Optimal Fiscal and Monetary Policy in Customer Markets*

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July 22, 2007

Abstract

A growing body of evidence suggests that ongoing relationships between consumers and firms may be important for understanding price dynamics. We investigate whether the existence of such customer relationships has important consequences for the conduct of both long-run and short-run policy. Our central result is that when consumers and firms are engaged in long-term relationships, the optimal rate of price inflation volatility is very low even though all prices are completely flexible. This finding is in contrast to those obtained in first-generation Ramsey models of optimal fiscal and monetary policy, which are based on Walrasian markets. Echoing the basic intuition of models based on sticky prices, unanticipated inflation in our environment causes relative price distortions across markets. Such distortions are due to the long-term nature of relationships and makes pursuing inflation stability optimal.

Keywords: Inflation stability, Ramsey model, search models
JEL Classification: E30, E50, E61, E63

*The views expressed here are solely those of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System.

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1 Introduction

A growing body of evidence suggests that ongoing relationships between consumers and firms may be important for understanding price dynamics. In this paper, we investigate whether the existence of such customer relationships has important consequences for the conduct of both long-run and short-run policy. We explore this question using the Ramsey framework of optimal fiscal and monetary policy, in the tradition of Lucas and Stokey (1983) and Chari, Christiano, and Kehoe (1991), because it is a powerful laboratory for uncovering properties of optimal policy. Our central result is that long-term relationships between consumers and firms, which we model using search-based frictions in goods markets, make keeping inflation variability low an important goal of policy, even though all prices are completely flexible and not subject to any menu costs. This finding is in contrast to first-generation Ramsey models, which are based on Walrasian markets and thus are ill-suited to handle long-lived relationships. Our results continue to call into question the perceived wisdom that nominal rigidities are a necessary feature of a model in order for it to deliver a policy prescription of stabilizing inflation.

The basic reason that any model with nominal rigidities recommends inflation stability as the optimal policy is that variations in inflation affect relative prices of goods. Given technologically identical goods — as virtually all sticky-price-based models assume — it is transparent that allowing relative prices to deviate from unity as a result of variations in inflation is welfare-reducing. Hence the prescription to stabilize inflation. As a general tenet, we think this core intuition recommending inflation stability is sound. Our model and results show, though, that one does not need a typical sticky-price model to reach this prediction. In the environment we use to study optimal policy, fundamental trading frictions that lead to some goods being purchased in the context of long-term customer relationships, while others are purchased in the spot goods markets used as the basis for nearly all macroeconomic models, mean that volatile inflation induces the same sort of relative price distortions as in sticky-price models. Optimal policy thus stabilizes inflation.

Our environment builds on the quantitative search-based model of goods markets developed in Arseneau and Chugh (2007b). Their model, as does Hall's (2007) model, uses the search-and-matching framework familiar from the labor search literature as a basis for a model of goods markets. In both Arseneau and Chugh (2007b) and Hall (2007), the search frictions that both consumers and firms must overcome before goods trade can occur make customer relationships valuable to both parties. We extend Arseneau and Chugh (2007b) to a monetary environment, motivating money demand by layering over it a cash good/credit good structure, in the spirit of Lucas and Stokey (1983). In our model here, then, some search goods can be acquired only with cash, while others may be acquired using credit. As in a basic cash/credit model, there is no explicitly-modeled reason why some goods have to be purchased using cash. By situating a familiar cash/credit structure in a clearly-defined concept of customer relationships, however, we are able to show that goods trading frictions *per se*, even independent from those that generate an endogenous role for money, may have important consequences for policy recommendations.

Our primary result is that realized (ex-post) inflation is quite stable over time in the face of shocks, which is in contrast to the very volatile ex-post inflation rates found by Chari, Christiano, and Kehoe (1991) that have become the benchmark for the Ramsey monetary literature. Inflation volatility is high in the benchmark Ramsey model because surprise movements in the price level allow the government to synthesize real state-contingent debt payments from nominally risk-free government bonds without distorting relative prices. The government then need not change other, distortionary, tax rates much in response to shocks. In our model, in contrast, real activity is distorted by ex-post inflation because inflation affects relative prices of goods in a way that a basic flexible-price Ramsey monetary model cannot articulate. Quantitatively, the welfare cost of this relative-price distortion dominates the insurance value of generating state-contingent debt in our model, rendering inflation an order of magnitude more stable than in first-generation Ramsey models. Varying one key parameter that governs the importance of goods-trading frictions in our model allows us to trace out the spectrum between the optimal inflation volatility result of Chari, Christiano, and Kehoe (1991) and the optimal inflation stability result of a standard sticky-price model. Deep frictions underlying goods trade thus provide novel justification for the optimality of inflation stability, a prescription that resonates with central bankers.

Our second main result is that a deviation from the Friedman Rule of a zero net nominal interest rate may be optimal in the long run. The optimality of positive nominal interest rates is taken almost for granted by central bankers and those studying monetary policy using sticky-price-based models, in which the attendant deflation associated with the Friedman Rule is undesirable, but it is a result that usually has been difficult to obtain in flexible-price models. Two distinct reasons lead to a departure from the Friedman Rule in our model, and each connects naturally with recent results in the Ramsey literature. First, a positive nominal interest rate can be used to indirectly tax monopolistic producers' profits, a policy channel first identified by Schmitt-Grohe and Uribe (2004a). Second, a positive nominal interest rate can be used to offset inefficient search activity, similar to findings in the labor-search models of Cooley and Quadrini (2004) and Arseneau and Chugh (2007a) and the money-search model of Rocheteau and Wright (2005). As in all of these previous studies, allowing for policy instruments that directly tax monopoly profits and inefficient search activity restores the optimality of the Friedman Rule.

Other than Hall (2007) and Arseneau and Chugh (2007b), other studies have also taken the view that deeper models of relationships between consumers and firms, even if not applied to studying policy issues, may be important for understanding price dynamics. Such a view is motivated by the survey evidence of, for example, Blinder et al (1998) and Fabiani et al (2006), that firms often try to avoid upsetting their existing customers when considering price changes. Recent theoretical models that fall into this broadly-defined area are the deep habits models of Ravn, Schmitt-Grohe, and Uribe (2006) and Nakamura and Steinsson (2007) and the switching-cost model of Kleschelski and Vincent (2007). The main way in which our framework, along with Hall's (2007), differs from these other frameworks is that we embed customer relationships as a feature of the trading structure of the environment, rather than altering preferences to account for them. We also differ here, of course, in emphasis, using our framework to study optimal policy.

The Lucas and Stokey (1983) and Chari, Christiano, and Kehoe (1991) studies — henceforth LS and CCK, respectively — are the benchmark for Ramsey models of optimal fiscal and monetary policy. The LS/CCK framework is particularly effective at uncovering the welfare consequences of stabilizing inflation over the business cycle, an issue about which central bankers have strong priors. In a recent outburst of work in this area, Schmitt-Grohe and Uribe (2004a, 2004b, 2005), Siu (2004), and Chugh (2006, 2007) enrich the original Walrasian-based LS and CCK models along a number of dimensions, with a focus on studying the dynamics of optimal inflation. However, premised as they are on a fundamentally Walrasian view of markets, the primitive desirability of inflation volatility embedded in the basic LS/CCK structure underlies them all. In a different recent direction of the Ramsey literature, Arseneau and Chugh (2007a) and Aruoba and Chugh (2006) study the dynamics of optimal inflation when key markets feature fundamental trading frictions — frictions underlying labor market relationships in the former, and frictions underlying monetary trade in the latter. Our work here continues the theme begun in these two studies by employing a deeper description of trade in goods markets. Taken together, this emerging second generation of Ramsey models uncovers several novel insights regarding the economic forces that may shape policy, in particular monetary policy.

Although we use the canonical Ramsey framework of optimal taxation, the primary goal we set out to achieve is *not* the design of an efficient tax system. That is obviously one natural — and the original — objective to pursue using the Ramsey framework. Our model of course does have implications for optimal (regular) *fiscal* policy, the most basic being an echo of the standard Ramsey prescription of smoothing proportional labor tax rates over time. Instead, our primary goal here is to shed some light on how conventional thinking regarding the forces affecting *monetary* policy may be quite different once one treats non-Walrasian frictions in goods markets seriously, which we can isolate from a serious treatment of frictions underlying monetary trade. As second-generation and the most recent of the first-generation Ramsey monetary models have demonstrated, and as we mentioned at the outset, the Ramsey laboratory is effective at isolating such forces; Chugh (2007b) provides more discussion on this point.

The rest of our work is organized as follows. Section 2 lays out our model, which is a cash/credit version of the search-based model of goods markets developed in Arseneau and Chugh (2007b). Section 3 presents the Ramsey problem, and Section 4 presents and analyzes our steady-state and dynamic results. Section 5 summarizes and offers possible avenues for continued research.

2 The Economy

The environment builds on Arseneau and Chugh (2007b), which posits that, for some goods trades, households and firms each have to expend time and resources finding individuals on the other side of the market with whom to trade. A fraction of goods market exchange is thus explicitly bilateral, in contrast to all trades happening against the anonymous Walrasian auctioneer. The modeling device used by Arseneau and Chugh (2007b) and Hall (2007) to tractably capture these search frictions in goods markets is to adapt the aggregate matching function ubiquitous in the labor search literature.

To motivate money demand, we build on this idea by imposing a LS/CCK type of cash/credit margin on top of the search markets. Our model of money demand is as simple as existing cash/credit structures, and we think this makes our results readily comparable with most existing optimal-policy studies. We proceed to describe in turn the environment faced by households, the environment faced by firms, the determination of prices, aggregate matching dynamics, the nature of the consolidated fiscal-monetary government, and the private-sector equilibrium. At the end of the presentation of the household side of the model, we discuss the intuition for why the dynamics of Ramsey-optimal inflation have the potential to be quite different in our environment than in a baseline LS/CCK model.

2.1 Households

There is a measure one of identical, infinitely-lived households in the economy, each composed of a measure one of individuals. In a given period, an individual member of the representative household can be engaged in one of six activities: purchasing goods (shopping) at a cash location, purchasing goods (shopping) at a credit location, searching for cash goods, searching for credit goods, working, or enjoying leisure. More specifically, l_t members of the household are working in a given period; s_{1t} (s_{2t}) members are *searching* for firms from which to buy cash (credit) goods; N^h_{1t} (N^h_{2t}) members are *shopping* at firms with which they previously formed cash (credit) relationships; and $1 - l_t - s_{1t} - s_{2t} - N^h_{1t} - N^h_{2t}$ members are enjoying leisure.

We make more precise the distinction between cash shoppers and credit shoppers below; for now, note our more general distinction between shopping and searching for goods. Individuals who are searching are looking to form relationships with firms, which takes time. Individuals who are shopping were previously successful in forming customer relationships, but the act of acquiring and bringing home goods itself takes time.[1] We assume that all members of a household share equally the consumption that shoppers acquire.

