmer \(2011\)](#), which is developed independently from our paper.<sup>4</sup> They also model costly search for goods in final goods markets, and study how this search interacts with search in the labor market and influences the business cycle properties of the model. Our contribution is also related to several papers emphasizing the effects of search frictions in shaping TFP ([Lagos \(2006\)](#), [Faig and Jerez \(2005\)](#), and [Alessandria \(2005\)](#)) although none of these focus on business cycles. Moreover, [Diamond \(1982\)](#) and [Guerrieri and Lorenzoni \(2009\)](#) show that due to a search friction, the difficulty of coordination of trade can give rise to and exacerbate aggregate fluctuations.

Finally, there are some papers that examine, as we do, how demand changes could affect productivity and capacity utilization, although they investigate very different mechanisms. In [Fagnart, Licandro, and Portier \(1999\)](#), monopolistic firms with putty-clay technology are subject to idiosyncratic demand shocks, which causes fluctuations in capacity utilization. [Floetotto and Jaimovich \(2008\)](#) consider changes in markup rates due to the number of firms changing over the business cycle. In their model, changes in markups cause changes in the measured Solow residual. [Swanson \(2006\)](#) uses a heterogeneous sector model and shows that shocks from government demand can increase aggregate output, consumption, and investment.

The paper is organized as follows. Section 2 lays out the main mechanism in a simple Lucas-tree version of the economy where we show how increases in demand are partially accommodated by an increase in productivity via more search and by an increase in prices, whereas in the original [Lucas \(1978\)](#), all the adjustment occurs in prices. The full neoclassical growth model is analyzed in Section 3. We then map the model to data in Section 4. In Section 5 we analyze the properties of the model when restricting attention to univariate shock processes (one shock at a time) and

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<sup>3</sup>[Cooley, Hansen, and Prescott \(1995\)](#) focus on a different source of discrepancy between the Solow residual and true TFP: Due to a strong complementarity between workers and capital at the plant level, firms may choose to leave plants idle, so only part of the capital stock is in use.

<sup>4</sup>A different strand of literature studies firms’ search for customers in order to form long-lasting customer relationships ([Rudanko and Gourio \(2011\)](#), [Hall \(2008\)](#), and [Mateos-Planas and Ríos-Rull \(2007\)](#)). These papers emphasize the role of customers as capital, and their focus is very different from ours.

when we have only demand shocks. In Section 6 we estimate the full model with various shocks simultaneously to gauge their relative contribution. In Section 7 we explore other implications of the model, such as the relative price of investment, asset prices, and capacity utilization. Section 8 concludes, and an Appendix provides the proofs, additional tables, and computational and data details.

## 2 Competitive search for goods in a Lucas' tree model

We start by illustrating the workings of the model in a simple search model where output is produced by trees instead of capital and labor. We show that the search process has an impact on aggregate output in a way that appears as a level effect on the Solow residual. In an example we show how shocks to preferences are partly accommodated by increases in prices and interest rates and partly accommodated by increases in quantities, and demonstrate that absent the search friction, the same shocks translate only to price increases.

### 2.1 Technology and preferences

There is a continuum of trees (i.e., suppliers) with measure  $T = 1$ . Each tree yields one piece of fruit every period. A standard search friction makes it difficult for consumers to find trees. To overcome this friction, the consumer sends out a number of shoppers to search for fruit. The aggregate number of fruits found,  $Y$ , is given by the Cobb-Douglas matching function:

$$Y = A D^\alpha T^{1-\alpha}, \tag{1}$$

where  $D$  is the aggregate measure of shoppers searching for fruit (we sometimes call it aggregate demand) and  $A$  and  $\alpha$  are parameters of the matching technology.

Following Moen (1997), we assume a competitive search protocol where agents can choose to search in specific locations indexed by both the price and market tightness, defined as the ratio of trees per shopper,  $Q = T/D$ . The probability that a tree is found (i.e., matched with a shopper) is  $\Psi_T(Q) = A Q^{-\alpha} = A D^\alpha / T^\alpha$ . Once a match is formed, then the fruit is traded at the posted price  $p$ . By the end of the period, all fruit that is not found is lost. The trees pay out sales revenues as dividends and the expected dividend is  $\varsigma = p\Psi_T(Q)$ .

The economy has a continuum of identical, infinitely lived households of measure one. Their

preferences are given by

$$E \left\{ \sum_t \beta^t u(c_t, d_t, \theta_t) \right\}, \quad (2)$$

where  $c_t$  is consumption,  $d_t$  is the measure of shopping units (search effort) by the household, and  $\theta$  is a preference shock that follows a stochastic Markov process. The probability that an individual shopping unit is successful is given by the ratio of matches to the aggregate number of shoppers. Given the matching technology (1), this can be expressed in terms of market tightness as  $\Psi_d(Q) = A Q^{1-\alpha}$ , so  $c_t$  is given by

$$c = d \Psi_d(Q) = d A Q^{1-\alpha}. \quad (3)$$

Trees are owned by households and are traded every period. We normalize the price of the tree to unity and use it as the numéraire good. Let  $s$  denote the number of shares owned by the household. The aggregate number of shares is unity. Consequently, with identical households the aggregate state of the economy is just  $\theta$ , whereas the individual state also includes individual wealth  $s$ .<sup>5</sup> The representative household problem can then be expressed recursively as

$$v(\theta, s) = \max_{c, d, s'} u(c, d, \theta) + \beta E \{v(\theta', s') | \theta\} \quad (4)$$

$$\text{s.t.} \quad c = d \Psi_d[Q(\theta)] \quad (5)$$

$$P(\theta) c + s' = s [1 + \varsigma(\theta)]. \quad (6)$$

It is easy to see that this is a simple extension of the original Lucas (1978) economy, which is one where  $\alpha = 0$  and  $A$  is large enough to make consumption worthwhile in equation (3).

## 2.2 Competitive search in the market for goods

There are differentiated markets indexed by the price and market tightness (number of trees or firms per shopper). Let  $\varsigma$  denote the outside value for firms of going to the most attractive market, yet to be determined. Clearly a market can attract trees only if it offers them at least  $\varsigma$ . This

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<sup>5</sup>Throughout the paper, we take advantage of the perfect correlation between the idiosyncratic and aggregate shocks to preferences, and we write only one of them as a state variable.

constrains the feasible combinations of prices and market tightness that shoppers can offer:

$$\varsigma \leq p \Psi_T(Q). \quad (7)$$

The expected contribution to household utility of a shopper that chooses the best price–tightness pair is<sup>6</sup>

$$\Phi = \max_{Q,p} \{u_d(\theta, s) + \Psi_d(Q) (u_c(\theta, s) - p \hat{m})\} \quad \text{s.t. } \varsigma \leq p \Psi_T(Q), \quad (8)$$

where  $u_d(\theta, s)$  and  $u_c(\theta, s)$  are the marginal utility of increases in  $d$  and  $c$ , respectively. Moreover,  $\hat{m} = m[\theta, s'(\theta, s)]$  is the expected discounted marginal utility of an additional unit of savings:

$$m(\theta, s') = \beta E \left\{ \frac{P(\theta) [1 + \varsigma(\theta')]}{P(\theta')} \frac{\partial v(\theta', s')}{\partial s'} \middle| \theta \right\}.$$

Solve (8) by substituting (7) at equality and take the first-order condition w.r.t.  $Q$ . This yields the unique equilibrium price  $p$  and value of the tree  $\varsigma$  as functions of market tightness  $Q$ :

$$p = (1 - \alpha) \frac{u_c(\theta, s)}{\hat{m}}, \quad (9)$$

$$\varsigma = p A Q^{-\alpha}. \quad (10)$$

## 2.3 Equilibrium

A *competitive search equilibrium* is defined by a set of individual decision rules,  $c(\theta, s)$ ,  $d(\theta, s)$ , and  $s'(\theta, s)$ , the aggregate allocations  $D(\theta)$  and  $C(\theta)$ , good prices  $P(\theta)$ , and the rate of return on trees  $\varsigma(\theta)$  so that

1. The individual decision rules,  $c(\theta, s)$ ,  $d(\theta, s)$ , and  $s'(\theta, s)$  solve the household problem (4).
2. The individual decision rules are consistent with the aggregate functions

$$C(\theta) = c(\theta, 1) \quad D(\theta) = d(\theta, 1) \quad s'(\theta, 1) = 1.$$

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<sup>6</sup>To derive this, take the first-order condition of (4) with respect to  $d$  and consider the price–tightness posting problem when the cost  $\bar{u}_d$  of sending an additional shopper has been borne. The idea is that each shopper is equipped with a credit card and if no fruit is found, then utility is not affected over and above the sunk search cost.

3. Shoppers and firms search optimally in the market for goods, i.e.,  $(p(\theta), Q(\theta), \varsigma(\theta))$  satisfy the search conditions (9) and (10), where market tightness is  $Q(\theta) = 1/D(\theta)$ .
4. The goods market clears:

$$C(\theta) = A D(\theta)^\alpha. \quad (11)$$

The competitive search equilibrium and its efficiency properties can then be characterized by the following proposition.

**Proposition 1.** 1. *Aggregate search  $D$  is determined by the functional equation*

$$0 = \alpha A D(\theta)^{\alpha-1} u_c[A D(\theta)^\alpha, D(\theta), \theta] + u_d[A D(\theta)^\alpha, D(\theta), \theta]. \quad (12)$$

*The functions  $C$ ,  $Q$ , and  $\varsigma$  then follow directly from the equilibrium conditions  $C(\theta) = A D(\theta)^\alpha$ ,  $Q(\theta) = 1/D(\theta)$ , and  $\varsigma(\theta) = p(\theta) A D(\theta)^\alpha$ .*

2. *The equilibrium price is defined by the functional equation*

$$u_c[C(\theta), D(\theta), \theta] = \beta E \left\{ \frac{P(\theta) [1 + \varsigma(\theta')]}{P(\theta')} u_c[C(\theta'), D(\theta'), \theta'] \mid \theta \right\}. \quad (13)$$

3. *The competitive equilibrium is efficient.*

The proof of the first two items is straightforward: simply derive the first-order conditions of households and combine them with the competitive search conditions (see the Appendix for details). For efficiency, we consider a planner solving  $\max_{C,D} \{u(C, D, \theta)\}$  subject to the aggregate resource constraint  $C = A D^\alpha$ . The solution to equation (12) solves this planner problem, which establishes efficiency. Interestingly, the Euler equation (13) is the same as the one in the standard Lucas tree model.

We now turn to our focus, the measured total factor productivity  $Z$ , which is defined as  $C = Z T$ . The Solow residual  $Z$  is a function of the search effort and fluctuates in response to preference shocks. A direct application of the equilibrium formulation of aggregate consumption from Proposition 1 and  $T = 1$  yields the following corollary:

**Corollary 1.** *In equilibrium, the Solow residual is a function of preference shocks and given by*

$$Z(\theta) = A (D(\theta))^\alpha. \quad (14)$$

## 2.4 An example

The explicit consideration of an example allows us to show with the aid of closed-form solutions how preference shocks that increase the desire to consume are accommodated in part by an increase in the price of consumption today relative to consumption later and in part by an increase in search effort that translates into squeezing more output out of the economy, thereby making it more productive. Consider a version of this economy with preferences given by

$$u(c, d, \theta) = \theta_c \log c - d,$$

where  $\theta_c$  is independently and identically distributed with  $E\{\theta_c\} = 1$  and  $\theta_c > 0$ . Given these preferences, the equilibrium conditions (12) and (11) yield the following equilibrium allocations:

$$D(\theta) = \alpha \theta_c, \quad C(\theta_c) = A \alpha^\alpha \theta_c^\alpha.$$

It is straightforward to verify that the equilibrium price and interest rate (in terms of the consumption good) are

$$P(\theta) = \left( \frac{1}{\beta} - 1 \right) \frac{1}{A \alpha^\alpha} \theta_c^{1-\alpha}, \quad 1 + r(\theta) = \frac{\theta_c^{1-\alpha}}{\beta E\{(\theta'_c)^{1-\alpha}\}}.$$

An increase in the desire to consume today translates into an increase in consumption proportional to the shock to the power of  $\alpha$  and an increase in the gross interest rate proportional to the shock to the power of  $1 - \alpha$ . As  $\alpha \rightarrow 0$ , the shopping economy converges to the standard Lucas tree model. In this case, aggregate consumption is invariant to the demand shock, and all the adjustment to the shock takes place through prices.