Defining $N_t^h = N_{1t}^h + N_{2t}^h$ and $s_t = s_{1t} + s_{2t}$, the household's discounted lifetime utility is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u(x_{1t}, x_{2t}) + \vartheta v \left(\int_0^{N_{1t}^h} c_{i1t} di, \int_0^{N_{2t}^h} c_{i2t} di \right) + g(1 - l_t - s_t - N_t^h) \right], \tag{1}$$

where x_1 is consumption of a standard Walrasian cash good, x_2 is consumption of a standard Walrasian credit good, and c_{i1t} and c_{j2t} are the quantities of the search cash and search credit good, respectively, that cash shopper i and credit shopper j bring back to the household. Instantaneous utility of leisure is $g(.)$, and the parameter ϑ governs how the household prefers to divide its total consumption between search and non-search goods.

As in Arseneau and Chugh (2007b), note that consumption of search goods potentially has two dimensions: an extensive margin (the number of cash (credit) shoppers that buy goods) and an intensive margin (the number of cash (credit) goods that each cash (credit) shopper buys). Given the complexity of our model and to keep the focus on the extensive margin of search consumption, we close down adjustment at the intensive margin and assume that the intensive quantity of either cash or credit goods obtained in a match is always $\bar{c} = 1$. Arseneau and Chugh (2007b) show the technical details one requires to open up the intensive margin; extending those requirements to our more complicated environment here is straightforward in principle, but we refrain from doing so to illustrate as clearly as possible how some conventional thinking regarding policy may change due to the presence of just the search (extensive) margin of consumption. However, we keep the notation general and continue writing c_{ijt}, but it will be understood from here on that $c_{ijt} = \bar{c} = 1 \ \forall i, j, t$.

The household faces the sequence of flow budget constraints,

$$\begin{aligned} & M_t - M_{t-1} + B_t - R_{t-1} B_{t-1} = \\ & \quad (1 - \tau_{t-1}^l) W_{t-1} l_{t-1} - P_{t-1} x_{1t-1} - P_{t-1} x_{2t-1} - \int_0^{N_{1t-1}^h} P_{i1t-1} c_{i1t-1} di - \int_0^{N_{2t-1}^h} P_{i2t-1} c_{i2t-1} di + P_{t-1} d_{t-1}, \end{aligned} \tag{2}$$

where M_{t-1} is the nominal money the household brings into period t, B_{t-1} is nominal bonds brought into period t, P_t is the nominal price level (equivalently, the nominal price of both Walrasian cash and Walrasian credit goods), R_t is the gross nominal interest rate on nominally risk-free government bonds held between t and $t+1$, τ_t^l is the tax rate on labor income, and d_t is real dividends distributed lump-sum by firms to households. All of these objects are standard in the line of cash/credit models begun by LS and CCK and recently used by Siu (2004), Chugh (2006, 2007a), and Arseneau and

[1] For example, even if one knows exactly where to go to buy certain goods, one may still have to walk around the aisles, stand in the checkout line, etc.

Chugh (2007a). Finally, the nominal prices of cash search goods and credit search goods purchased by cash shopper i and credit shopper j, respectively, are P_{i1t} and P_{j2t}.

The household also faces the sequence of cash-in-advance constraints,

$$P_t x_{1t} + \int_0^{N_{1t}^h} P_{i1t} c_{i1t} di \leq M_t, \tag{3}$$

that apply to both a subset of Walrasian goods and a subset of search goods. As in LS, CCK, and the subsequent literature, the purchase of some goods requires the use of money for an unstated reason; it is a reduced-form way of motivating money demand. We extend this idea to cover both a subset of standard Walrasian goods and a subset of goods acquired via ongoing customer relationships. We point out that these ideas are quite different from those emphasized by Lagos and Wright (2005) and the related literature, in which search-type frictions in some goods trades lead endogenously to a welfare-enhancing role for fiat money. That is not the case here, as we do not use search frictions to motivate a fundamental role for money.[2] We interpret our setup as one that separates search frictions in goods markets from the (to use a term favored in the money-search class of models) "essentiality" of money central to money-search-based models like Lagos and Wright (2005). Our cash in advance constraint, applied to both search and non-search goods, nevertheless forms the basis of our central hypothesis that inflation variability is undesirable in the environment we study; we discuss this hypothesis further after we complete our description of the household problem.

Apart from the obvious differences due to our inclusion of search markets, the timing of both the budget constraints and cash-in-advance constraints conforms to that of LS and CCK and the ensuing literature. In addition to these constraints, the representative household also faces perceived laws of motion for the numbers of active cash customer relationships and credit customer relationships in which it is engaged,

$$N_{1t+1}^h = (1-\rho^x)(N_{1t}^h + s_{1t} k^h(\theta_{1t})) \tag{4}$$

and

$$N_{2t+1}^h = (1-\rho^x)(N_{2t}^h + s_{2t} k^h(\theta_{2t})). \tag{5}$$

The probability that a searching individual forms a cash (credit) relationship is k^h, which in turn depends on aggregate market tightness θ_1 (θ_2) in cash (credit) search markets. Market tightness, defined as the aggregate number of advertisements per searching individual in a given market, is taken as given by the household, hence matching probabilities are taken as given by the household.

[2] One crucial way in which our environment is different from Lagos and Wright (2005) and related models is that during the course of a long-term relationship, a customer and a firm are *not* anonymous. Anonymity of buyers and sellers is a crucial feature underlying the role for money in money-search types of models.

With fixed probability ρ^x, which is known to both households and firms, an existing customer relationship dissolves at the beginning of a period.[3]

This completes the basic description of the environment households face. We relegate more formal details of the household optimization problem to Appendix A; we proceed here directly to the optimality conditions. Before presenting household optimality conditions, a few points are in order. First, we restrict attention to equilibria that are symmetric across all cash relationships and symmetric across all credit relationships — that is, $P_{i1t} = P_{i'1t} = P_{1t}\ \forall\ i \neq i'$ and $P_{j2t} = P_{j'2t} = P_{2t}$ $\forall\ j \neq j'$. Second, define $p_{1t} \equiv P_{1t}/P_t$ and $p_{2t} \equiv P_{2t}/P_t$ as the symmetric equilibrium relative prices of search cash and search credit goods, respectively. Third, to conserve on notation, from here on let v_{it} stand for $v_i\left(\int_0^{N_{1t}^h} c_{i1t}di, \int_0^{N_{2t}^h} c_{i2t}di\right)$, g'_t stand for $g'(1 - l_t - s_t - N_t^h)$, and u_{it} stand for $u_i(x_{1t}, x_{2t})$

Three household optimality conditions are identical to those in standard cash/credit models: the consumption-leisure optimality condition

$$\frac{g'_t}{u_{2t}} = (1 - \tau_t^l)w_t, \tag{6}$$

the (Walrasian) cash-good/credit-good optimality condition

$$\frac{u_{1t}}{u_{2t}} = R_t, \tag{7}$$

and an Euler equation that prices a one-period nominally risk-free bond

$$1 = R_t E_t\left[\frac{\beta u_{1t+1}}{u_{1t}}\frac{1}{\pi_{t+1}}\right], \tag{8}$$

where $\pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate between periods $t-1$ and t.

In search markets, the household's choice of s_{it} to hit a target N_{it+1}^h make shopping decisions akin to investment decisions, just as in Arseneau and Chugh (2007b) and Hall (2007). The optimal shopping condition for cash goods is

$$\frac{g'_t}{k^h(\theta_{1t})} = \beta(1-\rho^x)E_t\left\{c_{1t+1}\left[\vartheta v_{1t+1} - p_{1t+1}u_{1t+1}\right] - g'_{t+1} + \frac{g'_{t+1}}{k^h(\theta_{1t+1})}\right\}, \tag{9}$$

and the optimal shopping condition for credit goods is

$$\frac{g'_t}{k^h(\theta_{2t})} = \beta(1-\rho^x)E_t\left\{c_{2t+1}\left[\vartheta v_{2t+1} - p_{2t+1}u_{2t+1}\right] - g'_{t+1} + \frac{g'_{t+1}}{k^h(\theta_{2t+1})}\right\}. \tag{10}$$

The cash (credit) shopping condition simply states that at the optimum, the household sends a number of individuals out to search for cash (credit) goods such that the expected marginal cost of

[3] To keep things symmetric, we assume ρ^x is identical across cash and credit relationships, and, as we present below, we assume a number of other features of the environment are symmetric across the two types of relationships. One could easily relax such assumptions, but we think it makes the most sense to begin with as symmetric an environment as possible.

shopping for a cash (credit) good equals the expected marginal benefit of forming a cash (credit) relationship. The expected marginal benefit of a cash (credit) relationship is composed of two parts: the utility gain from obtaining c_{1t} (c_{2t}) more cash (credit) goods via the search market rather than via the Walrasian market (net of the direct disutility g' of shopping) and the asset value to the household of having one additional pre-existing cash (credit) customer relationship entering period $t+1$.

Because it will be useful in understanding our optimal policy results, we define the *shadow nominal interest rate*

$$R_t^* \equiv \frac{k^h(\theta_{2t})}{k^h(\theta_{1t})}. \tag{11}$$

With this definition, note that the shopping conditions (9) and (10) can be condensed into a household shopping margin,

$$\frac{E_t\left\{c_{1t+1}\left[\vartheta v_{1t+1} - p_{1t+1}u_{1t+1}\right] - g'_{t+1} + \frac{g'_{t+1}}{k^h(\theta_{1t+1})}\right\}}{E_t\left\{c_{2t+1}\left[\vartheta v_{2t+1} - p_{2t+1}u_{2t+1}\right] - g'_{t+1} + \frac{g'_{t+1}}{k^h(\theta_{2t+1})}\right\}} = R_t^*, \tag{12}$$

which emphasizes that, when sending members out to shop for goods, the household faces a cash-search/credit-search decision margin. The relevant price influencing this margin is relative matching probabilities. The higher is the matching probability $k^h(\theta_{2t})$ in the credit market, the more costly it is, *ceteris paribus*, for a household to assign an additional member to search in the cash market. This cost is an opportunity cost — the foregone opportunity of matching in the credit market. We use the label shadow nominal interest rate because condition (12) is quite similar in idea to (7), although of course, because it takes time to form relationships, the "marginal rate of substitution" on the left-hand-side of (12) is an expectational one. From the point of view of the optimal policy problem we will construct, however, R_t^* is a price that can be manipulated by the Ramsey government.