## 3 The stochastic growth model version of the economy

We now extend the search model to an otherwise standard growth model suitable for quantitative business cycle analysis. We add capital, which requires for its installation both investment goods and professionals to shop for those goods, and a disutility of working. We start with describing technology and preferences. We then analyze the problems faced by households and firms, and study price determination in the presence of competitive search for consumption and investment goods. Along the way, we prove a few results that guarantee that all firms make the same choices of labor and investment. We also establish that the equilibrium is Pareto optimal. Finally, we

discuss how the labor share and the Solow residual can be estimated using NIPA data.

### 3.1 Technology

There is a unit measure of firms. Each firm has a “location,” i.e., equivalent to the tree in Section 2. The firm has a certain amount of capital installed in that location. There is a technology that transforms capital and labor services into goods that is described by a standard (differentiable and strictly concave) production function  $f(k, n)$ . To install new capital for the following period, the firm, like the households, has to shop. The firm has a technology that transforms one unit of labor (that cannot be used for production) into  $\zeta$  shopping units.

As in Section 2, we assume a competitive search protocol in specific locations. Markets are indexed by a triplet  $(Q, P, F)$  of market tightness, price, and the quantity of the good produced which in turn is a function of the firm’s pre-installed capital stock and labor. Recall that the quantity produced was not part of the variables indexing markets in the simple Lucas tree model.

At the beginning of each period, there could potentially be a distribution of firms with different pre-installed capital, perhaps specializing in the consumption or investment good. We proceed by guessing and verifying below that if firms have the same capital today, they choose the same capital for tomorrow. This approach allows us to look only at a representative firm and thus drastically reduce the state space of the economy from a distribution of firms to an aggregate level of capital. To simplify our presentation of the problems of firms and households, we use  $(\theta, K)$ , the preference shock and aggregate capital, to denote the state of the economy. Choosing the same capital stock, firms may, however, choose to produce different goods – consumption or investment goods – and charge different prices and market tightness. In equilibrium, there are two markets, one for consumption with index  $(Q^c, P^c, F^c)$  and one for investment with index  $(Q^i, P^i, F^i)$ . These goods are identical from the viewpoint of production but not from the viewpoint of search and prices. The share of firms producing consumption goods is given by  $T(\theta, K)$ .

### 3.2 Households

There is a measure one of households who have preferences over consumption  $c$ , shopping  $d$ , and working  $n$  and who are affected by preference shocks  $\theta$  perfectly correlated across households. This is summarized in the utility function  $u(c, d, n, \theta)$ .

The state variable for the household is the state of the economy  $(\theta, K)$  and the individual wealth, i.e., the number of shares  $s$ . The households take a number of aggregate variables as

given: market tightness  $Q^c$ , price  $P^c$ , and quantity  $F^c$  in the consumption good market, the rate of return, the wage, and the law of motion of capital denoted  $G(\theta, K)$ . These objects are equilibrium functions of the state variable  $(\theta, K)$ .

**Household problem** The representative household solves

$$v(\theta, K, s) = \max_{c, d, n, s'} u(c, d, n, \theta) + \beta E \{v(\theta', K', s') | \theta\} \quad (15)$$

$$\text{s.t.} \quad c = d \Psi_d[Q^c(\theta, K)] F^c(\theta, K), \quad (16)$$

$$P^c(\theta, K) c + s' = s [1 + R(\theta, K)] + n w(\theta, K), \quad (17)$$

$$K' = G(\theta, K). \quad (18)$$

Equation (16) shows that consumption requires the household's shopping effort, but it also depends on market tightness and the amount produced by consumption-producing firms. Equation (17) is the budget constraint in terms of shares.

The solution to this problem is a set of individual decision rules  $d(\theta, K, s)$ ,  $c(\theta, K, s)$ ,  $n(\theta, K, s)$ , and  $s'(\theta, K, s)$ . Anticipating equilibrium conditions, we introduce the aggregate counterparts of these functions:

$$C(\theta, K) = c(\theta, K, 1) \quad (19)$$

$$D^c(\theta, K) = d(\theta, K, 1) \quad (20)$$

$$N(\theta, K) = n(\theta, K, 1) \quad (21)$$

$$s'(\theta, K, 1) = 1. \quad (22)$$

The last condition stems from the fact that stock market shares are the only asset in positive net supply and the equilibrium condition that these shares add up to unity. Abusing notation, we use these aggregate conditions to write marginal utility as a function only of aggregate state variables yielding  $u_c(\theta, K) = u_c[C(\theta, K), D(\theta, K), N(\theta, K), \theta]$ . Using these aggregate conditions, the stochastic discount factor can be expressed as

$$\Pi(\theta, \theta', K) = \beta \frac{P^c(\theta, K)}{P^c(\theta', G(\theta, K))} \frac{u_c[\theta', G(\theta, K)] + \frac{u_d[\theta', G(\theta, K)]}{\Psi_d[Q^c(\theta', G(\theta, K))] F^c(\theta', G(\theta, K))}}{u_c(\theta, K) + \frac{u_d(\theta, K)}{\Psi_d[Q^c(\theta, K)] F^c(\theta, K)}}. \quad (23)$$

So the intertemporal Euler becomes

$$1 = E \{ [1 + R(\theta', G(\theta, K))] \Pi(\theta, \theta', K) \mid \theta \}, \quad (24)$$

while the intratemporal first-order condition is

$$u_c(\theta, K) + \frac{u_d(\theta, K)}{\Psi_d[Q^c(\theta, K)]} \frac{P^c(\theta, K)}{F^c(\theta, K)} = u_n(\theta, K) \frac{P^c(\theta, K)}{w(\theta, K)}. \quad (25)$$

To further simplify notation, let  $m(\theta, K, \theta, s)$  denote the value in terms of marginal utility of an additional unit of savings and let  $M(\theta, K)$  be its aggregate counterpart,

$$M(\theta, K) = \beta E \left\{ \frac{[1 + R(\theta', G(\theta, K))]}{P^c(\theta', G(\theta, K))} \left( u_c[\theta', G(\theta, K)] + \frac{u_d[\theta', G(\theta, K)]}{\Psi_d[Q^c(\theta', G(\theta, K))]} \frac{P^c(\theta', G(\theta, K))}{F^c(\theta', G(\theta, K))} \right) \mid \theta \right\}. \quad (26)$$

### 3.3 Firms

Given the state of the economy  $(\theta, K)$  and its individual state  $k$ , each firm has to choose three things in a particular order: first, whether to produce for investment or consumption, second, the specific submarket to go to, and third, how much to invest. Firms choose to produce whichever good that gives higher value, i.e.,

$$\Omega(\theta, K, k) = \max\{\Omega^c(\theta, K, k), \Omega^i(\theta, K, k)\}, \quad (27)$$

where  $\Omega^j(\theta, K, k)$  is the best value for producing consumption goods,  $j = c$ , or investment goods,  $j = i$ ; that is, they choose  $(Q^j, P^j, F^j)$  among those available (a still to be determined set):

$$\Omega^j(\theta, K, k) = \max \tilde{\Omega}^j(\theta, K, k, Q^j, P^j, F^j) \quad \text{for all available } (Q^j, P^j, F^j).$$

A firm in a  $(Q^c, P^c, F^c)$  consumption goods submarket chooses labor for shopping  $n^k$ , invest-

ment  $i$ , and next period's capital stock  $k'$  to solve the following problem:

$$\begin{aligned} \tilde{\Omega}^c(\theta, K, k, Q^c, P^c, F^c) = \max_{n^k, k', i} & \frac{\Psi_d(Q^c)}{Q^c} P^c F^c - w(\theta, K) [n(k, F^c) + n^k] \\ & - P^i(\theta, K) i + E \{ \Omega(\theta', K', k') \Pi(\theta, \theta', K) | \theta \} \end{aligned} \quad (28)$$

$$\text{s.t.} \quad i = n^k \zeta \Psi_d[Q^i(\theta, K)] F[K, N^i(\theta, K)] \quad (29)$$

$$k' = i + (1 - \delta)k \quad (30)$$

$$K' = G(\theta, K) \quad (31)$$

where  $n(k, y)$  is the inverse function of the production function  $y = f(k, n)$  for a given  $k$ , and  $\zeta$  is a technological requirement specifying how many shopping workers are needed to provide one unit of shopping service. Finally  $N^i(\theta, K)$  is the equilibrium amount of production workers in investment goods production, so  $f(K, N^i(\theta, K))$  is the amount of investment good produced by investment-producing firms.

As for investment good producers, a firm delivering to an investment good market  $(Q^i, P^i, F^i)$  chooses labor for shopping  $n^k$ , investment  $i$ , and next period's capital stock  $k'$  to solve the following problem:

$$\begin{aligned} \tilde{\Omega}^i(\theta, K, k, Q^i, P^i, F^i) = \max_{n^k, k', i} & \frac{\Psi_d(Q^i)}{Q^i} P^i F^i - w(\theta, K) [n(k, F^i) + n^k] \\ & - P^i(\theta, K) i + E \{ \Omega(\theta', K', k') \Pi(\theta, \theta', K) | \theta \} \end{aligned} \quad (32)$$

subject to (29), (30), and (31).

The first-order condition over investment is given by

$$E \{ \Omega_k(\theta', K', k') \Pi(\theta, \theta', K) | \theta \} = \frac{w(\theta, K)}{\zeta \Psi_d[Q^i(\theta, K)] f[K, N^i(\theta, K)]} + P^i(\theta, K). \quad (33)$$

Let  $\varsigma(\theta, K, k)$  denote the firm's revenue induced by selling to the best market (expressed in units of shares), whether a consumption good market or an investment good market:

$$\varsigma(\theta, K, k) = \max \{ \varsigma^c(\theta, K, k), \varsigma^i(\theta, K, k) \},$$

where  $\varsigma^j(\theta, K, k)$  is the maximum over the available submarkets of  $\varsigma^j(\theta, K, k, Q^c, P^c, F^c)$ ,

$$\varsigma^j(\theta, K, k, Q^j, P^j, F^j) = P^j \frac{\Psi_d(Q^j)}{Q^j} F^j - w(\theta, K) n(k, F^j), \quad (34)$$

with  $j$  being both consumption and investment.

Before analyzing the search equilibrium, it is useful to establish that firms in all submarkets have the same expected revenue.

**Lemma 1.**  $\Omega^c(\theta, K, k) = \Omega^i(\theta, K, k)$  implies  $\varsigma^c(\theta, K, k) = \varsigma^i(\theta, K, k)$ .

A direct consequence of this lemma is that it allows firms to consider only the current revenue (and so the demand for current labor) instead of lifetime revenue (and so the lifetime labor demands) in deciding which markets to enter.

### 3.4 Competitive search in the market for consumption goods

In addition to the decisions made by the households with respect to the main elements of the allocation (how much to consume, shop, work, and save), its shoppers choose how to conduct their shopping, i.e., which market to go to. In our environment with competitive search, this means choosing a triplet  $(Q^c, P^c, F^c)$  of market tightness, price, and quantity. These choices will give us two conditions to be satisfied by these three variables.