We now return to a point we mentioned earlier: our central hypothesis can be seen in our model's cash-in-advance constraint. As in nearly all cash-in-advance models, we focus on an equilibrium in which the cash-in-advance constraint binds. In a symmetric equilibrium, the time-t and $t-1$ versions of (3) can thus be combined to yield

$$\pi_t\left[\frac{x_{1t} + p_{1t}N_{1t}c_{1t}}{x_{1t-1} + p_{1t-1}N_{1t-1}c_{1t-1}}\right] = \mu_t, \tag{13}$$

where $\mu_t \equiv M_t/M_{t-1}$ is the gross growth rate of the nominal money stock. If there were no search frictions, this would reduce to $\pi_t(x_{1t}/x_{1t-1}) = \mu_t$, the standard condition relating inflation to money growth in cash-in-advance models. In a deterministic steady state, the monetarist condition $\pi = \mu$ pins down inflation. Despite search frictions, the simple monetarist relation obviously continues to hold in the steady state of our model. But dynamics in the search market complicate the dynamic relationship between fluctuations in money growth and inflation. In particular, and this forms the basis for the central hypothesis of our project, note that (13) links realized inflation π_t to the relative price p_{1t}. Fluctuations in π_t thus have the potential to transmit into fluctuations in p_{1t}, which in turn may disrupt search markets. This means that state-contingent movements in π_t under the Ramsey plan may be undesirable in a way that does not occur in a baseline LS/CCK model. We can only assess this conjecture quantitatively.

Finally, define

$$\Xi_{t+1|t} = \frac{\beta u_{2t+1}}{u_{2t}} \tag{14}$$

as the conditional real discount factor between period t and $t+1$, which will be useful in constructing firms' optimization problems, to which we turn next.

2.2 Walrasian Firms

To make pricing labor simple, we assume that there is a representative firm that buys labor in and sells the Walrasian goods x_1 and x_2 in competitive spot markets. The firm operates a linear production technology subject to aggregate TFP fluctuations. Profit-maximization yields the standard results that the real wage is equated to the marginal product of labor,

$$w_t = z_t, \tag{15}$$

where z_t is the period-t realization of aggregate TFP. All participants in the economy, including the non-Walrasian firms described next, take this w_t as given.

2.3 Non-Walrasian Firms

There is a measure one of identical firms that sell goods through bilateral relationships with customers. Bilateral relationships are classified as either cash relationships or credit relationships, and a given relationship is always one or the other for as long as it remains intact. For each good that it sells through either a cash or a credit relationship, the firm must first attract a customer. To attract customers, the firm must advertise, and how any given level of cash (credit) advertisements it posts maps into how many cash (credit) customers it finds is governed by matching technologies to be described below. Owing to frictions associated with finding customers, be they cash customers or credit customers, the firm views existing customers as assets. Its total stocks of cash customers and credit customers evolve according to the perceived laws of motion

$$N^f_{1t+1} = (1-\rho^x)(N^f_{1t} + a_{1t}k^f(\theta_{1t})) \tag{16}$$

and

$$N^f_{2t+1} = (1-\rho^x)(N^f_{2t} + a_{2t}k^f(\theta_{2t})), \tag{17}$$

which are obviously analogous to the customer laws of motion facing households; k^f denotes a firm's probability of attracting a customer through an advertisement, which in turn depends on the aggregate tightness of the market in which the advertisement is placed.

As with competitive firms, search firms' production technology is linear in labor and subject to aggregate productivity z_t. Because we assume a constant-returns production technology with no fixed costs of production (there is a fixed cost of advertising, but no fixed cost of producing), its real marginal cost of production is constant and coincides with average cost. Denoting period-t marginal production cost by mc_t, we can express the firm's total production costs as the sum of production costs across all of its active customer relationships, $\int_0^{N^f_{1t}} mc_t c_{i1t} di + \int_0^{N^f_{2t}} mc_t c_{i2t} di$.

With this structure in place, total nominal profits of the representative search firm in a given period t are

$$\int_0^{N^f_{1t}} P_{i1t} c_{i1t} di + \int_0^{N^f_{2t}} P_{i2t} c_{i2t} di - \int_0^{N^f_{1t}} P_t mc_t c_{i1t} di - \int_0^{N^f_{1t}} P_t mc_t c_{i1t} di - P_t \gamma (a_{1t} + a_{2t}), \qquad (18)$$

where γ is the flow cost of posting an advertisement in either the cash market or the credit market.[4] The firm's customer bases N^f_{1t} and N^f_{2t} are pre-determined entering period t. Discounted lifetime nominal profits of the firm are thus

$$E_0 \sum_{t=0}^{\infty} \left(\Xi_{t|0} \frac{P_0}{P_{t+1}} \right) \left[\int_0^{N^f_{1t}} P_{i1t} c_{i1t} di + \int_0^{N^f_{2t}} P_{i2t} c_{i2t} di - \int_0^{N^f_{1t}} P_t mc_t c_{i1t} di - \int_0^{N^f_{2t}} P_t mc_t c_{i2t} di - P_t \gamma (a_{1t} + a_{2t}) \right], \qquad (19)$$

where $\left(\Xi_{t|0} \frac{P_0}{P_{t+1}} \right)$ is the period-0 value to the household of a period-t nominal unit, which we assume the firm uses to discount nominal profit flows because households are the ultimate owners of firms.[5]

Firms maximize (19) subject to the customer evolution constraints (16) and (17) by choosing $\left\{ a_{1t}, a_{2t}, N^f_{1t+1}, N^f_{2t+1} \right\}$. Optimization leads to what we refer to (following Arseneau and Chugh (2007b)) as the firm's optimal advertising conditions: one for advertising in cash markets,

$$\frac{\gamma}{k^f(\theta_{1t})} = (1 - \rho^x) E_t \left\{ \Xi_{t+1|t} \left(p_{1t+1} c_{1t+1} - mc_{t+1} c_{1t+1} + \frac{\gamma}{k^f(\theta_{1t+1})} \right) \right\}, \qquad (20)$$

and one for advertising in credit markets,

$$\frac{\gamma}{k^f(\theta_{2t})} = (1 - \rho^x) E_t \left\{ \Xi_{t+1|t} \left(p_{2t+1} c_{2t+1} - mc_{t+1} c_{2t+1} + \frac{\gamma}{k^f(\theta_{2t+1})} \right) \right\}. \qquad (21)$$

The term $\Xi_{t+1|t} \equiv \Xi_{t+1|0} / \Xi_{t|0}$ is the household real discount factor (again, technically, the real interest rate) between period t and $t+1$. In equilibrium, $\Xi_{t+1|t} = \frac{\beta E_{t+1} \phi_{t+2}}{E_t \phi_{t+1}}$, which in turn by

[4] Echoing a point we made earlier, allowing γ to differ across the two markets might be another natural feature in which to introduce asymmetry across cash and credit relationships.

[5] Technically, of course, it is the real interest rate with which firms discount profits, and in equilibrium the real interest rate between time zero and time t is measured by $\Xi_{t|0}$. Because there will be no confusion using this equilibrium result "too early," we skip this intermediate level of notation and structure.

the household's optimal choice of Walrasian credit goods, is $\Xi_{t+1|t} = \frac{\beta u_{2t+1}}{u_{2t}}$ — see Appendix A for more details. In writing (20) and (21), we have imposed symmetry across all cash relationships and across all credit relationships.

Finally, because of the assumptions we make regarding the matching process, the shadow nominal interest rate R_t^* defined in (11) affects the allocation of total advertising across cash and credit markets,

$$\frac{E_t\left\{\Xi_{t+1|t}\left(p_{1t+1}c_{1t+1} - mc_{t+1}c_{1t+1} + \frac{\gamma}{k^f(\theta_{1t+1})}\right)\right\}}{E_t\left\{\Xi_{t+1|t}\left(p_{2t+1}c_{2t+1} - mc_{t+1}c_{2t+1} + \frac{\gamma}{k^f(\theta_{2t+1})}\right)\right\}} = R_t^* \frac{\theta_{1t}}{\theta_{2t}}. \tag{22}$$

However, this condition is different from (12) because it is not just R^* that governs firms' allocation of search activities across cash and credit markets, but rather R^* scaled by relative market tightness.[6]

2.4 Price Determination

We use as our benchmark Nash bargaining over price in both cash relationships and credit relationships. Appendix B provides the details behind the solutions that we present here. The relative prices p_{1t} and p_{2t} of cash search goods and credit search goods, respectively, that emerge from Nash bargaining are

$$p_{1t}c_{1,t} = (1-\eta)\left(\frac{\tilde{v}^1(c_{1t})}{\beta E_t\phi_{t+1} + \lambda_t}\right) + \eta(mc_t c_{1,t} - \gamma\theta_{1t}) \tag{23}$$

and

$$p_{2t}c_{2,t} = (1-\eta)\left(\frac{\tilde{v}^2(c_{2t})}{\beta E_t\phi_{t+1}}\right) + \eta(mc_t c_{2,t} - \gamma\theta_{2t}), \tag{24}$$

where η is the Nash bargaining power of customers in both cash and credit relationships. The total payment $p_{it}c_{it}$ a customer hands over to a firm is a convex combination of the customer's valuation of the goods obtained (given by the first terms in parentheses on the right-hand-side of (23) and (24)) and the firm's effective marginal cost of selling those goods (given by the second terms in parentheses on the right-hand-side of (23) and (24)), which takes into account both the production cost and the resources spent finding the customer in the first place. The function $\tilde{v}^1(.)$ is the marginal utility to the household of obtaining cash consumption from the i-th match, and

[6] As we state below, we assume identical matching functions for cash relationships and credit relationships, and furthermore that the matching process is constant returns in both the levels of search and advertising. This means that $k^h(\theta_i) \equiv m(s_i, a_i)/s_i = m(1, \theta_i)$ and $k^f(\theta_i) \equiv m(s_i, a_i)/a_i = m(1/\theta_1, 1)$, $i = 1, 2$. Dividing (20) by (21) gives rise to the term $k^f(\theta_2)/k^f(\theta_1)$. By the properties of the matching function and given our definition of R^*, it is straightforward to show that $k^f(\theta_2)/k^f(\theta_1) = R^*\theta_1/\theta_2$. We also point out that although in the ways in which we have written conditions (12) and (22) it seems that relative tightness affects the latter but not the former, relative market tightness indeed is the only factor driving both, which simply follows from constant-returns matching.

$\tilde{v}^2(.)$ is the marginal utility to the household of obtaining credit consumption from the i-th match. Hence, $\tilde{v}^i(.) \equiv v_{it}(.)$, $i = 1, 2$.

The main difference between (23) and (24) is in the factor by which the household discounts $\tilde{v}^i(.)$. Let ϕ_t/P_{t-1} denote the Lagrange multiplier on the household's budget constraint (2) and λ_t/P_t the Lagrange multiplier on the cash-in-advance constraint (3). Because cash must be used, by definition, for cash relationships, the relevant discount takes into account both these multipliers. For credit relationships, only the multiplier on the wealth constraint is relevant because cash does not need to be held. In equilibrium, by the household first-order conditions on Walrasian cash goods and Walrasian credit goods (presented in Appendix A), $\beta E_t \phi_{t+1} = u_{2t}$ and $\beta E_t \phi_{t+1} + \lambda_t = u_{1t}$, which are standard in cash/credit models.[7] Recalling condition (7), these equilibrium relations mean that the nominal interest rate R_t implicitly affects the price ratio p_{1t}/p_{2t}.

2.5 Goods Market Matching

The numbers of new customer-firm cash relationships and credit relationships that form in any period t are described by a pair of aggregate matching functions $m^1(s_{1t}, a_{1t})$ and $m^2(s_{2t}, a_{2t})$. We assume symmetry across the matching technologies (although we again point out that one could relax this assumption), so from here on we write $m(.) = m^1(.) = m^2(.)$. As is standard in a Mortensen-Pissarides type of framework, the matching technology is Cobb-Douglas, $m(s_t, a_t)$. With Cobb-Douglas matching, the probabilities that shoppers and firms, respectively, find partners in the cash market are

$$k^h(\theta_1) = \frac{m(s_1, a_1)}{s_1} = m\left(1, \frac{a_1}{s_1}\right) = m(1, \theta_1) \tag{25}$$

and

$$k^f(\theta_1) = \frac{m(s_1, a_1)}{a_1} = m\left(\frac{s_1}{a_1}, 1\right) = m(\theta_1^{-1}, 1), \tag{26}$$

with $\theta_1 \equiv a_1/s_1$ a measure of how tight (the ratio of firms searching for customers to individuals searching for goods in the cash market) the cash goods market is. Matching probabilities and market tightness in the credit search market are defined in the obvious way, with s_2 replacing s_1, a_2 replacing a_1, and θ_2 replacing θ_1.

As in the labor search literature and as adapted by Hall (2007) and Arseneau and Chugh (2007b), the matching function is meant to be a reduced-form way of capturing the idea that it takes resources, be it time or otherwise, for parties on opposite sides of the market to meet. Rogerson, Shimer, and Wright (2005, p. 968) note that the ability to be agnostic about the actual mechanics of the process by which parties make contact with each other may be a virtue. Our modeling motivation is very much in line with this idea.

[7] Again, more details are provided in Appendices A and B.

With the matching functions describing the flow of new customer relationships, the aggregate numbers of active cash customer relationships and credit customer relationships evolve according to

$$N_{1t+1} = (1-\rho^x)(N_{1t} + m(s_{1t}, a_{1t})) \tag{27}$$

and

$$N_{2t+1} = (1-\rho^x)(N_{2t} + m(s_{2t}, a_{2t})). \tag{28}$$

2.6 Government

The government's flow budget constraint is

$$M_t + B_t + \tau_{t-1}^l P_{t-1} w_{t-1} l_{t-1} = M_{t-1} + R_{t-1} B_{t-1} + P_{t-1} g_{t-1}, \tag{29}$$

where g_t denotes exogenous government consumption in period t. The government finances its spending through proportional labor income taxation, issuance of nominal one-period debt, and money creation. Note that government consumption is a credit good, following Chari, Christiano, and Kehoe (1991), because g_{t-1} is not paid for until period t.

2.7 Resource Constraint

Cash goods and credit goods are technologically identical. Furthermore, Walrasian consumption goods and search consumption goods are also technologically identical. Hence, the only "differentiation" along both dimensions is in terms of transactions methods/trading structures. The resource constraint of the economy is thus

$$x_{1t} + x_{2t} + \int_0^{N_{1t}} c_{i1t} di + \int_0^{N_{2t}} c_{i2t} di + g_t + \gamma(a_{1t} + a_{2t}) = z_t l_t. \tag{30}$$

In symmetric equilibrium,

$$x_{1t} + x_{2t} + N_{1t} c_{1t} + N_{2t} c_{2t} + g_t + \gamma(a_{1t} + a_{2t}) = z_t l_t. \tag{31}$$

2.8 Private-Sector Equilibrium

A private-sector equilibrium is made up of endogenous processes $\{x_{1t}, x_{2t}, l_t, s_{1t}, s_{2t}, a_{1t}, a_{2t}, N_{1t+1}, N_{2t+1}, p_{1t}, p_{2t}, \pi_t, R_t, w_t\}$ that satisfy the household optimality conditions (6), (7), (8), (9), and (10); efficiency in the labor market (15); the firm advertising conditions (20) and (21); the Nash pricing conditions (23) and (24); the aggregate laws of motion for active cash relationships and active credit relationships (27) and (28); the government budget constraint (29); and the aggregate resource constraint (31) for given exogenous processes $\left\{z_t, g_t, \tau_t^l, \mu_t\right\}$. Furthermore, the restriction $R_t \geq 1$, which states that the net nominal interest rate cannot be less than zero, is a requirement for a monetary equilibrium. Also, as we have already pointed out, $c_{1t} = c_{2t} = \bar{c} = 1 \ \forall t$.

3 Ramsey Problem

In standard Ramsey models with flexible prices, a well-known result is that household optimality conditions can be condensed into a single, present-value implementability constraint (PVIC) that encodes all of the equilibrium conditions that, apart from the resource frontier, must be respected by Ramsey allocations. In more complicated environments, such as Schmitt-Grohe and Uribe (2004b), Chugh (2006), and Arseneau and Chugh (2007a), it is not always possible to construct a PVIC, meaning that, in principle, all of the household (and other) optimality conditions must be imposed explicitly as constraints on the Ramsey problem.

Our environment presents an intermediate case. We can construct a PVIC using the "standard" household optimality conditions (6), (7), and (8), but the household and firm optimality conditions surrounding the search markets cannot easily be captured by it. Thus, we adopt a hybrid approach, constructing a Ramsey problem that is constrained by the resource frontier, the PVIC, as well as all conditions surrounding search and pricing activities in the non-Walrasian markets. As we show in Appendix D, starting with the household flow budget constraint (2), conditions (6), (7), and (8) can be condensed into the PVIC,

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u_{1t}x_{1t} + u_{2t}x_{2t} - g_t' l_t + (u_{1t} - u_{2t})p_{1t}N_{1t}c_{1t} + u_{2t}mc_t N_{1t}c_{1t} + u_{2t}mc_t N_{2t}c_{2t} + u_{2t}\gamma(a_{1t} + a_{2t}) \right] = A_0. \tag{32}$$

In constructing (32), we impose a binding cash-in-advance constraint (which is standard in Ramsey analyses based on a cash/credit structure) and substitute in the symmetric equilibrium expression for real firm dividend payments, $d_t = (p_{1t} - mc_t)N_{1t}c_{1t} + (p_{2t} - mc_t)N_{2t}c_{2t} - \gamma(a_{1t} + a_{2t})$. If there were no search frictions and hence no customer relationships, we would have $\gamma = N_1 = N_2 = 0$, in which case the PVIC would roll back to $E_0 \sum_{t=0}^{\infty} \beta^t \left[u_{1t}x_{1t} + u_{2t}x_{2t} - g_t' l_t \right] = A_0$, identical to that in LS and CCK.

The Ramsey problem is thus to choose state-contingent processes $\{x_{1t}, x_{2t}, l_t, s_{1t}, s_{2t}, \theta_{1t}, \theta_{2t}, N_{1t+1}, N_{2t+1}, p_{1t}, p_{2t}\}_{t=0}^{\infty}$ to maximize (1) subject to the PVIC (32), the resource constraint (31), the household shopping conditions (9) and (10), the firm advertising conditions (20) and (21), the Nash pricing conditions (23) and (24), and the aggregate laws of motion of cash and credit customer relationships (27) and (28). By using the resource constraint and the household budget constraint (which is embedded inside (32)), we do not need to specify the government budget constraint (29) as a constraint on the Ramsey problem because it is implied. The Ramsey government takes as given the exogenous processes $\{z_t, g_t\}_{t=0}^{\infty}$. Given the Ramsey allocation, we can then construct the policy processes $\{\tau_t^l, R_t, \pi_t\}_{t=0}^{\infty}$ using (6), (7), and (8), and the process for the shadow nominal interest rate $\{R_t^*\}_{t=0}^{\infty}$ using (11); the Ramsey-optimal money growth rate process $\{\mu_t\}_{t=0}^{\infty}$ can be constructed using (13).

In principle, we must also impose the inequality condition

$$u_{1t} - u_{2t} \geq 1 \tag{33}$$

as a constraint on the Ramsey problem, which would guarantee (in terms of allocations — refer to condition (7)) that the zero-lower-bound on the net nominal interest rate is not violated. We thus refer to constraint (33) as the ZLB constraint. The ZLB constraint in general is an occasionally-binding constraint. Because our model likely is too complex, given current technology, to solve using global approximation methods (as we describe below, we use a locally-accurate approximation method) that would be able to properly handle occasionally-binding constraints, for our dynamic results we drop the ZLB constraint and then check whether the ZLB constraint is ever violated. For our benchmark calibration, it turns out it is never violated, meaning we are justified in dropping the ZLB constraint. For our steady-state results, keeping the ZLB constraint in place poses no computational problem because we use a non-linear equation solver.

Finally, throughout, we assume that the first-order conditions of the Ramsey problem are necessary and sufficient and that all allocations are interior.

4 Optimal Policy

We characterize both the Ramsey steady-state and dynamic policies and allocations numerically. Before turning to our results, we describe how we parameterize our model. Because our model weds a standard cash/credit foundation to a search-based view of (some) goods trades, we draw on two different literatures in choosing our baseline parameter settings. Parameters surrounding the basic cash/credit structure are drawn from LS, CCK, and Siu (2004), while the parameters surrounding search in goods markets are drawn from Arseneau and Chugh (2007b) and Hall (2007).

4.1 Parameterization

The time unit in our model is one quarter, so we set the subjective time discount factor to $\beta = 0.9924$, in line with an average real interest rate of three percent. For instantaneous utility over Walrasian cash and credit goods, we choose

$$u(x_{1t}, x_{2t}) = \frac{\left\{\left[(1-\kappa_x)x_{1t}^{\phi_x} + \kappa_x x_{2t}^{\phi_x}\right]^{1/\phi_x}\right\}^{1-\sigma_x} - 1}{1-\sigma_x}; \tag{34}$$

such a CES aggregate of cash and credit goods nested inside CRRA utility is standard in cash/credit models. Following Siu (2004), we set $\phi_x = 0.79$, and, consistent with many macro models, we set $\sigma_x = 1$, making utility log in the consumption aggregate. For instantaneous utility over leisure, we choose

$$g(1 - l_t - s_t - N_t) = \frac{\zeta}{1-\nu}(1 - l_t - s_t - N_t)^{1-\nu}, \tag{35}$$

also standard. We set $\nu = 0.4$, which makes our calibration of the elasticity of leisure with respect to the real wage consistent with most macro models; however, we point out that this does not necessarily mean that the wage elasticity of labor supply is the same as in standard models because in addition to labor and leisure, searching and shopping are part of a household's "time constraint" as well. Given the rest of our calibration, $N + s$ is much smaller than either labor or leisure, so our parameter setting seems not grossly misleading. We set $\zeta = 4.3$ so that $l = 0.28$ in the deterministic Ramsey steady state of our benchmark specification.