We can write the contribution to the utility of a household of a shopper that chooses the best price-tightness-quantity triplet as

$$\Phi = \max_{Q^c, P^c, F^c} u_d(\theta, K) + \Psi_d(Q^c) F^c (u_c(\theta, K) - P^c m(\theta, K, s'))$$

subject to the constraint

$$\varsigma^c \leq P^c \frac{\Psi_d(Q^c)}{Q^c} F^c - w(\theta, K) n(k, F^c). \quad (35)$$

This constraint reflects the fact that the only relevant markets are those that guarantee certain expected revenue for the firms. Substituting (35) with  $k = K$  and the definition for  $\Psi_d(Q)$  and replacing  $m(\theta, K, s')$  with  $M(\theta, K)$ , we rewrite the problem as

$$\Phi = \max_{Q^c, F^c} \left\{ u_d(\theta, K) + A (Q^c)^{1-\alpha} F^c \left( u_c(\theta, K) - \frac{\varsigma^c + w(\theta, K) n(k, F^c)}{A(Q^c)^{-\alpha} F^c} M(\theta, K) \right) \right\}. \quad (36)$$

The first-order condition over  $Q^c$  yields an equation for equilibrium  $P^c$  and an equation for price  $P^c$ :

$$\begin{aligned} 0 &= (1 - \alpha) \frac{AF^c}{(Q^c)^\alpha} u_c(\theta, K) - [\zeta^c + w(\theta, K)n(k, F^c)] M(\theta, K) \\ &= (1 - \alpha) \frac{AF^c}{(Q^c)^\alpha} u_c(\theta, K) - \frac{AP^c}{(Q^c)^\alpha} F^c M(\theta, K), \end{aligned}$$

which yields an equation for the equilibrium price  $P^c$ :

$$P^c(\theta, K) = (1 - \alpha) \frac{u_c(\theta, K)}{M(\theta, K)}. \quad (37)$$

The first-order condition over  $F^c$ , together with the relation of  $\partial n / \partial F^c = 1/f_n$  and  $k = K$ , gives us

$$0 = A(Q^c)^{1-\alpha} u_c(\theta, K) - Q^c M(\theta, K) w(\theta, K) \frac{\partial n}{\partial F^c}.$$

Substituting the equilibrium price from equation (37) and the relation  $\partial n / \partial F^c = 1/f_n$  for the given  $k = K$ , we have

$$\frac{w(\theta, K)}{P^c(\theta, K)} = \frac{1}{1 - \alpha} A(Q^c)^{-\alpha} f_n [K, N^c(\theta, K)],$$

where  $N^c(\theta, K) = n(K, F^c(\theta, K))$  is the labor associated with  $k = K$  and proposed  $F^c$ . The market tightness  $Q^c$  is a function of the equilibrium value for producing consumption goods  $\zeta^c(\theta, K)$ ,

$$Q^c(\theta, K) = \left[ \frac{A P^c(\theta, K) f(K, N^c(\theta, K))}{\zeta^c(\theta, K) + w(\theta, K) N^c(\theta, K)} \right]^{\frac{1}{\alpha}}. \quad (38)$$

### 3.5 Competitive search in the market for investment goods

In the same way as households do, firms shop investment goods by sending shoppers to markets offering the best triplet of tightness, price, and quantity,  $(Q^i, P^i, F^i)$ . These choices yield two conditions to be satisfied by these three variables.

A shopper for the firm chooses the best price-tightness pair  $\{Q^i, P^i, F^i\}$  to solve

$$\begin{aligned} \Phi_F &= \max_{Q^i, P^i, F^i} -w(\theta, K) + \zeta \Psi_d(Q^i) F^i [E \{ \Omega(\theta', K', k') \Pi(\theta, \theta', K) | \theta \} - P^i] \\ \text{s.t.} \quad \zeta^i &\leq P^i \frac{\Psi_d(Q^i)}{Q^i} F^i - w(\theta, K) n(k, F^i). \end{aligned}$$

Substituting  $P^i$ , we can rewrite the problem as

$$\max_{Q^i, F^i} -w(\theta, K) + \zeta A(Q^i)^{1-\alpha} F^i \left[ E \{ \Omega(\theta', K', k') \Pi(\theta, \theta', K) | \theta \} - \frac{\zeta^i + w(\theta, K) n(k, F^i)}{A(Q^i)^{-\alpha} F^i} \right].$$

The first-order condition over  $Q^i$  is given by

$$0 = \frac{(1-\alpha)\zeta A}{(Q^i)^\alpha} F^i E \{ \Omega(\theta', K', k') \Pi(\theta, \theta', K) | \theta \} - \zeta(\zeta^i + w(\theta, K) n(k, F^i)),$$

which implies that the equilibrium price is

$$P^i(\theta, K) = (1-\alpha) E \{ \Omega(\theta', K', k') \Pi(\theta, \theta', K) | \theta \}. \quad (39)$$

The first-order condition over  $F^i$  is given by

$$0 = \zeta A (Q^i)^{1-\alpha} E \{ \Omega(\theta', K', k') \Pi(\theta, \theta', K) | \theta \} - \zeta Q^i w(\theta, K) \frac{\partial n}{\partial F^i}.$$

Substituting equation (39) for price and  $\partial \tilde{n} / \partial F^i = 1/f_n$  for given  $k = K$ , we have

$$\frac{w(\theta, K)}{P^i(\theta, K)} = \frac{1}{1-\alpha} A(Q^i)^{-\alpha} f_n(K, N^i(K, \theta)),$$

where  $n^i(\theta, K) = n(K, F^i(\theta, K))$  is the labor associated with  $k = K$  and the amount produced by investment firms,  $F^i$ . The equilibrium market tightness  $Q^i$  as a function of  $\zeta^i$  is given by

$$Q^i(\theta, K) = \left[ \frac{A P^i(\theta, K) F[K, N^i(\theta, K)]}{\zeta^i(\theta, K) + w(\theta, K) n^i(\theta, K)} \right]^{\frac{1}{\alpha}}. \quad (40)$$

### 3.6 Equilibrium

We have now established the necessary conditions for equilibrium that arise from the households' and firm's problems.

Before formally defining equilibrium, we provide a set of results – stated in a series of lemmas – that allows us to verify our conjecture that  $(\theta, K)$  is a sufficient aggregate state variable. The results show that if all firms start with the same capital, they will make the same choice of labor and investment and will, hence, have identical capital  $K'$  next period.

**Lemma 2.** *All firms with  $k = K$  choose markets with the same quantity  $F = F^c = F^i$  and the same labor input for production.*

We therefore use  $N^y(\theta, K)$  to denote the aggregate labor input,  $N^y(\theta, K) = N^c(\theta, K) = N^i(\theta, K)$  for any  $(\theta, K)$ .

**Lemma 3.** *The expected revenue per unit of output is the same in both sectors:*

$$P^c(\theta, K) \frac{\Psi_d[Q^c(\theta, K)]}{Q^c(\theta, K)} = P^i(\theta, K) \frac{\Psi_d[Q^i(\theta, K)]}{Q^i(\theta, K)}. \quad (41)$$

**Lemma 4.** *Firms with the same  $k$  choose the same  $k'$  as future capital stock.*

The following two lemmas will prove useful later. The first states properties of investment prices unveiling a relation between the direct and the indirect costs of installing capital.

**Lemma 5.** *The investment price is proportional to the ratio of the wage and the amount of shopping that a worker can carry out:*

$$\frac{w(\theta, K)}{\zeta \Psi_d[Q^i(\theta, K)] f(K, N^y(\theta, K))} = \frac{\alpha}{1 - \alpha} P^i(\theta, K). \quad (42)$$

The last lemma characterizes firms' optimal choice of capital accumulation. When making decisions for future capital, firms face an explicit cost of investment (the price paid) and an implicit cost (the wages of shoppers). Interestingly, the Euler equation in equilibrium looks almost exactly like the one in a standard RBC model in that the implicit wage cost disappears. The reason is that competitive search links the implicit wage cost and explicit cost. In equilibrium, the following lemma holds:

**Lemma 6.** *The Euler equation of a firm equates the price of investment to the value of capital tomorrow.*

$$E \left\{ P^i(\theta', K') \Pi(\theta, \theta', K) \left[ \frac{\Psi_d(Q^i)}{Q^i} f_k(K', N^y(\theta', K')) + (1 - \delta) \right] \right\} = P^i(\theta, K). \quad (43)$$

We are now ready to define equilibrium in this economy.

**Definition 1.** *Equilibrium is a set of decision rules and values for the household  $\{c, d, n, s', v\}$  as functions of its state  $(\theta, K, s)$ , firms' decisions and values  $\{n^y, n^k, i, k', \Omega\}$  as functions of its state  $(\theta, K, k)$ , and aggregate functions for shopping for investment  $D^i$ , shopping for consumption  $D^c$ , consumption  $C$ , labor  $N$ , labor for production  $N^y$ , labor for shopping  $N^k$ , investment  $I$ , aggregate capital  $G$ , expected revenues  $\varsigma$ , the measure of consumption-producing firms  $T$ , wages  $w$ , consumption good prices  $P^c$ , consumption market tightness  $Q^c$ , production of firms  $F^c$  and  $F^i$ , investment good prices  $P^i$ , investment market tightness  $Q^i$ , and the rate of return of the economy  $R$  as functions of the aggregate state  $(\theta, K)$  that satisfy the following conditions:*

1. Households' choices and value functions  $d(\theta, K, s)$ ,  $c(\theta, K, s)$ ,  $n(\theta, K, s)$ ,  $s'(\theta, K, s)$ , and  $v(\theta, K, s)$  satisfy (15-17) and (24-25).
2. Firms choose  $n^k(\theta, K, k)$ ,  $i(\theta, K, k)$ ,  $k'(\theta, K, k)$ , and  $\Omega(\theta, K, k)$  to solve their problem (27). They satisfy conditions (29-30) and (33).
3. Competitive search conditions: Shoppers and sellers go to the appropriate submarkets, i.e., equations (37-38) and (39-40).
4. Representative agent and equilibrium conditions: Individual decisions are consistent with aggregate variables.

5. Market clearing conditions:

$$s'(\theta, K, 1) = 1 \quad (44)$$

$$I(\theta, K) = D^i(\theta, K) \Psi_d(Q^i(\theta, K)) F^i(\theta, K) \quad (45)$$

$$C(\theta, K) = D^c(\theta, K) \Psi_d(Q^c(\theta, K)) F^c(\theta, K) \quad (46)$$

$$N(\theta, K) = N^y(\theta, K) + N^k(\theta, K) \quad (47)$$

$$Q^c(\theta, K) = \frac{T(\theta, K)}{D^c(\theta, K)} \quad (48)$$

$$Q^i(\theta, K) = \frac{1 - T(\theta, K)}{D^i(\theta, K)}. \quad (49)$$

Note that since the numéraire is the stock market pre-dividends,  $\Omega$  must be given by  $\Omega(\theta, K, K) = 1 + R(\theta, K)$ . The financial wealth of the household is  $s(1 + R)$  and is equal to the stock market today including the dividends. Note also that the share of consumption expenditure equals the fraction of firms producing consumption goods  $T$ , i.e.,  $T = P^c C / (P^c C + P^i I)$ .

### 3.7 The equilibrium is efficient

This section analyzes the efficiency properties of the competitive search equilibrium. To this end, we start by characterizing the efficient allocation arising from the problem of a social planner who also faces the technology constraints that searching efforts have to be exerted for consumption goods and investment goods to be found. We then prove that the competitive search equilibrium is efficient.

**Definition 2.** *An allocation  $\{T, D^c, D^i, N^y, C, K'\}$  is said to be efficient if it solves the following social planner problem:*

$$V(\theta, K) = \max_{T, D^c, D^i, N^y, C, K'} u \left( C, D, N^y + \frac{D^i}{\xi}, \theta \right) + \beta E\{V(\theta', K')|\theta\}$$

subject to

$$C \leq A(D^c)^\alpha (T)^{1-\alpha} f(K, N^y) \quad (50)$$

$$K' - (1 - \delta)K \leq A(D^i)^\alpha (1 - T)^{1-\alpha} f(K, N^y). \quad (51)$$

**Proposition 2.** *The competitive search equilibrium is efficient.*

Note that efficiency requires that markets are indexed by per-unit price, tightness, *and* quantity. This is necessary to avoid a hold-up problem between firms and consumers. Recall that once the consumers' search cost has been sunk and a consumer has been matched with a firm, a trade between them would be carried out regardless of the quantity offered. Therefore, if markets were characterized only by tightness and price, firms might find it optimal to deviate from the efficient quantity. However, once firms are allowed to index their market also on quantity, this hold-up problem disappears, and the competitive equilibrium allocation is efficient.<sup>7</sup>

### 3.8 Understanding Solow residual and labor share

We can use our model economy to compute the Solow residual provided that we specify a particular production. Let such production function be  $f(k, n) = z k^{\gamma_k} n^{\gamma_n}$ , where  $z$  is a parameter that determines units and  $\gamma_k + \gamma_n < 1$  (see Section 4 for a discussion). Measured with base year prices, GDP is given by

$$Y = P_0^c C + P_0^i I \quad (52)$$

where  $P_0^c$  is the base year consumption price and  $P_0^i$  is the base year investment price. By replacing  $C$  and  $I$  with the aggregate production function, GDP can be expressed as

$$Y = [P_0^c A(D^c)^\alpha T^{1-\alpha} + AP_0^i (D^i)^\alpha (1-T)^{1-\alpha}] z K^{\gamma_k} (N^y)^{\gamma_n}. \quad (53)$$

The Solow residual  $\bar{Z}$  is defined as  $\bar{Z} = \frac{Y}{K^{1-\gamma} N^\gamma}$ , where  $\gamma$  denotes the average labor share of output. In our model, the labor share in steady state is

$$\gamma = \frac{1}{1-\alpha} \gamma_n + \frac{\alpha \delta}{(1-\alpha)(1/\beta - 1 + \delta)} \gamma_k. \quad (54)$$

If we use this steady-state labor share to compute the Solow residual in our model, we have

$$\bar{Z} = A z \underbrace{[P_0^c (D^c)^\alpha T^{1-\alpha} + P_0^i (D^i)^\alpha (1-T)^{1-\alpha}]}_{\text{Demand Effect}} \underbrace{\left(\frac{N^y}{N}\right)^{\gamma_n}}_{\text{Effective Work}} \underbrace{K^{\gamma_k - (1-\gamma)} N^{\gamma_n - \gamma}}_{\text{Share's Error}}. \quad (55)$$

<sup>7</sup>See [Faig and Jerez \(2005\)](#) for a related argument in economies with private information. They find that to restore efficiency, it is necessary to index markets by a non-linear price-quantity schedule. In the case of symmetric information, their efficient indexation simplifies to our triplet index of price, tightness, and quantity.