To make preferences symmetric across Walrasian and non-Walrasian goods, instantaneous utility v is

$$v\left(\int_0^{N_{1t}} c_{i1t}di, \int_0^{N_{2t}} c_{i2t}di\right) = \frac{\left\{\left[(1-\kappa_c)\left[\int_0^{N_{1t}} c_{i1t}di\right]^{\phi_c} + \kappa_c\left[\int_0^{N_{2t}} c_{i2t}di\right]^{\phi_c}\right]^{1/\phi_c}\right\}^{1-\sigma_c} - 1}{1-\sigma_c}, \tag{36}$$

again a CES aggregate of cash (search) and credit (search) goods nested inside CRRA utility. Natural baseline setting are $\phi_c = \phi_x = 0.79$ and $\sigma_c = \sigma_x = 1$; to finish making u and v as symmetric as possible, we would want $\kappa_c = \kappa_x$. Siu (2004) estimates $\kappa_x = 0.62$, and this value is adopted by Chugh (2006, 2007) and Arseneau and Chugh (2007a). In the interest of making things *really* symmetric, however, we will set as our baseline $\kappa_c = \kappa_x = 0.5$, delivering symmetry along the cash/credit dimensions of both search goods and non-search goods; this parameter choice will help in understanding some of the core forces at work in the model. We explore sensitivity to asymmetric preferences in some of our experiments.

We set the preference parameter $\vartheta = 1$, which governs the composition of search consumption in total consumption, as a baseline. With this baseline setting and given the rest of our calibration, the fraction of total consumption that is comprised of consumption obtained through search is about 25 percent in the Ramsey equilibrium. That is, $\vartheta = 1$ delivers $\frac{N_1c_1+N_2c_2}{N_1c_1+N_2c_2+x_1+x_2} = 0.25$, which does not seem unreasonable. Varying ϑ varies this share, and doing so helps illuminate some forces at work in our model, especially for our dynamic results. In the limit, $\vartheta = 0$ collapses our model to a standard LS/CCK cash/credit model in which all goods are exchanged via Walrasian trade. Our calibration also delivers $\frac{N_1+s_1+N_2+s_2}{l} = 0.32$, meaning that households spend about one-third as much time in shopping-related activities as they do working. As discussed in Arseneau and Chugh (2007b), this is close to the evidence in the American Time Use Survey that the average individual spends about one hour in shopping activities for every four hours of work.

As we stated earlier, we choose a standard Cobb-Douglas matching function,

$$m(s,a) = \psi s^{\xi_s} a^{1-\xi_s} \tag{37}$$

and set the elasticity to $\xi_s = 0.5$. We calibrate ψ so that the steady-state quarterly probability a searching individual successfully forms a customer relationship is 90 percent, $k^h = 0.9$. For the Nash bargaining weight η, we choose $\eta = \xi_s = 0.5$, which has the virtue, well-known to search theorists since Hosios (1990), that it makes the underlying search equilibrium socially-efficient. We of course do not know if an efficient search equilibrium in the goods market is the best description of the data, but Hosios efficiency seems useful as a starting point for our theoretical investigation. Hosios efficiency, or the lack thereof, turns out to be one of the important forces at work in our model shaping the long-run Ramsey policy.

We set the cost γ to a firm of posting an advertisement such that total advertising expenditures $\gamma(a_1 + a_2)$ absorb about four percent of output in the Ramsey equilibrium, consistent with, although a bit higher than, the evidence presented in Arseneau and Chugh (2007b) that advertising expenditures make up about 2.5 percent of GDP. The reason we calibrate a bit higher is that given our cash/credit structure, we think that some "long-term cash relationships" may be a product of relatively informal advertising expenditures that would not be recorded in the data.[8] Finally, absent direct evidence, we simply set $\rho^x = 0.10$, which states that a firm loses ten percent of its existing customers in any given period. Equivalently, this parameter setting means that a newly-formed customer-firm relationship is expected to last for $1/\rho^x = 10$ periods (quarters), which we think does not seem implausible.

The exogenous productivity and government spending shocks follow AR(1) processes in logs,

$$\ln z_t = \rho_z \ln z_{t-1} + \epsilon_t^z, \tag{38}$$

$$\ln g_t = (1-\rho_g) \ln \bar{g} + \rho_g \ln g_{t-1} + \epsilon_t^g, \tag{39}$$

where $\bar{g}$ denotes the steady-state level of government spending, which we calibrate in our baseline model to constitute 18 percent of steady-state output in the Ramsey allocation. The resulting value is $\bar{g} = 0.06$, which we hold constant as we try other specifications of our model. The innovations ϵ_t^z and ϵ_t^g are distributed $N(0, \sigma_{\epsilon^z}^2)$ and $N(0, \sigma_{\epsilon^g}^2)$, respectively, and are independent of each other. We choose parameters $\rho_z = 0.95$, $\rho_g = 0.97$, $\sigma_{\epsilon^z} = 0.006$, and $\sigma_{\epsilon^g} = 0.03$, consistent with the RBC

[8] For example, the advertising expenditures — a colorful banner, a hand-written sign showing sale prices — of a hot dog vendor one goes to every day, one that accepts only cash, on a street corner of New York City probably do not get recorded in advertising data.

literature and CCK. Also regarding policy, we assume that the steady-state government debt-to-GDP ratio (at an annual frequency) is 0.5, in line with evidence for the U.S. economy and with the calibrations of Schmitt-Grohe and Uribe (2004b) and Siu (2004).

4.2 Ramsey Steady State

We begin by describing the deterministic Ramsey steady state, dividing the discussion into four parts. First, we discuss how purely exogenous fiscal and monetary policy affect households' search incentives in our environment. Understanding these unique policy channels will be helpful in understanding how our Ramsey results connect with both the benchmark results of CCK as well as later optimal-policy results in the literature. We next present our model's Ramsey steady-state allocations and policies, comparing them with socially-efficient allocations. We then successively allow for alternative policy instruments to illustrate how the nominal interest rate in our model plays two auxiliary roles not present in the basic LS/CCK model. Finally, we document how the Ramsey steady-state varies as we vary three key parameters associated with search.

We provide a thorough analysis of how Ramsey policy operates in the long run because our model is novel; as such, we think it worthwhile to spend some effort understanding the forces at work, knowing that future work will reveal some of these mechanisms to be more important that others. Readers primarily interested in understanding the dynamic policy implications of our model, however, may safely skip to Section 4.3 with the following summary of the steady-state results in mind. If the planner is able to use only the basic Ramsey instruments of a labor income tax and nominal interest rate, a strictly positive nominal interest rate is optimal, which violates the Friedman Rule of a zero net nominal interest rate that is optimal in a wide class of models. A strictly positive net nominal interest rate $R-1$ has three effects in our model. In addition to the standard wedge that it creates in the margin between Walrasian cash goods x_1 and Walrasian credit goods x_2, it indirectly taxes firms' profit flows, and it also plays a role in guiding search markets towards their Hosios-efficient outcomes. The ability of a positive nominal interest rate to stand in for a direct tax on firm profits is identical to that first found by Schmitt-Grohe and Uribe (2004a). The ability of a positive nominal interest rate to guide the economy towards Hosios efficiency is related to that found by Cooley and Quadrini (2004) and Arseneau and Chugh (2007a) in labor-search models and Rocheteau and Wright (2005) in a money-search model. We recover the optimality of the Friedman Rule if we allow for both a profit tax and a direct tax on household search, but not if we allow just one or the other of these alternative instruments. Our findings thus in some sense connect the auxiliary role for nominal interest rates discovered by Schmitt-Grohe and Uribe (2004a) with the auxiliary role discovered by Cooley and Quadrini (2004), Arseneau and Chugh (2007a), and Rocheteau and Wright (2005). Even absent these alternative instruments, however, the steady-state nominal interest rate is not very large; for our baseline calibration, the optimal nominal interest rate is 5.6 percent at an annual rate.

4.2.1 Effects of Exogenous Policy on Search Behavior

In the standard CCK model, a deviation from the Friedman Rule is costly because it distorts the marginal rate of substitution between cash and credit goods. Implementing the Friedman Rule requires the Ramsey planner to raise the funds to finance the attendant deflation via the labor tax.[9] In the standard CCK model, financing a deflation with proportional labor income taxation does not generate any other distortions that undermine the optimality of the Friedman Rule. This conclusion does not carry over to our model for two reasons. To elucidate them, it is helpful to first consider how completely exogenous tax rates and nominal interest rates affect search behavior in our environment, channels of course not present in a standard model of goods markets.

First, due to the presence of search frictions and the fact that search and leisure are *both* alternatives to labor as uses of a household's time, the labor income tax distorts not only labor supply but also household shopping behavior. This is true even though ostensibly the Hosios parameterization for search efficiency is in place. Just as in the standard CCK model, all else equal, a higher labor tax rate causes households to substitute out of labor (l) and into leisure ($1 - l - s_1 - s_2 - N_1 - N_2$). However, in our environment, the resulting decline in the marginal utility of leisure, $g'(1 - l - s_1 - s_2 - N_1 - N_2)$, means that the cost of engaging in additional search activity falls as well, inducing households to spend more time searching for goods.[10] That is, s_1 and s_2 both rise as τ^l rises. To isolate this effect, we plot in the top row of Figure 1 the long-run responses of s_1 and s_2 to exogenous changes in the labor tax rate, holding monetary policy fixed at the Friedman Rule.[11] The resulting slackness in product markets (by which we mean a fall in θ_1 and θ_2) induces firms to reduce advertising expenditures because a given level of advertising now more readily yields new customers.[12] On net, the decline in advertising expenditures dominates, causing the number of active customer relationships (N_1 and N_2) to fall. Thus, because the labor tax distorts household labor supply, it also directly distorts shopping behavior and indirectly distorts advertising behavior. These latter effects, absent in a standard CCK model, make the welfare consequences of running the Friedman deflation financed via a labor tax quite different in our environment.

[9] Simply because of the Ramsey assumption that no direct lump-sum instruments of any sort exist. Thus, π and τ^l are tightly linked through the government budget constraint, as is the case in any Ramsey monetary model.

[10] Recall from the household shopping conditions (9) and (10) that $g'(.)/k^h(.)$ measures the marginal cost of shopping.

[11] To emphasize, Figure 1 presents non-Ramsey responses.

[12] Cobb-Douglas matching means that firm matching rates $k^f(\theta_i)$ increase as θ_i falls. For brevity, we do not plot all of these equilibrium responses, but we have confirmed them.

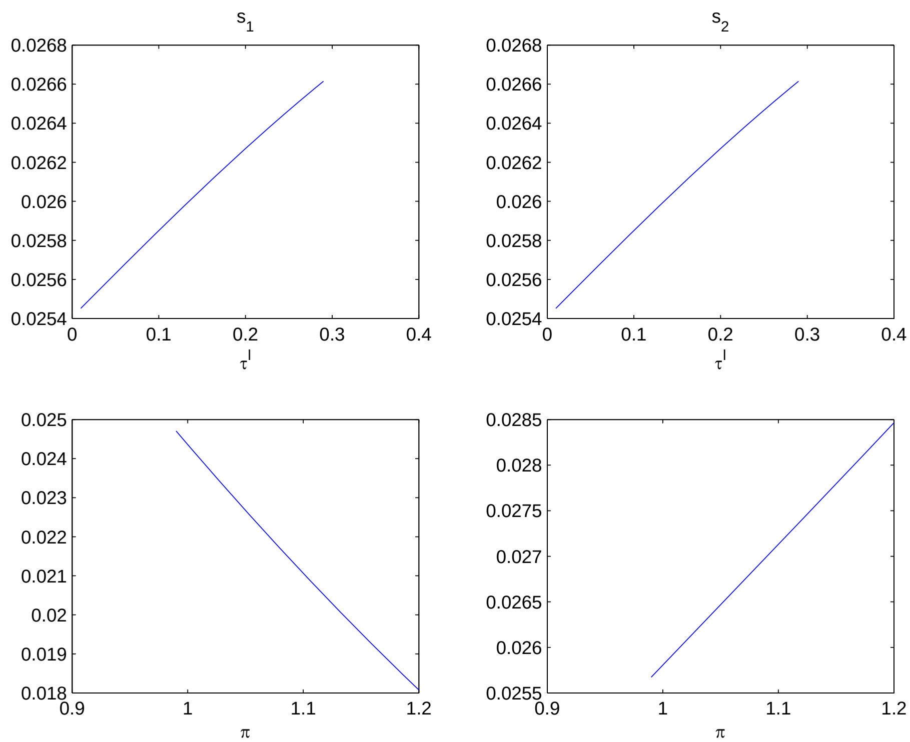

Figure 1: Steady-state household search behavior under exogenous policy. First row: money growth fixed at $\mu = \beta$. Second row: labor tax rate fixed at $\tau^l = 0$.

The second reason that a CCK type of argument does not carry over to our environment is that search frictions also result in welfare costs of anticipated inflation absent in a standard model. In a standard model, long-run inflation simply distorts the marginal rate of substitution between cash and credit goods. In our model, long-run inflation also affects the household shopping margin between cash search goods and credit search goods. Here, it is helpful to think in terms of the household shopping margin that we constructed in (12). In a high-inflation (and hence high nominal interest rate) steady state, the return to searching for and entering into a long-run credit relationship is greater than the return to searching for and entering into a long-run cash relationship, simply because the latter requires the use of money, whose value erodes with inflation, while the former does not. Substituting (7) into (12) and imposing steady state shows that a higher "regular" nominal interest rate R, *ceteris paribus*, results in a lower shadow nominal interest rate R^*.[13] With R^* defined as the relative probability $k^h(\theta_2)/k^h(\theta_1)$ a household matches in the credit market versus in the cash market, anticipated inflation thus directs household search away from the

[13]The *ceteris paribus* is important here; as we show below in an experiment where we vary the parameter η, a positive association between R and R^* can arise in the Ramsey equilibrium. It is of course more difficult to make analytical statements regarding the Ramsey equilibrium because the binding government budget constraint renders very few things *ceteris paribus*. This is a general statement about Ramsey models, not one about just our model.

cash sector and towards the credit sector. We confirm these effects in the bottom row of Figure 1 by plotting the long-run responses of s_1 and s_2 to exogenous changes in the inflation rate (governed by the long-run money growth rate), holding the labor tax fixed at $\tau^l = 0$. In summary, labor income taxation and anticipated inflation have consequences for search-market outcomes that a standard model cannot articulate, and these effects are important in shaping the Ramsey policy.

4.2.2 Ramsey Policy and Allocation

With this basic understanding about how π and τ^l affect search incentives, we proceed to begin analyzing the long-run Ramsey policy, presented in Table 1. For comparison, we also present in the upper row the allocation that solves the corresponding social planning problem, along with the implied policy computed residually from equilibrium conditions. By social efficiency, we mean those allocations that are subject to the technological constraints imposed by production and search and matching but which are not necessarily implementable as a decentralized equilibrium with proportional taxes, a requirement which of course is imposed on the Ramsey planner. Thus, Pareto-optimal allocations are the solution of the planning problem that maximizes (1) subject to (27), (28), and (31).

The most striking feature of the Ramsey solution in the second row of Table 1 is that the Friedman Rule is not optimal. In the next subsection, we parse out the reasons for this result by introducing into the decentralized environment two alternative tax instruments. In terms of allocations, given that a positive nominal interest rate is in place, it is quite intuitive that activity in the search cash market is depressed compared to activity in the search credit market. That is, N, s, and a are all lower in the cash sector than in the credit sector, and the intuition is just as described above in the exogenous-policy case: a positive nominal interest rate directs activity away from the cash search market and towards the credit search market. Also consistent with our discussion above, associated with the positive nominal interest rate $R - 1$ is a negative shadow nominal interest rate $R^* - 1$.[14]

4.2.3 Restoring the Friedman Rule Through Alternative Instruments

The deviation from the Friedman Rule is due to two distinct reasons, each related to recent results in the optimal policy literature: a positive nominal interest rate indirectly taxes firm profits and also serves to guide search markets towards efficiency. To assess the contribution of each of these auxiliary roles of the nominal interest rate to the magnitude of the departure from the Friedman Rule, we introduce in succession two alternative tax instruments to the environment.

[14] Note that the fact that $R^* - 1$ can be negative is not a violation of the ZLB. The ZLB applies to the proper price R, while R^* is more of a shadow price — which indeed is why we labeled it the shadow nominal interest rate.

$R-1$	$\pi-1$	τ^l	R^*-1	s_1	s_2	a_1	a_2	N_1	N_2	θ_1	θ_2	gdp
						Socially-efficient allocation						
0	-3	0	0	0.0146	0.0146	0.0221	0.0221	0.0308	0.0308	1.5135	1.5135	0.3372
						Ramsey policy and allocation						
5.6561	2.4864	0.2776	-3.4060	0.0133	0.0160	0.0156	0.0175	0.0248	0.0288	1.1718	1.0934	0.2734
						Ramsey policy and allocation with 100% profit tax						
3.1750	0.0797	0.1973	-1.8079	0.0140	0.0155	0.0177	0.0188	0.0270	0.0293	1.2601	1.2149	0.2929
						Ramsey policy and allocation with 100% profit tax and search tax						
0	-3	0.1648	0	0.0126	0.0126	0.0191	0.0191	0.0266	0.0266	1.5097	1.5097	0.2995

Table 1: Steady-state Ramsey and socially-efficient allocations. Nominal interest rate, inflation rate, and shadow nominal interest rate reported in annualized percentage points.

First, we allow the Ramsey planner access to a proportional tax on profit income. The way in which we allow for a profit tax follows closely Schmitt-Grohe and Uribe (2004a): we assume that household receipts of dividend payments by firms are taxed at the rate τ_t^{pr}. Formally, in the household flow budget constraint (2), we modify the last term on the right hand side to read $(1-\tau_{t-1}^{pr})P_{t-1}d_{t-1}$. Note that the presence of this profit tax does not affect any of the private-sector equilibrium conditions — because households take d_t as given — which is the key to understanding how it operates. The way in which the profit tax alters the PVIC is shown at the end of Appendix D.

As in Schmitt-Grohe and Uribe (2004a), assuming a natural upper bound of τ^{pr} of 100 percent, it is easy to show that the Ramsey planner would set $\tau^{pr} = 1$ because that achieves maximum relaxation of the PVIC.[15] The third row of Table 1 shows that with a 100 percent profit tax, the nominal interest rate falls from 5.65 percent to 3.18 percent. The labor income tax rate also falls because part of revenue is now raised through the profit tax, but we still have $\tau^l > 0$. Thus, over 2 percent of the positive nominal interest rate in the second row of Table 1 is a proxy for a profit

[15]More precisely, maximum relaxation of the PVIC would occur at that profit tax rate at which the multiplier on the PVIC in the Ramsey problem is zero. At this profit tax rate, the planner would be able to implement a zero *labor* income tax rate because all government spending would be financed through the non-distortionary profit tax. In our baseline model, the profit tax rate at which the Ramsey multiplier on the PVIC shrinks to zero is 140 percent. This result is not very interesting because it means that we effectively are no longer considering a *Ramsey* equilibrium, defined as one in which at least *some* distortionary instruments must be used. Hence the natural cap on τ^{pr} at 100 percent. Schmitt-Grohe and Uribe (2004a) also impose this natural upper limit, but we suspect that an unconstrained optimization over τ^{pr} must similarly yield $\tau^{pr} > 1$ in their model.

tax. Just as in Schmitt-Grohe and Uribe (2004a), Ramsey taxation of profits is non-distortionary in our environment, hence desirable. Taxation of long-run profit flows are non-distortionary in our environment because the pre-determined customer bases N_1 and N_2, which are the source of firm revenue and hence profit, cannot be altered.[16] In the absence of a direct tax on this fixed profit flow, the nominal interest rate can indirectly tax it. The fact that the nominal interest rate falls upon introduction of a profit tax is thus consistent with Schmitt-Grohe and Uribe (2004a); the fact that it does not fall all the way to zero is different from their result. There is thus yet another motivation for setting a positive nominal interest rate in our environment.