That is, the Solow residual depends on the demand; increases in demand without changes in technology increase the Solow residual. The two additional terms are due to the mismeasure of productive labor and to the imputation of constant returns to scale. In empirical applications  $N - N^y$  is small and  $\gamma_n$  is close to  $\gamma$ . This implies that the last two terms in equation (55) are almost constant over the business cycle and that all movements in the Solow residual are due to movements in demand.

## 4 Mapping the model to data

To map the model to data, we start by making the case for the functional forms that we use and by describing the eleven implied parameters. We then discuss the targets for the steady state of the model economy.

**Preferences (four parameters).** We pose separable preferences to be able to clearly discuss the role of the Frisch labor elasticity and also to isolate the role of shopping. The per-period utility function or felicity is given by (56),

$$u(c, n, d) = \frac{c^{1-\sigma}}{1-\sigma} - \chi \frac{n^{1+\frac{1}{\nu}}}{1+\frac{1}{\nu}} - d, \quad (56)$$

where we omit the shocks to preferences for simplicity. The involved parameters are the discount rate  $\beta$ , the coefficient of risk aversion,  $\sigma$ , the Frisch elasticity of labor,  $\nu$ , and the parameter that determines average hours worked,  $\chi$ . That the disutility of shopping is linear is not important, since the shocks that affect it will shape its properties.

**Production technology (five parameters).** Firms have a decreasing returns Cobb-Douglas production function

$$f(k, n) = z k^{\gamma_k} (n^y)^{\gamma_n} \quad (57)$$

There is no need to impose constant returns to scale given the fact that the number of locations is fixed.<sup>8</sup> Note also that  $z$  is a parameter to determine units (below we will allow for shocks to  $z$ ). In addition, a worker devoted to shopping for investment goods produces  $\zeta$  units of shopping services, allowing for the possibility that firms could be better at shopping investment goods than people are at shopping for consumption goods. Capital depreciates at rate  $\delta$ .

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<sup>8</sup>The model could easily be extended to accommodate the costly creation of such locations.

**Matching technology (two parameters).** The matching technology is Cobb-Douglas indexed by  $A$  and  $\alpha$ :

$$A D^\alpha T^{1-\alpha}. \quad (58)$$

## 4.1 Calibration

In this economy, most of the targets for the steady state (and associated parameters) are the standard ones in business cycle research, whereas others are specific to this economy. Table 1 reports the targets and the parameters closest associated with each target. The targets are defined in yearly terms even though the model period is a quarter.

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

| Targets                                              | Value | Parameter       | Value |
|------------------------------------------------------|-------|-----------------|-------|
| First Group: Parameters Set Exogenously              |       |                 |       |
| Risk aversion                                        | 2.    | $\sigma$        | 2.    |
| Real interest rate                                   | 4%    | $\beta$         | 0.99  |
| Frisch elasticity                                    | 0.72  | $\frac{1}{\nu}$ | 0.72  |
| Second Group: Standard Targets                       |       |                 |       |
| Fraction of time spent working                       | 30%   | $\chi$          | 16.81 |
| Physical capital to output ratio                     | 2.75  | $\delta$        | 0.07  |
| Consumption share of output                          | 0.80  | $\gamma_k$      | 0.23  |
| Labor share of income                                | 0.67  | $\gamma_n$      | 0.59  |
| Steady-state output                                  | 1     | $z$             | 2.03  |
| Third Group: Targets Specific to This Economy        |       |                 |       |
| Share of production workers                          | 97%   | $\zeta$         | 3.16  |
| Capacity Utilization of consumption sector           | 0.81  | $A$             | 0.97  |
| Capacity Utilization of investment sector            | 0.81  | $\alpha$        | 0.09  |
| Implications over Other Aggregate Variables          |       |                 |       |
| Percentage of GDP payable to shoppers                |       |                 | 2%    |
| Percentage of cost of new capital that is internal   |       |                 | 9%    |
| Relative price of investment in terms of consumption |       |                 | 1     |
| Wealth to output ratio                               |       |                 | 3.33  |

The first group of parameters is set independently of the equilibrium allocation. The intertemporal elasticity of substitution is set to two, and the real rate of return is 4%. The Frisch elasticity is more controversial. We choose a value of 0.72, based on [Heathcote, Storesletten, and Violante](#)

(2008), who take into account the response of hours worked for both men and women in a model that explicitly incorporates households with husbands and wives.<sup>9</sup>

The targets in the second group are standard in the business cycle literature. Note that the consumption to output ratio is set to 0.8, since investment in our model is strictly business investment. We exclude consumption durables, since business investment and consumer durables use different shopping technologies.

The third group of targets is specific to our model. Our notion of capacity utilization is related to the series published by the Federal Reserve Board.<sup>10</sup> We target a steady-state capacity utilization of 81% in both sectors, which corresponds to the postwar average of the official data series (see [Corrado and Matthey \(1997\)](#)). We target 3% of the workforce as being involved in investment shopping even if we do not have direct measurements of such a variable. As the last panel of Table 1 shows, this choice implies that 2% of GDP is spent on search activities, or that 9% of the cost of installing new capital is internal to the firm. We view this as a plausible magnitude for the adjustment costs associated with finding the right investment goods.

The last panel of Table 1 reports that the relative price of consumption and investment is 1 (a direct implication of equal capacity utilization in both sectors) and the wealth to output ratio which turns out to be 3.33. This result has the nice feature that the book value of firms is only 80% of their stock market value.

## 5 Demand shocks in univariate economies

We now study economies with univariate shocks, i.e., economies where all fluctuations are driven by one shock. We analyze two types of shocks to preferences: shocks to the shopping technology of firms and shocks to total factor productivity. In Section 5.1 we estimate univariate shock processes with Bayesian methods<sup>11</sup> using only Solow residual data. We pose AR(1) shocks and assume that the persistence follows a Beta distribution while the volatility follows an inverse Gamma

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<sup>9</sup>Table A-3 of the Appendix reports results for an economy with a Frisch elasticity of 1.1.

<sup>10</sup>The Federal Reserve Board's Industrial Production and Capacity Utilization series is based on estimates of capacity and capacity utilization for industries in manufacturing, mining, and electric and gas utilities. For a given industry, the capacity utilization rate is equal to an output index (seasonally adjusted) divided by a capacity index. The purpose of the capacity indexes is to capture the concept of sustainable maximum output – the greatest level of output a plant can maintain within the framework of a realistic work schedule, after factoring in normal downtime and assuming sufficient availability of inputs to operate the capital in place.

<sup>11</sup>See [An and Schorfheide \(2007\)](#) or [Ríos-Rull, Schorfheide, Fuentes-Albero, Kryshko, and Santaaulalia-Llopis \(2009\)](#) for details.

distribution. We show that each one of these shocks can, on their own, generate fluctuations in the Solow residual like those in the U.S. data. Section 5.2 studies the quantitative business cycle properties of the univariate shock economies, showing that these economies have strongly counterfactual implications. In particular, the demand shock to consumption induces a reduction in investment, whereas the reverse occurs with a demand shock to investment. This result indicates that a shock that is joint to both consumption and investment is more likely to generate the correct comovements. This is in fact the case and is studied in Section 5.3.

## 5.1 Estimating shock processes of univariate economies

We pose a shock to the disutility of shopping,  $\theta_d$ , and another to the disutility of work,  $\theta_n$ , so we have  $c^{1-\sigma}/(1-\sigma) - \theta_n n^{1+1/\nu}/(1+1/\nu) - \theta_d d$ , a shock to the firm's shopping technology,  $\zeta$ , and a technology shock,  $z$ . The estimates are in Table 2. The last column of the table reports

Table 2: Estimates of the Processes for Univariate Shocks

| Shocks to             | Univariate Versions of the Shopping Model |              |              |                | Standard RBC   |
|-----------------------|-------------------------------------------|--------------|--------------|----------------|----------------|
|                       | Shop. Disut                               | Labor Disut  | Firm's Shop. | Tech           | Tech           |
|                       | $\theta_d$                                | $\theta_n$   | $\zeta$      | $z$            | $z$            |
| $\rho$                | 0.946                                     | 0.720        | 0.985        | 0.960          | 0.945          |
| Para(1)               | 0.94                                      | 0.72         | 0.95         | 0.95           | 0.94           |
| Para(2)               | 0.05                                      | 0.05         | 0.03         | 0.05           | 0.05           |
| 90% Intv              | [0.91, 0.98]                              | [0.66, 78]   | [0.98,0.99]  | [0.93, 0.99]   | [0.91, 0.98]   |
| $\sigma$              | 0.086                                     | 0.171        | 0.334        | 0.006          | 0.006          |
| Para(1)               | 0.09                                      | 0.17         | 0.30         | 0.004          | 0.006          |
| Para(2)               | 0.20                                      | 0.20         | 0.20         | 0.20           | 0.20           |
| 90% Intv              | [0.08, 0.09]                              | [0.16, 0.18] | [0.31, 0.36] | [0.006, 0.007] | [0.006, 0.007] |
| Likelihood            | 735.13                                    | 737.09       | 732.62       | 733.98         | 735.05         |
| Var of $\bar{Z}$      | 3.44                                      | 3.02         | 2.08         | 3.36           | 3.45           |
| Autocorr of $\bar{Z}$ | 0.95                                      | 0.96         | 0.91         | 0.95           | 0.95           |

the results from a standard RBC economy (without shopping), where the technology shock is the Solow residual. As is evident from the table, all of these shocks can generate a process for the Solow residual like that in the data, without having to resort to shocks to technology. Moreover, the estimates are quite precise, and in terms of likelihood, they are as good as those of the RBC

economy.<sup>12</sup> The standard deviations of these shocks are, however, quite a bit larger than those of the productivity shock. Interestingly the process of the technology shock in the shopping economy does not have a smaller variance than that of the shock in a standard RBC model. If anything (due to the larger autocorrelation), technology shocks as the only shocks of the shopping economy have a larger variance. This property indicates that the shopping economy does not amplify TFP shocks.

## 5.2 Business cycle properties of univariate economies

Whether demand shocks provide a good rationale for business cycles does not depend only on their ability to generate movements in the Solow residual. Indeed, what has made the model with technology shocks so popular is its ability to generate the right comovements: the Solow residual, output, and the components of output and hours worked are all strongly correlated, and investment is much more volatile than output, which in turn is more volatile than consumption. Table 3 shows how this is the case and how the standard RBC economy displays the right comovements. In this economy, however, the variance of hours is quite small. This is due to the relatively low Frisch elasticity of substitution that we use in our calibration (that we are using variances gives an additional optical illusion of being small).

Table 3: Main Business Cycle Moments: U.S. Data and Standard RBC Model

|                    | U.S. Data   |           |         | Standard RBC |           |         |
|--------------------|-------------|-----------|---------|--------------|-----------|---------|
|                    | Variance    | Cor w $Y$ | Autocor | Variance     | Cor w $Y$ | Autocor |
| $Z$                | 3.19        | 0.43      | 0.94    | 3.45         | 0.99      | 0.95    |
| $Y$                | <b>2.38</b> | 1.00      | 0.86    | <b>0.82</b>  | 1.00      | 0.71    |
| $N$                | <b>2.50</b> | 0.87      | 0.91    | <b>0.04</b>  | 0.96      | 0.72    |
| $C$                | 1.55        | 0.87      | 0.87    | 0.05         | 0.95      | 0.76    |
| $I$                | 34.15       | 0.92      | 0.80    | 13.74        | 0.99      | 0.71    |
| $\text{cor}(C, I)$ | <b>0.74</b> |           |         | <b>0.93</b>  |           |         |

All variables except the Solow residual are HP-filtered.

The business cycle statistics of the shopping economies are reported in Table 4. Clearly, they differ significantly from each other and from the RBC economy and the U.S. data. The only feature

<sup>12</sup>Table A-2 in the Appendix shows the details of its calibration, which is designed to be as close as possible to those of the shopping economy.

they really have in common is that output and the Solow residual move together – something that follows immediately from the way the Solow residual is constructed.

Table 4: Main Business Cycle Moments: Various Economies with Demand Shocks

| (a) Shop Disut $\theta_d$        |              |              |         | (b) Labor Disut $\theta_n$ |              |         |
|----------------------------------|--------------|--------------|---------|----------------------------|--------------|---------|
|                                  | Variance     | Cor w $Y$    | Autocor | Variance                   | Cor w $Y$    | Autocor |
| $Z$                              | 3.44         | 1.00         | 0.94    | 3.02                       | <b>-0.85</b> | 0.94    |
| $Y$                              | <b>0.37</b>  | 1.00         | 0.71    | <b>35.49</b>               | 1.00         | 0.58    |
| $N$                              | <b>0.07</b>  | <b>-1.00</b> | 0.72    | <b>97.13</b>               | 0.99         | 0.55    |
| $C$                              | 0.51         | 1.00         | 0.72    | 2.90                       | 0.76         | 0.84    |
| $I$                              | 0.03         | 0.99         | 0.69    | 626.37                     | 0.98         | 0.55    |
| $\text{cor}(C, I)$               | <b>0.99</b>  |              |         | <b>0.63</b>                |              |         |
| (c) Firms' Shopping Tech $\zeta$ |              |              |         | (d) Technology Shock $z$   |              |         |
|                                  | Variance     | Cor w $Y$    | Autocor | Variance                   | Cor w $Y$    | Autocor |
| $Z$                              | 2.08         | 0.73         | 0.91    | 3.45                       | 0.99         | 0.95    |
| $Y$                              | <b>1.73</b>  | 1.00         | 0.75    | <b>0.59</b>                | 1.00         | 0.73    |
| $N$                              | <b>0.54</b>  | 0.78         | 0.69    | <b>0.01</b>                | <b>-0.52</b> | 0.96    |
| $C$                              | 0.45         | <b>-0.53</b> | 0.74    | 0.22                       | 0.98         | 0.78    |
| $I$                              | 69.22        | 0.96         | 0.70    | 4.08                       | 0.98         | 0.70    |
| $\text{cor}(C, I)$               | <b>-0.74</b> |              |         | <b>0.92</b>                |              |         |

All variables except the Solow residual are HP-filtered.

In the economy with shocks to the *shopping disutility* (Panel (a)), labor is negatively correlated with output. This is counterfactual. These shocks generate a positive wealth effect: consumption goes up and work goes down. Consumer shoppers are more effective, and consumption-producing firms operate at higher capacity, allowing for lower work effort. So shocks of this type by themselves cannot be the trigger of fluctuations.

The *labor disutility* shock (Panel (b)) generates the volatility of the Solow residual by attracting more search effort when labor is low, making productivity and output negatively correlated. The variance of output required for this to happen is tremendous, six times that of the data, and that of labor is even larger, about 15 times that of the data. This economy generates comovements that are dramatically different from those associated with business cycles in the data.

The shock to the *firm's shopping technology* (Panel (c)) has to generate all the movements of the Solow residual from a small part of GDP, and hence its variance is immense. It makes hours worked quite volatile and positively correlated with output, but consumption is negatively correlated with output.

The economy featuring a *technology shock* (Panel (d)) has implications different from those than in the standard RBC. The existence of the search margin implies that households do not take advantage of the higher productivity by working longer hours; in fact, hours fall slightly. The comovement of consumption and investment has the right sign. In the shopping model, a positive productivity shock induces enough of a wealth effect and decreases consumers' shopping effort. It makes firms allocate more labor into searching, however, due to a lower investment goods price arising from the positive productivity shock. According to the Solow residual decomposition shown in Section 3.8, both lower consumer shopping and fewer production workers decrease the Solow residual, whereas higher firm shopping increases the Solow residual. In sum, these effects cancel out somehow and generate almost no amplification of the productivity shock. This also explains why the estimated volatility of innovation in our model is similar to that in the standard RBC model.

To summarize, the shopping economies with only demand shocks do not display the business cycle properties of the data in terms of the comovements of the major variables. In economies subject to TFP shocks or to shocks to the MRS between consumption and labor, there is a negative relation between labor and output. More importantly, in the economies with pure demand shocks (to either consumption demand or investment demand) the increase in the expenditures of the variable affected by the shock generates an increase in labor and the Solow residual but a reduction in the other component of expenditures, indicating that if demand shocks are to play a role, they have to affect consumption and investment simultaneously, a topic that we explore next.

### 5.3 Joint demand shocks

We now pose an economy with only one source of uncertainty but one that affects consumption and investment simultaneously. Specifically, we pose that  $\theta_d$  follows an AR(1) process to be estimated and that  $\zeta$  is proportional to  $\theta_d$ , with the proportionality constant to be estimated. As before, we use Bayesian methods for the estimation, with the new parameter's prior assumed to be normal. The top panel of Table 5 shows the estimates. The standard deviation of the consumption demand shock is 60% of what was needed in the pure univariate economy, whereas the standard deviation of the demand shock, although being two and a half times the standard deviation of the consumption

shock, is about one-third of what it was in the pure univariate version.

Table 5: The Shopping Economy with Perfectly Correlated Demand Shocks

| Priors and Posteriors for the Shock Parameters             |            |         |         |       |                |
|------------------------------------------------------------|------------|---------|---------|-------|----------------|
| Shopping model with $(\theta_d, \zeta)$ , likelihood = 734 |            |         |         |       |                |
| Parameter                                                  | Density    | Para(1) | Para(2) | Mean  | 90% Intv.      |
| $\rho_d$                                                   | Beta       | 0.95    | 0.05    | 0.968 | [0.946, 0.992] |
| $\sigma_d$                                                 | Inv. Gamma | 0.05    | 0.20    | 0.052 | [0.044, 0.059] |
| $\sigma_\zeta/\sigma_d$                                    | Normal     | 2.60    | 0.50    | 2.643 | [1.854, 3.471] |

  

| Main Business Cycle Statistics |          |                     |       |                      |                     |      |
|--------------------------------|----------|---------------------|-------|----------------------|---------------------|------|
|                                | Variance |                     |       | Correlation with $Y$ |                     |      |
|                                | Data     | $(\theta_d, \zeta)$ | RBC   | Data                 | $(\theta_d, \zeta)$ | RBC  |
| Solow                          | 3.19     | 3.33                | 3.45  | 0.43                 | 0.98                | 1.00 |
| $Y$                            | 2.38     | 0.84                | 0.82  | 1.00                 | 1.00                | 1.00 |
| $N$                            | 2.50     | 0.05                | 0.04  | 0.87                 | 0.57                | 0.96 |
| $C$                            | 1.55     | 0.10                | 0.05  | 0.87                 | 0.75                | 0.95 |
| $I$                            | 34.15    | 13.92               | 13.74 | 0.92                 | 0.97                | 1.00 |

The lower panel of Table 5 shows the business cycle statistics of this economy and compares them with those of the standard RBC economy. Now the comovements of the variables are the appropriate ones. Consumption and investment are positively correlated, with investment being substantially more volatile. Although hours is positively correlated with output, its volatility is too small. This is a shortcoming shared with the standard RBC model and is caused by the low Frisch elasticity and by the assumption that all employment is voluntary. Table A-3 in the Appendix shows how a Frisch elasticity of 1.1 doubles the volatility of hours worked in both models. Moreover, Section B of the Appendix compares versions of the shopping and RBC economies with a higher hours volatility due to an additional shock to the MRS that increases the volatility of hours. The findings remain unaltered. The shopping economy with a shock to demand that jointly affects consumption and investment performs as satisfactorily as the RBC economy in terms of generating business cycle statistics.

## 6 Estimating the contribution of all shocks

So far we have compared the shopping model against the RBC model. We now estimate the full-blown version of the shopping model, allowing all four shocks to matter. This allows us to impute the contribution of each shock to aggregate fluctuations. These shocks are the two demand shocks, a shock to MRS, and a true TFP shock. We again use Bayesian methods. We assume that, except for the consumption and investment demand shocks that are correlated, the shocks are independent. The data that we use are the Solow residual, output, hours, and consumption, all linearly detrended. We assume that the autocorrelations follow a Beta distribution, that the standard deviation of the innovations follow an inverse Gamma distribution, and that the correlation between demand shocks follows a normal distribution. Because of its importance for identification, we explore below in more detail the role of the correlation of the demand shocks.

Table 6 shows the priors and posteriors for all shock parameters. The 90% intervals are tight except for the correlation between the demand shocks. The estimates for the standard deviations of all shocks are much smaller than in the univariate shock economies (a factor of 8 for the shock to the MRS, a factor of 3 for the TFP shock, and a factor of 2.5 for the investment demand shock) except for the consumption demand shock (a factor of 1.2), indicating that the role of the demand shocks is likely to be the strongest. This is confirmed by the variance decomposition of the major aggregate variables also reported in Table 6. Demand shocks are much more important than the productivity shock, not only in terms of its contribution to output (63% relative to 1%) but also in terms of its contribution to the Solow residual itself (95% relative to 2%).

The volatility of hours is still dependent mostly on shocks to the MRS, but the demand shocks contribute 14% and productivity shocks have no effect on hours. Demand shocks also account for more than half of consumption and 90% of investment, whereas the contribution of TFP shocks is less than 5%.

An interesting and somewhat surprising feature of the estimates is the estimate of the correlation between the two demand shocks. When we consider only demand shocks to consumption and investment, the correlation has to be very large to obtain the right comovements between consumption, investment, labor, and output,<sup>13</sup> This is not the case, however, when all shocks are permitted to be present. Now the shocks are essentially orthogonal, and the correct comovements

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<sup>13</sup>Estimating the Solow residual out of orthogonal consumption and investment shocks with the same persistence yields an HP-filtered correlation between consumption and investment of -0.13 and between hours and output of 0.45.

of the main variables arise from the joint response to all shocks.

It is hard to say exactly where the identification comes from, given that the system is somewhat complicated. We think it has to do with the timing of the relative moment of the variables. In addition, the 90% interval of the estimated demand shock correlation is not very tight. To see how sensitive the variance decompositions are to this parameter, we re-estimated the shocks for values of the correlation between the demand shocks within the confidence interval varying from  $-0.1$  to  $0.1$ . The log-likelihood ratios of the estimates for the various values of the correlation are not significantly different from each other. As the correlation increases, the contribution of the demand shocks to the Solow residual goes from 97% to 65%, whereas that of output goes from 65% to 41%. See Table A-4 in the Appendix for details.