This second motivation stems from inefficiently-high s_1 and s_2 induced by the positive labor income tax, an effect we documented, recall, for the exogenous-policy case in the top row of Figure 1. The natural instrument to correct inefficiently-high search is a tax directly on search. Denote by τ^{s_1} (τ^{s_2}) a proportional tax on cash (credit) search activity. We introduce search taxation by including $\tau^{s_1}_{t-1}s_{1t-1} + \tau^{s_2}_{t-1}s_{2t-1}$ on the left-hand-side of the household budget constraint (2). For generality, we allow for differential search taxation, reflected in our notation, on cash search and credit search, but it turns out that $\tau^{s_1} = \tau^{s_2}$. Unlike the profit tax, search taxes do affect equilibrium conditions. Specifically, they modify the equilibrium versions of the cash and credit shopping conditions to

$$\frac{g'_t + u_{2t}\tau^{s_i}_t}{k^h(\theta_{it})} = \beta(1-\rho^x)E_t\left\{c_{it+1}\left[\vartheta v_{it+1} - p_{it+1}u_{it+1}\right] - g'_{t+1} + \frac{g'_{t+1} + u_{2t+1}\tau^{s_i}_{t+1}}{k^h(\theta_{it+1})}\right\}, \qquad (40)$$

for $i = 1, 2$, which is a straightforward and intuitive modification of the shopping conditions (9) and (10): search taxes add to the marginal cost of searching (the left-hand-side), but also add to the expected future marginal benefit of successfully forming a customer relationship (the right-hand-side) by allowing the household to save on future search taxes. We also introduce $\tau^{s_1}_t s_{1t} + \tau^{s_2}_t s_{2t}$ as a revenue item in the government budget constraint, making it part of the optimal government financing problem. This means that the PVIC includes the search taxes; we show at the end of Appendix D how search taxes alter the PVIC.

Optimizing directly in the Ramsey problem with respect to $\tau^{s_1}_t$ and $\tau^{s_2}_t$, we find the optimal steady-state search tax rates are $\tau^{s_1} = \tau^{s_2} = 0.48$. At first glance, this seems quite high, but on further reflection one realizes that because we do not seem to observe search taxes at all in reality, there really is no basis for judging whether or not it is "high." In any case, our main interest here is not in the search taxes themselves, but rather in what their presence implies for the rest of the Ramsey policy mix. The bottom row of Table 1 presents the Ramsey policy and allocation in the presence of these search taxes and the 100-percent profit tax. The most important result here is that optimality of the Friedman Rule is restored. We omit it from the table, but

[16] In Schmitt-Grohe and Uribe (2004a), the fixity of firm profits stems from the exogenous Dixit-Stiglitz-style monopoly power firms wield.

we also computed the Ramsey solution in the presence of just search taxes and $\tau^{pr} = 0$. Here, we found $100(R-1) = 5.6601$ (virtually identical to that in the second row of Table 1), $\tau^{l} = 0.2198$, $\tau^{s_1} = 0.5593$, and $\tau^{s_2} = 0.7258$. Thus, both profit taxes and search taxes are required to restore the optimality of the Friedman Rule. The deviation from the Friedman Rule in our environment thus has connections with the findings of both Schmitt-Grohe and Uribe (2004a) and with those of Cooley and Quadrini (2004), Arseneau and Chugh (2007a), and Rocheteau and Wright (2005).

In terms of welfare, steady-state utility (not shown) is strictly increasing as we move down Table 1 from the Ramsey equilibrium with neither profit nor search taxes to the Ramsey equilibrium with profit taxes but no search taxes to the Ramsey equilibrium with both profit and search taxes. Qualitatively examining how allocations vary as instruments are successively added, it is clear that allocations move closer to the Pareto optimum shown in the first row of Table 1. Of course, the Ramsey equilibrium can never get all the way to the Pareto optimum because $\tau^{l} > 0$ is required under any Ramsey equilibrium.

Having demonstrated that positive nominal interest rates proxy for multiple instruments in our environment, the remainder of our analysis omits these alternative instruments. Our reason for omitting the alternative instruments is that in studying Ramsey dynamics, given that we drop the ZLB constraint from the dynamic solution, we want to ensure our equilibrium does not pierce the zero lower bound during simulations. Results obtained by Cooley and Quadrini (2004) and Arseneau and Chugh (2007a) suggest that causing such a level-shift in policy in this way does not blur interpretation of dynamics.

4.2.4 Varying Search Parameters

Before turning to dynamics, we also briefly document how the Ramsey equilibrium varies with a few novel parameters associated with search markets. Figures 2 and 3 analyze the Ramsey steady state along the bargaining-power dimension, plotting key policy and allocation variables as a function of customer bargaining power η. Varying η away from 0.5 moves the economy away from the usual notion of Hosios efficiency. This type of departure from search efficiency is the one most related to the existing labor-search or money-search literature, in contrast to our demonstration above that labor-income taxation also makes outcomes in search markets inefficient, which is a more novel, policy-induced, type of departure from Hosios efficiency.[17]

Based on the results above that the optimal nominal interest rate can proxy for direct search taxes, it is natural to expect that the nominal interest rate will vary with η. Indeed, as the upper left panel of Figure 2 shows, the optimal nominal interest rate is increasing in η. This response arises

[17] Arseneau and Chugh (2006) also demonstrate that policy-induced departures from Hosios efficiency lead to auxiliary roles for other "standard" tax instruments; their focus was on a capital income tax.

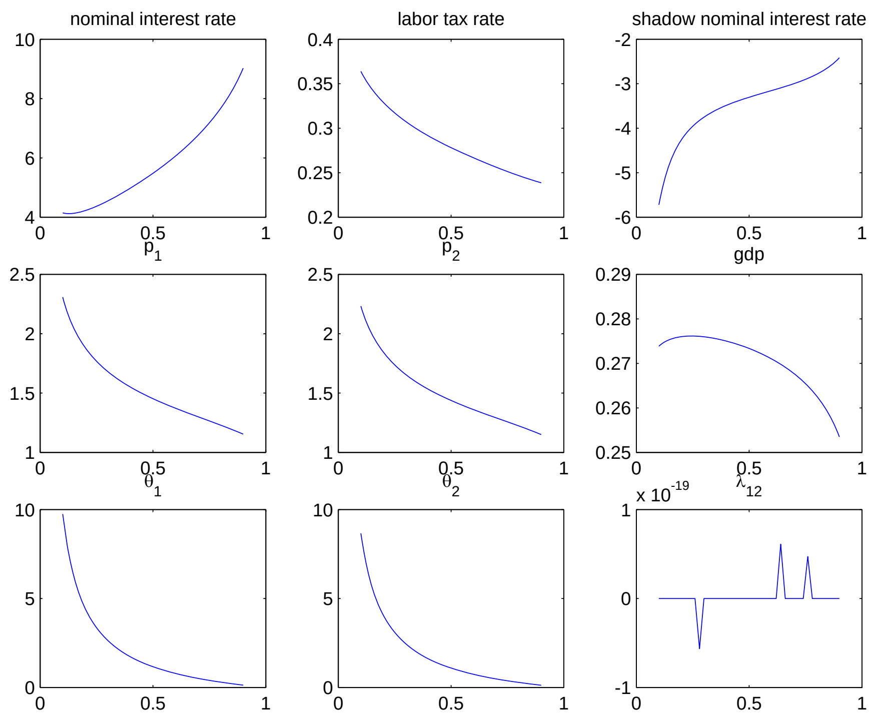

Figure 2: Steady-state Ramsey policy and allocation variables as function of customer bargaining power η.

because the Ramsey government tries to mitigate households' increased search activity induced by higher η. Absent the policy response shown in the upper left panel of Figure 2, the rise in the sum of s_1 and s_2 (each of which is shown in Figure 3) would be even larger, which we can confirm by running the corresponding experiments in the exogenous (non-Ramsey) policy environment.[18] In terms of how other allocation variables vary with η (i.e., a_1 and a_2 depend negatively on η, p_1 and p_2 depend negatively on η, and so on), the results in Figures 2 and 3 match up with those of Arseneau and Chugh (2007b), so we refer the reader there for more analysis.

Figures 4 and 5 display how the Ramsey steady-state depends on ϑ, which, recall from the specification of household preferences in (1), governs how valuable search goods are to the household. In the absence of direct evidence, recall that we set as our baseline $\vartheta = 1$. Setting $\vartheta = 0$ eliminates search markets and collapses our model to a standard CCK cash/credit economy. The optimal nominal interest rate, shown in the upper left panel of Figure 4, rises as ϑ rises because profits generated from search markets (not shown) grow with ϑ. A larger profit base makes taxing profits more attractive to the Ramsey planner, and we already showed above that the nominal interest

[18] Specifically, in the exogenous-policy environment, we find, computationally, $\partial s_i/\partial\eta > 0$, $i = 1, 2$, which is intuitive (a higher return to search, measured by higher bargaining power, induces a household to increase its search), and also that $\partial s/\partial\pi < 0$, where $s = s_1 + s_2$. The latter can also be seen in the bottom row of Figure 1, in which s_1 falls by more than s_2 rises as π rises, meaning $s_1 + s_2$ falls.

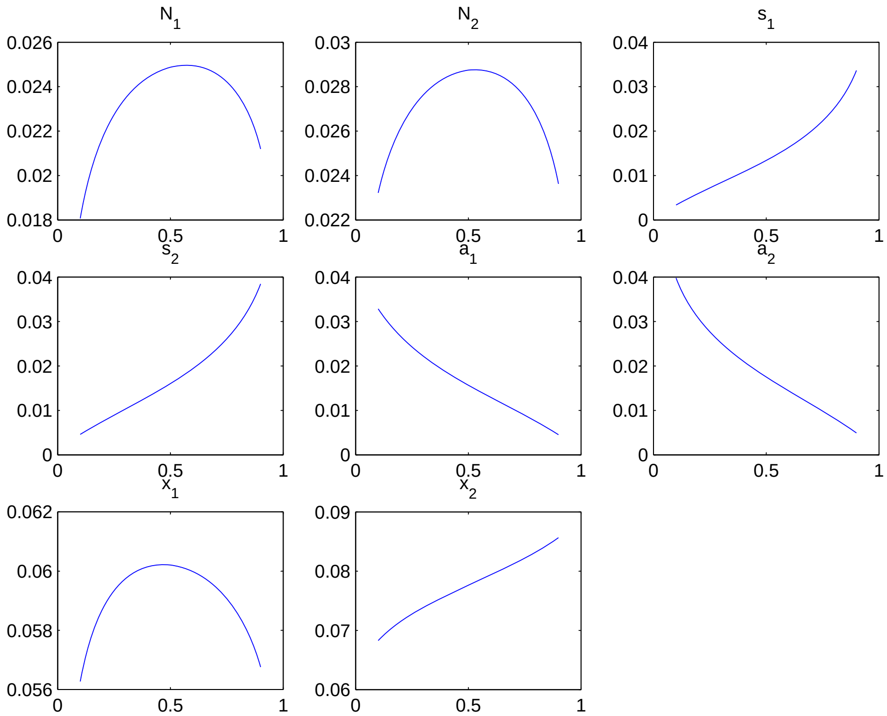

Figure 3: Steady-state Ramsey policy and allocation variables as function of customer bargaining power η.

rate has the ability to indirectly tax profits. The responses of search-market allocation variables as ϑ rises (i.e., N_i, a_i, and s_i, $i = 1, 2$, all increase) all are intuitive: the more important (all) search goods are in preferences, the more resources the economy directs to search activities.