Table 6: Full Estimation of the Shopping Model

| Priors and Posteriors for the Shock Parameters (Likelihood = 2244.29) |               |         |         |               |                 |
|-----------------------------------------------------------------------|---------------|---------|---------|---------------|-----------------|
| Parameter                                                             | Density       | Para(1) | Para(2) | Mean          | 90% Intv.       |
| $\rho_d$                                                              | Beta          | 0.96    | 0.05    | <b>0.953</b>  | [0.930, 0.979]  |
| $\sigma_d$                                                            | Inverse Gamma | 0.072   | 0.20    | <b>0.073</b>  | [0.066, 0.084]  |
| $\rho_\zeta$                                                          | Beta          | 0.96    | 0.05    | <b>0.953</b>  | [0.930, 0.979]  |
| $\sigma_\zeta$                                                        | Inverse Gamma | 0.13    | 0.20    | <b>0.128</b>  | [0.109, 0.144]  |
| $\rho_z$                                                              | Beta          | 0.93    | 0.05    | <b>0.918</b>  | [0.840, 0.997]  |
| $\sigma_z$                                                            | Inverse Gamma | 0.002   | 0.20    | <b>0.002</b>  | [0.001, 0.003]  |
| $\rho_n$                                                              | Beta          | 0.95    | 0.05    | <b>0.996</b>  | [0.992, 1.000]  |
| $\sigma_n$                                                            | Inverse Gamma | 0.02    | 0.20    | <b>0.022</b>  | [0.020, 0.024]  |
| $\text{Cor}(\theta_d, \zeta)$                                         | Normal        | -0.10   | 0.20    | <b>-0.055</b> | [-0.225, 0.080] |

  

|       | Variance Decomposition (%) |         |      |            | Business Cycle Statistics |         |
|-------|----------------------------|---------|------|------------|---------------------------|---------|
|       | $\theta_d$                 | $\zeta$ | $z$  | $\theta_n$ | Variances                 | Cor w Y |
| $Y$   | 32.44                      | 30.46   | 1.21 | 35.89      | 1.07                      | 1.00    |
| Solow | 81.66                      | 14.23   | 2.15 | 1.97       | 12.88                     | 0.63    |
| $N$   | 2.91                       | 10.88   | 0.02 | 86.18      | 1.29                      | 0.61    |
| $C$   | 52.34                      | 15.52   | 0.75 | 31.39      | 0.69                      | 0.62    |
| $I$   | 1.84                       | 87.76   | 0.52 | 9.88       | 16.44                     | 0.77    |

Lastly, we report the major business cycle statistics for the estimations conducted in this section in the bottom right panel of Table 6. The shopping economy gets the right comovements between the main variables. With respect to the variances, they are too high for the Solow residual and too

low for output and labor.

## 7 Other business cycle implications of the shopping economies

In this section, we explore additional interesting implications of the shopping economies that are absent from the standard RBC model. In the shopping model, the relative price of investment, the stock market price, and capacity utilization are all endogenous variables that move over the cycle. Table 7 reports the properties of the data and the two main versions of the shopping model that we have explored: the version with perfectly correlated demand shocks and the economy estimated with all shocks.

1. *The relative price of investment.* The role of the relative price of investment in shaping economic performance has been studied in various contexts, from its role in shaping the skill premia (Krusell, Ohanian, Rios-Rull, and Violante (2000)) to its role as a direct source of business cycles (Fisher (2006)). In most of these cases, such relative price is taken to be an exogenous object that depends purely on technological considerations (an exception is Valles (1997), which uses a non-linear production possibility frontier). In our economy, the relative price of consumption and investment is purely an economic object, since consumption and investment are perfect substitutes in production. In the shopping environment, a reduction in the disutility (or cost) of shopping translates into a willingness to shop longer while facing a cheaper price for the consumption (or the investment) good. In the data, the relative price of investment is countercyclical and less volatile than output. The model economies also pose a countercyclical relative price of investment. The economy with only demand shocks has a volatility that is twice that in the data and, like the data, is negatively correlated with output, albeit much more than the data. The multiple shock economy has an extremely volatile relative price of investment with the correct correlation. We find this encouraging because we believe that in the data, consumption and investment goods are only partially substitutable and hence the model is likely to exaggerate the volatility of the relative price.
2. *The stock market price.* Given our normalization, the stock market is just the inverse of the price of consumption. In the shopping economy, the value of firms changes not only because of changes in the cost of shopping for new capital, but also because the value of locations capable of matching with shoppers changes. As is well known, the stock market price in the data is extremely volatile with a variance of log about 40 times that of output. It is also procyclical. Our model does indeed generate a procyclical stock price. Not surprisingly, the

variance of the price is much smaller than that of the data, but still sizeable especially given the low risk aversion that we have posed. The correlation is similar to that of the data in both economies.

3. *Capacity utilization.* In the shopping economies, the ratio of output to potential output is constantly changing, with higher utilization resulting in higher measured productivity. In the United States, the Federal Reserve Board has constructed a series of capacity utilization, which is about twice as volatile as output and very procyclical. Our model without frictions in production also has procyclical utilization, although with lower volatility than the data. One indication of this finding might be that there are other fixed factors in production besides capital, and such omitted factors contributes to the larger value of the volatility in the data.

We conclude that the shopping economy captures the qualitative aspects of the additional dimensions of business cycles.

Table 7: Other Business Cycle Statistics for the Full Estimation Shopping Model

|                        | Variance |                   |                                    | Correlation with $Y$ |                   |                                    |
|------------------------|----------|-------------------|------------------------------------|----------------------|-------------------|------------------------------------|
|                        | Data     | $\theta_d, \zeta$ | $\theta_d, \zeta$<br>$z, \theta_n$ | Data                 | $\theta_d, \zeta$ | $\theta_d, \zeta$<br>$z, \theta_n$ |
| $p_i/p_c$              | 0.47     | 0.98              | 2.71                               | -0.23                | -1.00             | -0.30                              |
| Stock Market (S&P 500) | 42.64    | 0.26              | 1.82                               | 0.41                 | 0.26              | 0.33                               |
| Capacity Utilization   | 10.02    | 0.68              | 0.57                               | 0.89                 | 0.99              | 0.71                               |

## 8 Conclusions and Extensions

In this paper, we have developed a model where demand shocks generate procyclical productivity via a cyclical use of production capacity that implies inconveniences for shoppers. We have developed the theory using search frictions under competitive search protocols that imply optimality (and hence existence and uniqueness) of equilibrium. We have shown how demand shocks can replicate the movements of the Solow residual that the RBC literature typically identifies with technology shocks. We show that correlated shocks to the demand of consumption and investment replicate the properties of the standard real business cycle models in terms of the comovements of macroeconomic variables. If anything, our model performs marginally better. When allowing in our model economy for the coexistence of demand shocks and technology shocks, a full Bayesian estimation imputes essentially no role to technology shocks even in shaping the properties of the

Solow residual. In addition, our shopping economies have implications for other macroeconomic variables (relative price of consumption and investment, the stock market, capacity utilization) over which standard models are silent. Such implications are remarkably consistent with the data.

Our assessment of the findings is that our modeling structure provides an alternative to technology shocks as a source of fluctuations. We think that these findings can and should be naturally applied to the other most popular lines of business cycle research (New Keynesian and Mortensen-Pissarides type of models) to accommodate demand shocks as a substitute for technology shocks as the main source of fluctuations. We also think that our findings may provide a rationale for fiscal stimulus packages, a feature that is hard to rationalize in standard macro models. The research agenda we think is clear and has two directions: to pose deep models of demand shocks: financial shocks, shocks to the real exchange rate, wealth shocks, monetary policy, etc.; and to accommodate mechanisms that substitute the frictionless labor market.

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## APPENDIX

### A Proofs

#### Proof of Proposition 1.

*Proof.* Substituting  $d = c/\Psi_d(D)$  into the period utility and differentiating  $u$  w.r.t.  $c$ , we get

$$\frac{du}{dc} = u_c + \frac{\partial u}{\partial d} \frac{\partial d}{\partial c} = u_c + \frac{u_d}{\Psi_d(D)}$$

The Euler equation can then be expressed as

$$u_c + \frac{u_d}{\Psi_d(D)} = p(\theta)m.$$

Impose the representative agent conditions  $c = C = AD^\alpha$  and  $d = D$ , and use (9) to substitute out the term  $p(\theta)m$ . This gives one functional equation:

$$u_c(C(\theta), D(\theta), \theta) + \frac{u_d(C(\theta), D(\theta), \theta)}{\Psi_d(D(\theta))} = (1 - \alpha) u_c(C(\theta), D(\theta), \theta).$$

Rearranging this equation and using (11) yields the functional equation (12). The functional equation (13) is derived from the equilibrium price equation (9) and the definition of  $m$ , where we exploit the envelope theorem and (5) to express  $\partial v/\partial s$  as

$$\frac{\partial v(\theta, s)}{\partial s} = u_c(C(\theta), D(\theta), \theta) + \frac{u_d(C(\theta), D(\theta), \theta)}{\Psi_d[Q(\theta)]}.$$

At the equilibrium, the agents' budget constraint (6) is satisfied. Given (12)-(13), the first-order conditions of (4) hold, which guarantees individual optimization.

Consider the planner problem  $\max_{C,D} \{u(C, D, \theta)\}$  subject to the aggregate resource constraint  $C = A D^\alpha$ . It is straightforward to verify that the solution to equation (12) solves this planner problem, which establishes efficiency.  $\square$

**Lemma 1.**  $\Omega^c(\theta, K, k) = \Omega^i(\theta, K, k)$  implies  $\varsigma^c(\theta, K, k) = \varsigma^i(\theta, K, k)$ .

*Proof.* From the firms' first-order condition over  $k'$  (33), it is clear that both marginal return

and marginal cost of capital are independent of the firms' current choice over which goods to produce and choice of labor for production. This implies that firms simply search for the markets that give them the best current revenue. Thus,  $\Omega^c(\theta, K, k) = \Omega^i(\theta, K, k)$  implies  $\varsigma^c(\theta, K, k) = \varsigma^i(\theta, K, k)$ .  $\square$

**Lemma 2.** *All firms with  $k = K$  choose markets with the same output  $F = F^c = F^i$  and also the same labor input for production.*

*Proof.* Let's define  $n^c(K, \theta)$  as the necessary labor for a consumption-producing firm with capital  $k = K$  to produce output  $y^c(\theta, K)$ , namely,  $n^c(K, \theta) = n(K, y^c(\theta, K))$ . Similarly, we define  $n^i(K, \theta) = n(K, y^i(\theta, K))$  for investment-producing labor. In equilibrium, firms are indifferent between producing consumption goods or investment goods, i.e.,  $\varsigma^c = \varsigma^i$ . By definition,  $\varsigma^c = P^c(\theta, K)A[Q^c(\theta, K)]^{-\alpha}y^c(\theta, K) - w(\theta, K)n^c(\theta, K)$ . We can further rewrite  $\varsigma^c$  using equilibrium conditions from the competitive search  $\frac{w(\theta, K)}{P^c(\theta, K)} = \frac{1}{1-\alpha}A(Q^c)^{-\alpha}f_n[K, n^c(\theta, K)]$ ,

$$\begin{aligned}\varsigma^c &= P^c(\theta, K)A[Q^c(\theta, K)]^{-\alpha}y^c(\theta, K) - w(\theta, K)n^c(\theta, K) \\ &= w(\theta, K) \left[ \frac{P^c(\theta, K)A[Q^c(\theta, K)]^{-\alpha}y^c(\theta, K)}{w(\theta, K)} - n^c(\theta, K) \right] \\ &= w(\theta, K) \left[ (1-\alpha) \frac{A[Q^c(\theta, K)]^{-\alpha}y^c(\theta, K)}{A[Q^c(\theta, K)]^{-\alpha}f_n[K, n^c(\theta, K)]} - n^c(\theta, K) \right] \\ &= w(\theta, K) \left[ (1-\alpha) \frac{f[K, n^c(\theta, K)]}{f_n[K, n^c(\theta, K)]} - n^c(\theta, K) \right].\end{aligned}$$

Similarly, we have

$$\varsigma^i = w(\theta, K) \left[ (1-\alpha) \frac{f[K, n^i(\theta, K)]}{f_n[K, n^i(\theta, K)]} - n^i(\theta, K) \right].$$

Equalizing  $\varsigma^i$  and  $\varsigma^c$  implies that  $n^c(\theta, K) = n^i(\theta, K)$  under the assumption that the production function is concave and strictly increasing in labor. Thus, the labor inputs are the same for the firms with the same capital  $k = K$ . Their outputs must be the same too.  $\square$

**Lemma 3.** *The expected revenue per unit of output is the same in both sectors:*

$$P^c(\theta, K) \frac{\Psi_d[Q^c(\theta, K)]}{Q^c(\theta, K)} = P^i(\theta, K) \frac{\Psi_d[Q^i(\theta, K)]}{Q^i(\theta, K)}. \quad (\text{A-1})$$

*Proof.* Under Lemma 2, firms with the same  $k = K$  have the same labor input for production, the same output, and the same  $\varsigma$ . This implies equation (A-1).  $\square$

**Lemma 4.** *Firms with the same  $k$  choose the same  $k'$  as future capital stock.*

*Proof.* According to Lemma 2, firms with the same  $k$  choose the same labor input. For a firm that considers producing consumption goods tomorrow, the first-order condition over  $k'$  is given by

$$E \left\{ \left[ -w(\theta', K') n_k(k', y(\theta', K')) + (1 - \delta) \left( \frac{w(\theta', K')}{\varsigma \Psi_d[Q^i(\theta', K')] f[(\theta', K')]} + P^i(\theta', K') \right) \right] \Pi(\theta, \theta', K) \middle| \theta \right\} \\ = \frac{w(\theta, K)}{\varsigma \Psi_d[Q^i(\theta, K)] f[(\theta, K)]} + P^i(\theta, K).$$

For a firm that considers producing investment goods tomorrow, the first-order condition over  $k'$  is

$$E \left\{ \left[ -w(\theta', K') n_k(k', y(\theta', K')) + (1 - \delta) \left( \frac{w(\theta', K')}{\varsigma \Psi_d[Q^i(\theta', K')] f[K^i(\theta', K')]} + P^i(\theta', K') \right) \right] \Pi(\theta, \theta', K) \middle| \theta \right\} \\ = \frac{w(\theta, K)}{\varsigma \Psi_d[Q^i(\theta, K)] f[(\theta, K)]} + P^i(\theta, K). \quad (\text{A-2})$$

With Lemma 2, it is easy to see that the first-order conditions for  $k'$  of future consumption-producing firms and investment-producing firms are identical. Thus, all the firms with the same current capital choose the same future capital.  $\square$

**Lemma 5.** *The investment price is proportional to the ratio of the wage and the amount of shopping that a worker can carry out:*

$$\frac{w(\theta, K)}{\varsigma \Psi_d[Q^i(\theta, K)] f(K, N^y(\theta, K))} = \frac{\alpha}{1 - \alpha} P^i(\theta, K).$$

*Proof.* From investment-producing firms' first-order condition over  $k'$ , we have

$$E \{ \Omega(\theta', K', k') \Pi(\theta, \theta', K) | \theta \} = \frac{w(\theta, K)}{\zeta \Psi_d[Q^i(\theta, K)] f[K, N^i(\theta, K)]} + P^i(\theta, K).$$

The equilibrium search in the investment goods market implies

$$P^i(\theta, K) = (1 - \alpha) E \{ \Omega(\theta', K', k') \Pi(\theta, \theta', K) | \theta \}.$$

Combining the above two equations proves the lemma.  $\square$

**Lemma 6.** *The Euler equation of a firm equates the price of investment with the value of capital tomorrow:*

$$E \left\{ P^i(\theta', K') \left[ \frac{\Psi_d(Q^i)}{Q^i} f_k(K', N^y(\theta', K')) + (1 - \delta) \right] \Pi(\theta, \theta', K) \middle| \theta \right\} = P^i(\theta, K).$$

*Proof.* Recall that investment-producing firms choose future capital stock evaluated at  $K'$  according to equation (A-2). According to Lemma 5, we can replace  $\frac{w(\theta, K)}{\zeta \Psi_d[Q^i(\theta, K)] f(K, N^y(\theta, K))}$  with  $\frac{\alpha}{1-\alpha} P^i(\theta, K)$ . The same is true for the future variables. The Euler becomes

$$E \left\{ \frac{-w(\theta', K') n_k(K', y(\theta', K')) + (1 - \delta) P^i(\theta', K')}{1 - \alpha} \Pi(\theta, \theta', K) \middle| \theta \right\} = \frac{P^i(\theta, K)}{1 - \alpha}.$$

Multiplying  $1 - \alpha$  on both sides and reorganizing the equation, we have

$$E \left\{ P^i(\theta', K') \Pi(\theta, \theta', K) \left[ -(1 - \alpha) \frac{w(\theta', K') n_k(K', y(\theta', K'))}{P^i(\theta', K')} + (1 - \delta) \right] \middle| \theta \right\} = P^i(\theta, K).$$

Substituting  $w(\theta', K')/P^i(\theta', K')$  with  $\frac{1}{1-\alpha} \frac{\Psi_d(Q^i)}{Q^i} f_n(K', N^y(\theta', K'))$  from the competitive search problem, we can rewrite the Euler as

$$E \left\{ P^i(\theta', K') \Pi(\theta, \theta', K) \left[ -\frac{\Psi_d(Q^i)}{Q^i} f_n(K', N^y(\theta', K')) n_k(K', y(\theta', K')) + (1 - \delta) \right] \middle| \theta \right\} = P^i(\theta, K).$$

According to the implicit function theorem,  $n_k \equiv \frac{dn}{dk} = -\frac{f_k}{f_n}$ . Thus,  $f_k = -f_n n_k$ . Substituting

$-f_n n_k$  with  $f_k$  in the Euler equation, we have

$$E \left\{ P^i(\theta', K') \left[ \frac{\Psi_d(Q^i)}{Q^i} f_k(K', N^y(\theta', K')) + (1 - \delta) \right] \Pi(\theta, \theta', K) \middle| \theta \right\} = P^i(\theta, K).$$

□

## A.1 Proof of Proposition 2.

*Proof.* Let  $\lambda$  be the multiplier for condition (50) and  $\mu$  be the multiplier for condition (51). The first-order conditions are given by

$$\begin{aligned} u_C &= \lambda \quad (\text{over } C) \\ u_D &= \lambda \alpha A(D^c)^{\alpha-1} (T)^{1-\alpha} f \quad (\text{over } D^c) \\ \frac{u_N}{\zeta} &= \mu \alpha A(D^i)^{\alpha-1} (1-T)^{1-\alpha} f \quad (\text{over } D^i) \\ u_N &= \lambda A(D^c)^\alpha (T)^{1-\alpha} f_n + \mu A(D^i)^\alpha (1-T)^{1-\alpha} f_n \quad (\text{over } N^y) \\ \lambda(1-\alpha)A(D^c)^\alpha (T)^{-\alpha} &= \mu(1-\alpha)A(D^i)^\alpha (1-T)^{-\alpha} \quad (\text{over } T) \\ \mu &= \beta E \left\{ \lambda' A'(D^{c'})^\alpha (T')^{1-\alpha} f_{k'} + \mu' A'(D^{i'})^\alpha (1-T')^{1-\alpha} f_{k'} + \mu'(1-\delta)|\theta \right\} \end{aligned}$$

After simplifying, the efficient allocation  $\{T, D^c, D^i, N^y, C, K'\}$  can be characterized by the following six equations:

$$\frac{u_N}{u_C} = A(D^c)^\alpha (T)^{-\alpha} f_n \quad (\text{A-3})$$

$$\frac{u_D}{u_C} = \alpha A(D^c)^{\alpha-1} (T)^{1-\alpha} f \quad (\text{A-4})$$

$$f_n = \frac{\alpha \zeta (1-T) f}{D^i} \quad (\text{A-5})$$

$$u_C \frac{(D^c)^\alpha (T)^{-\alpha}}{(D^i)^\alpha (1-T)^{-\alpha}} = \beta E \left\{ u_{C'} \frac{(D^{c'})^\alpha (T')^{-\alpha}}{(D^{i'})^\alpha (1-T')^{-\alpha}} \left[ A'(D^{i'})^\alpha (1-T')^{1-\alpha} f_{k'} + (1-\delta) \right] \right\} \quad (\text{A-6})$$

$$C \leq A(D^c)^\alpha (T)^{1-\alpha} f(K, N^y) \quad (\text{A-7})$$

$$K' - (1-\delta)K \leq A(D^i)^\alpha (1-T)^{1-\alpha} f(K, N^y) \quad (\text{A-8})$$

Equation (A-3) implies that the marginal rate of substitution between consumption and leisure equals the marginal product of labor. Equation (A-4) implies that the marginal rate of substitution between consumption and shopping effort equals the marginal product of shopping in the consumption-goods-producing sector. Equation (A-5) implies that the marginal products of production labor and search labor are the same. Equation (A-6) is the Euler equation for capital. Equations (A-7) and (A-8) are the resource constraints.

To show that the competitive search equilibrium is efficient, we must prove that the equilibrium allocation satisfies equations (A-3)-(A-8). Clearly, the resource constraints (A-7)-(A-8) are satisfied. In equilibrium, wage is equal to both the marginal product of labor of consumer-producing firms and the marginal rate of substitution between leisure and consumption of households, i.e.,

$$\begin{aligned}\frac{w}{P^c} &= \frac{1}{1-\alpha} A(D^c)^\alpha (T)^{-\alpha} f_n, \\ \frac{w}{P^c} &= \frac{u_N}{(1-\alpha)u_C}.\end{aligned}$$

Combining these two equations implies that the equilibrium allocation satisfies equation (A-3).

Equation (A-4) is also satisfied through the following two conditions in equilibrium:

$$\begin{aligned}u_c - \frac{u_D}{A(D^c)^{\alpha-1}(T)^{1-\alpha}f} &= P^c M, \\ P^c &= (1-\alpha) \frac{u_c}{M},\end{aligned}$$

where  $M$  is the expected discounted marginal utility of an additional unit of savings. The first equation is from consumers' optimal choice between consumption and shopping effort. The second equation comes from optimal consumer search.

Similarly, combining consumers' first-order condition over labor with the firms' and consumer's search problems, we can obtain equation (A-5).

Lastly, we show that the Euler equation for capital, equation (A-6), is satisfied. According to Lemma 6 in the paper,

$$E \left\{ \Pi(\theta, \theta', K) P^{i'} \left[ \frac{\Psi_d(Q^{i'})}{Q^{i'}} f_{k'} + (1-\delta) \right] \right\} = P^i. \quad (\text{A-9})$$

Substituting the definition for  $\Pi$  and  $\Psi_d(Q^i)/Q^i = A(D^i)^\alpha(1-T)^{-\alpha}$  into equation (A-9), we have

$$\beta E \left\{ \frac{P^c u_{C'}}{P^c u_C} P^{i'} [A'(D^{i'})^\alpha(1-T')^{-\alpha} f_{k'} + (1-\delta)] \right\} = P^i.$$

Reorganizing the above equation, we have

$$\beta E \left\{ \frac{P^{i'}}{P^c} u_{C'} [A'(D^{i'})^\alpha(1-T')^{-\alpha} f_{k'} + (1-\delta)] \right\} = \frac{P^i}{P^c} u_c.$$

Recall that

$$\frac{P^i}{P^c} = \frac{(D^c)^\alpha(T)^{-\alpha}}{(D^i)^\alpha(1-T)^{-\alpha}}.$$

Thus, the Euler equation in the competitive search equilibrium can be written as

$$\beta E \left\{ u_{C'} \frac{(D^c)^\alpha(T)^{-\alpha}}{(D^{i'})^\alpha(1-T')^{-\alpha}} [A'(D^{i'})^\alpha(1-T')^{-\alpha} f_{k'} + (1-\delta)] \right\} = \frac{(D^c)^\alpha(T)^{-\alpha}}{(D^i)^\alpha(1-T)^{-\alpha}} u_c,$$

which is exactly the Euler equation from the social planner's problem, equation (A-6). □

## B Main shocks plus shocks to the MRS in the shopping and RBC economies

As a further comparison of the shopping and the RBC economy's performance, we estimate versions of both economies where, in addition to the main shock that moves the Solow residual (both a shock to the demand of consumption and investment in the shopping economy and a shock to TFP in the RBC economy), we pose a shock to the MRS that moves the willingness to work. We assume that both the main shocks and the MRS shocks are uncorrelated and, as in Section 5.3, we estimate the relative size of the demand shocks to consumption and investment (they are perfectly correlated). The estimations for both models use Bayesian methods over the Solow residual and output data. We assume that the autocorrelations follow Beta distributions and that innovations of the shocks follow inverse Gamma distributions. The priors, posteriors, and the estimated parameters are reported in Table A-1. The log likelihood for the shopping model is 1492, significantly higher than that in the standard RBC model of 1484. The 90% intervals are tight, indicating significant estimated parameters. All shocks are highly persistent. The volatility

of the demand shocks is much larger than that of the technology shock of the RBC model, and the volatility and persistence of the shock to the MRS are a bit lower. Table A-1 also reports the variance decomposition over the major business cycle variables. We see that the demand shocks play a more central role in the shopping model than the TFP shock in the RBC model: the variance of the MRS shock is lower in the shopping model, and the contribution of the demand shock to the variance of the endogenous variables is larger. The last panel of Table A-1 presents the business cycle statistics for the major variables, for both the shopping model and the standard RBC model. They are very similar, with the volatility of hours being slightly higher in the RBC model.

## C Computational Details

**Data** We used seven raw data series in the paper: GDP, consumption, investment, labor, capacity utilization, stock market price, and relative price of investment. The data series of GDP, consumption, investment, and labor are from the Bureau of Economic Analysis (BEA) for the period of 1948:Q1-2009:Q4. The data series of capacity utilization is the Industrial Production and Capacity Utilization published by the Federal Reserve Board. The series is from 1967:Q1 to 2009Q4 and is based on estimates of capacity utilization for industries in manufacturing, mining, and electric and gas utilities. For a given industry, the capacity utilization rate is equal to an output index (seasonally adjusted) divided by a capacity index. The raw data of S&P 500 stock market price is a monthly data series compiled by Robert Shiller based on the daily price of S&P 500 stock market price, available at <http://www.econ.yale.edu/~shiller/data.htm>. Our quarterly data of stock price is the monthly average of the raw data in each quarter. Lastly, the relative price of investment is from 1948Q1 to 2009Q4, constructed in Ríos-Rull, Schorfheide, Fuentes-Albero, Kryshko, and Santaella-Llopis (2009). We detrend all data series with a Hodrick-Prescott filter.

**Computation.** The model is estimated using Dynare, which adopts a Metropolis-Hastings algorithm for the Bayesian estimation. Using Dynare, we exploited twelve endogenous variables

Table A-1: Comparison of Shopping Model and RBC Model: Main Shocks Plus Shocks to the MRS

| Priors and Posteriors for the Shock Parameters |                          |            |           |              |                  |
|------------------------------------------------|--------------------------|------------|-----------|--------------|------------------|
| Shopping model (likelihood = 1499)             |                          |            |           |              |                  |
| Parameter                                      | Density                  | Para(1)    | Para(2)   | Mean         | 90% Intv.        |
| $\rho_d$                                       | Beta                     | 0.95       | 0.05      | <b>0.926</b> | [0.900, 0.952]   |
| $\sigma_d$                                     | Inverse Gamma            | 0.20       | 0.20      | <b>0.061</b> | [0.053, 0.068]   |
| $\sigma_\zeta/\sigma_d$                        | Normal                   | 0.50       | 0.50      | <b>1.861</b> | [1.131, 2.320]   |
| $\rho_n$                                       | Beta                     | 0.95       | 0.05      | <b>0.982</b> | [0.969, 0.999]   |
| $\sigma_n$                                     | Inverse Gamma            | 0.06       | 0.20      | <b>0.019</b> | [0.017, 0.020]   |
| RBC model (likelihood = 1484)                  |                          |            |           |              |                  |
| Parameter                                      | Density                  | Para(1)    | Para(2)   | Mean         | 90% Intv.        |
| $\rho_z$                                       | Beta                     | 0.93       | 0.05      | <b>0.952</b> | [0.925, 0.981]   |
| $\sigma_z$                                     | Inverse Gamma            | 0.006      | 0.20      | <b>0.006</b> | [0.0055, 0.0065] |
| $\rho_n$                                       | Beta                     | 0.94       | 0.05      | <b>0.993</b> | [0.981, 1.000]   |
| $\sigma_n$                                     | Inverse Gamma            | 0.02       | 0.20      | <b>0.021</b> | [0.018, 0.023]   |
| Variance Decomposition (%)                     |                          |            |           |              |                  |
|                                                | Shopping model           |            | RBC model |              |                  |
|                                                | $\theta_d, \theta_\zeta$ | $\theta_n$ | $z$       | $\theta_n$   |                  |
| $Y$                                            | 74.62                    | 25.38      | 63.13     | 36.87        |                  |
| Solow                                          | 98.47                    | 1.53       | 100.00    | 0.00         |                  |
| $N$                                            | 6.17                     | 93.83      | 3.08      | 96.92        |                  |
| $C$                                            | 44.36                    | 55.64      | 19.71     | 80.29        |                  |
| $I$                                            | 89.19                    | 10.81      | 86.02     | 13.98        |                  |
| Business Cycle Statistics                      |                          |            |           |              |                  |
|                                                | Shopping model           |            | RBC model |              |                  |
|                                                | Variance                 | Cor w $Y$  | Variance  | Cor w $Y$    |                  |
| $Y$                                            | 1.23                     | 1.00       | 1.27      | 1.00         |                  |
| Solow                                          | 2.45                     | 0.78       | 4.19      | 0.79         |                  |
| $N$                                            | 0.94                     | 0.63       | 1.09      | 0.73         |                  |
| $C$                                            | 0.26                     | 0.82       | 0.31      | 0.88         |                  |
| $I$                                            | 16.34                    | 0.96       | 14.58     | 0.96         |                  |

$\{C, I, K', N^y, N, T, D^c, D^i, P^c, P^i, R, w\}$  with the following twelve equations:

$$\begin{aligned}
P^i \frac{C^{-\sigma}}{P^c} &= \beta E \left\{ P^{i'} \frac{(C')^{-\sigma}}{P^{c'}} \left[ \gamma_k \frac{P^{c'} C'}{P^{i'} K' T'} + (1 - \delta) \right] \right\}, \\
\frac{C^{-\sigma}}{P^c} &= \beta E \left\{ \frac{(1 + R')(C')^{-\sigma}}{P^{c'}} \right\}, \\
(1 - \alpha) \frac{w}{P^c} &= \chi \theta_n N^{\frac{1}{\nu}} C^\sigma, \\
(1 - \alpha) \frac{w}{P^c} &= \gamma_n \frac{C}{N^y T}, \\
\theta_d D^c &= \alpha C^{1-\sigma}, \\
P^c (D^c)^\alpha T^{-\alpha} &= P^i (D^i)^\alpha (1 - T)^{-\alpha}, \\
P^i &= \frac{1 - \alpha}{\alpha} \frac{w D^i}{\zeta I}, \\
N &= N^y + D^i / \zeta, \\
C &= A (D^c)^\alpha (T)^{1-\alpha} z K^{\gamma_k} (N^y)^{\gamma_n}, \\
I &= A (D^i)^\alpha (1 - T)^{1-\alpha} z K^{\gamma_k} (N^y)^{\gamma_n}, \\
I &= K' - (1 - \delta) K, \\
R &= P^c C - w N.
\end{aligned}$$

## D Additional tables

Table A-2 presents the calibration for the standard RBC model. The intertemporal elasticity of substitution  $\sigma$  is set to 2, and the real rate of return is 4%. We choose a Frisch elasticity of 0.72. We calibrate the depreciation rate to match the observed consumption to output ratio of 0.8. The labor share is 0.67 in the data, which implies  $\gamma_n = 0.67$ . The disutility parameter  $\chi$  is calibrated to match the average time spent at working of 30%. We normalize the mean of the productivity shock such that aggregate output is 1 at steady state.

Table A-2: Calibration for the Standard RBC Model

| Targets                        | Value | Parameter       | Value |
|--------------------------------|-------|-----------------|-------|
| Risk aversion                  | 2     | $\sigma$        | 2     |
| Real interest rate             | 4%    | $\beta$         | 0.99  |
| Frisch elasticity              | 0.72  | $\frac{1}{\nu}$ | 0.72  |
| Fraction of time spent working | 30%   | $\chi$          | 18.49 |
| Consumption Share of Output    | 0.80  | $\delta$        | 0.06  |
| Labor Share of income          | 0.67  | $\gamma_n$      | 0.67  |
| Units of output                | 1     | $z$             | 0.94  |

Table A-3: Perfectly Correlated Demand Shocks in the Shopping Economy versus  
TFP Shocks in an RBC Economy with a Frisch Elasticity of 1.1

Priors and Posteriors for the Shock Parameters

| Shopping model with $(\theta_d, \zeta)$ , likelihood = 733.43 |            |         |         |       |                |
|---------------------------------------------------------------|------------|---------|---------|-------|----------------|
| Parameter                                                     | Density    | Para(1) | Para(2) | Mean  | 90% Intv.      |
| $\rho_d$                                                      | Beta       | 0.95    | 0.05    | 0.979 | [0.962, 0.995] |
| $\sigma_d$                                                    | Inv. Gamma | 0.05    | 0.20    | 0.049 | [0.036, 0.061] |
| $\sigma_\zeta/\sigma_d$                                       | Normal     | 2.60    | 0.90    | 2.860 | [1.414, 4.328] |

  

| RBC model with $z$ , likelihood = 734.8 |            |         |         |       |                  |
|-----------------------------------------|------------|---------|---------|-------|------------------|
| Parameter                               | Density    | Para(1) | Para(2) | Mean  | 90% Intv.        |
| $\rho_z$                                | Beta       | 0.95    | 0.05    | 0.948 | [0.916, 0.984]   |
| $\sigma_z$                              | Inv. Gamma | 0.006   | 0.20    | 0.006 | [0.0055, 0.0065] |

  

Main Business Cycle Statistics

|       | Variance |                     |       | Correlation with $Y$ |                     |      |
|-------|----------|---------------------|-------|----------------------|---------------------|------|
|       | Data     | $(\theta_d, \zeta)$ | RBC   | Data                 | $(\theta_d, \zeta)$ | RBC  |
| Solow | 3.19     | 3.51                | 3.59  | 0.43                 | 0.98                | 1.00 |
| $Y$   | 2.38     | 0.93                | 0.92  | 1.00                 | 1.00                | 1.00 |
| $N$   | 2.50     | 0.10                | 0.08  | 0.87                 | 0.61                | 0.96 |
| $C$   | 1.55     | 0.09                | 0.05  | 0.87                 | 0.73                | 0.95 |
| $I$   | 34.15    | 13.46               | 15.40 | 0.92                 | 0.98                | 1.00 |

Table A-4: Sensitivity Analysis over the Correlation between the  
Consumption and Investment Demand Shocks

|                                               | Correlation |         |         |         |
|-----------------------------------------------|-------------|---------|---------|---------|
|                                               | -0.2        | -0.1    | 0       | 0.1     |
| Estimates                                     |             |         |         |         |
| Likelihood                                    | 2244.02     | 2244.87 | 2244.48 | 2244.52 |
| $\rho_d$                                      | 0.958       | 0.956   | 0.954   | 0.958   |
| $\sigma_d$                                    | 0.076       | 0.074   | 0.072   | 0.067   |
| $\rho_n$                                      | 0.997       | 0.997   | 0.996   | 0.996   |
| $\sigma_n$                                    | 0.022       | 0.022   | 0.022   | 0.022   |
| $\rho_\zeta$                                  | 0.958       | 0.956   | 0.954   | 0.954   |
| $\sigma_\zeta$                                | 0.133       | 0.131   | 0.126   | 0.126   |
| $\rho_z$                                      | 0.924       | 0.918   | 0.886   | 0.888   |
| $\sigma_z$                                    | 0.001       | 0.001   | 0.002   | 0.004   |
| Variance decomposition for output             |             |         |         |         |
| $\theta_d$                                    | 36.63       | 32.30   | 27.77   | 15.06   |
| $\zeta$                                       | 28.76       | 30.75   | 31.97   | 25.97   |
| $z$                                           | 0.65        | 0.74    | 2.18    | 22.89   |
| $\theta_n$                                    | 33.96       | 36.21   | 38.08   | 36.08   |
| Variance decomposition for the Solow residual |             |         |         |         |
| $\theta_d$                                    | 83.65       | 82.43   | 79.89   | 52.23   |
| $\zeta$                                       | 13.44       | 14.35   | 14.82   | 12.60   |
| $z$                                           | 1.07        | 1.23    | 3.18    | 33.18   |
| $\theta_n$                                    | 1.84        | 1.99    | 2.10    | 1.99    |