Finally, our baseline calibration has $\kappa_c = \kappa_x = 0.5$, meaning the importance of cash and credit goods in preferences is symmetric across search and non-search markets. A natural conjecture may be that cash transactions are less important in markets with long-lived relationships. Because of repeat interactions, a firm may be more willing to "extend credit" to a good customer. We can probe this idea by varying κ_c, holding all other parameters fixed at their baseline values; Figures 6 and 7 plot the Ramsey steady state as we vary κ_c. Higher values of κ_c mean that cash is less intensively used for goods acquired in bilateral transactions. The results are again quite intuitive. As κ_c rises, cash search goods are valued less and less, so activity in the cash search market disappears, as evidenced by the fact that N_1 (the number of active cash relationships), s_1 (the number of individuals searching for cash goods), and a_1 (advertisements posted in the cash search market) all tend towards zero. For $\kappa_c > 0.6$, the ZLB binds, revealed by the fact that the Ramsey multiplier on the ZLB constraint (denoted λ_{12} and displayed in the lower right panel of Figure 6) rises above zero.

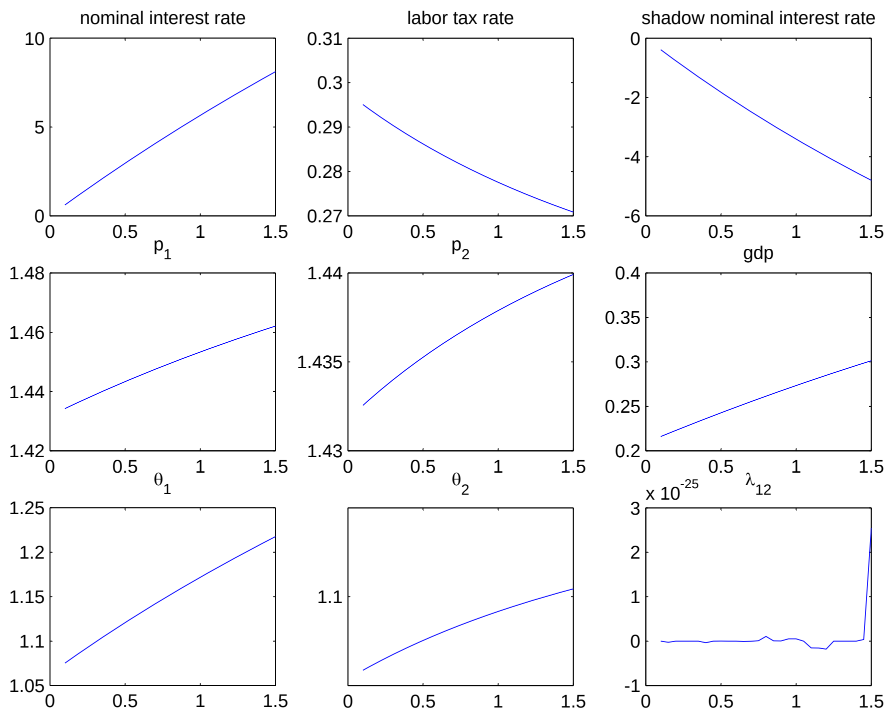

Figure 4: Steady-state Ramsey policy and allocation variables as function of importance of search goods, governed by ϑ.

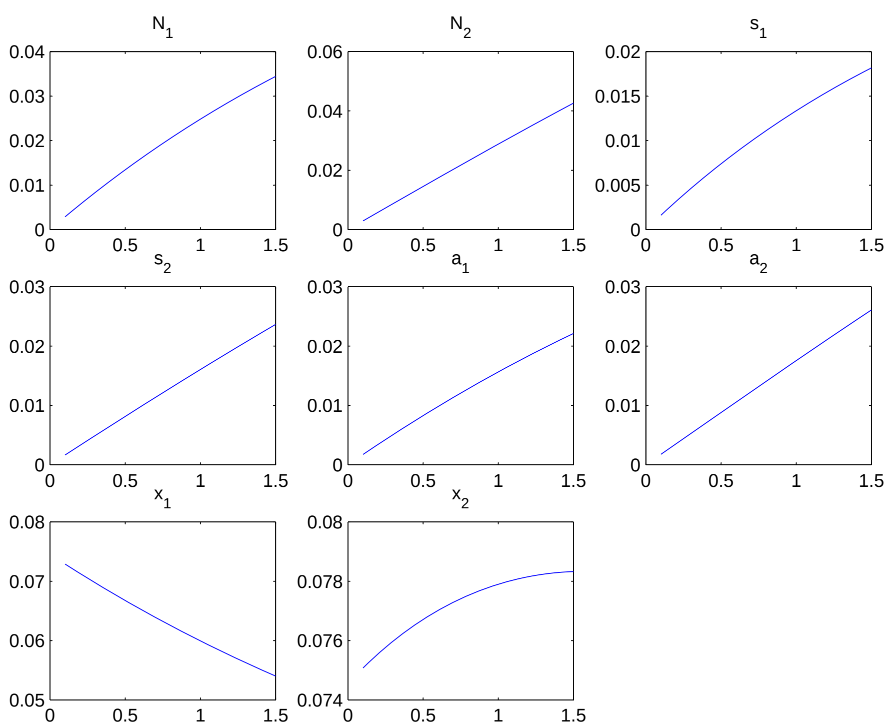

Figure 5: Steady-state Ramsey policy and allocation variables as function of importance of search goods, governed by ϑ.

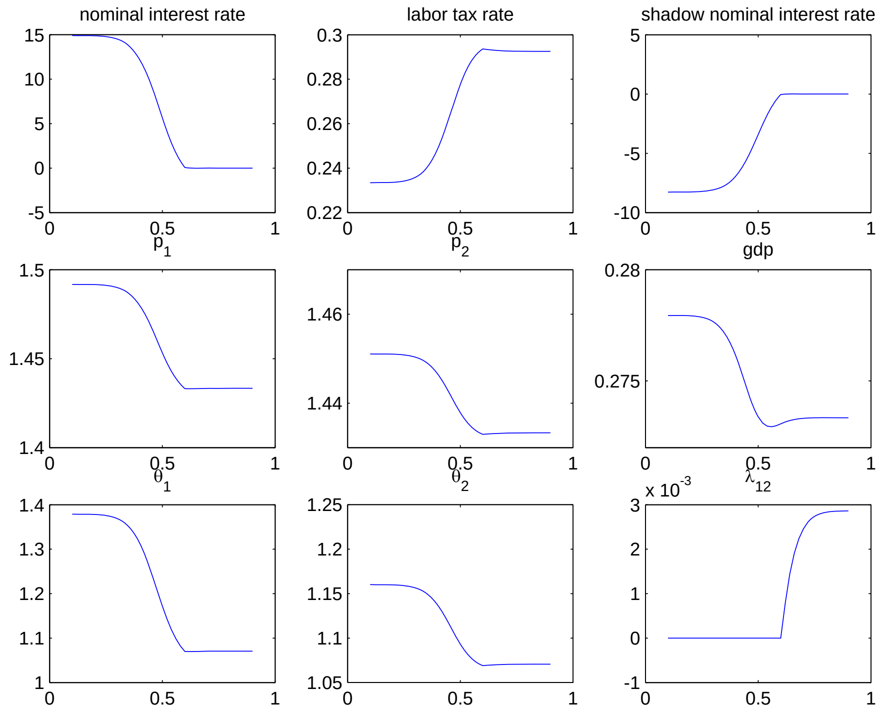

Figure 6: Steady-state Ramsey policy and allocation variables as function of share parameter κ_c.

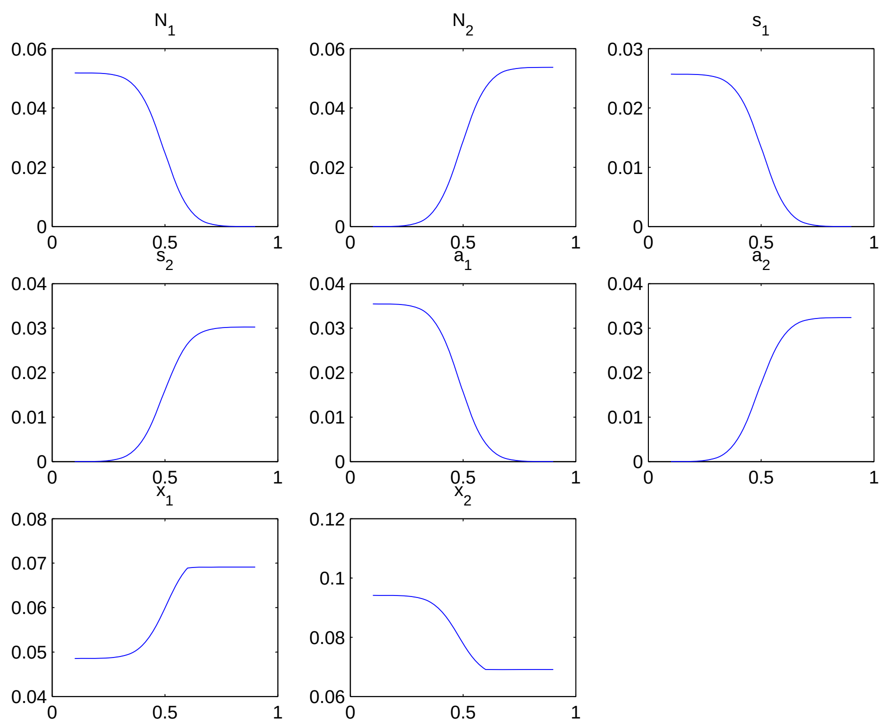

Figure 7: Steady-state Ramsey policy and allocation variables as function of share parameter κ_c.

4.3 Ramsey Dynamics

To study dynamics, we approximate our model by linearizing in levels the Ramsey first-order conditions for time $t > 0$ around the non-stochastic steady-state of these conditions. We use our approximated decision rules to simulate time-paths of the Ramsey equilibrium in the face of a complete set of TFP and government spending realizations, the shocks to which we draw according to the parameters of the laws of motion described above. Our numerical method is our own implementation of the perturbation algorithm described by Schmitt-Grohe and Uribe (2004c). As in Khan, King, and Wolman (2003) and others, we assume that the initial state of the economy is the asymptotic Ramsey steady state. As we mentioned above, we assume throughout, as is common in the literature, that the first-order conditions of the Ramsey problem are necessary and sufficient and that all allocations are interior. We also point out that because we assume full commitment on the part of the Ramsey planner, the use of state-contingent inflation is not a manifestation of time-inconsistent policy. The "surprise" in surprise inflation is due solely to the unpredictable components of government spending and technology and not due to a retreat on past promises.

We conduct 5000 simulations, each 200 periods long. For each simulation, we then compute first and second moments and report the medians of these moments across the 5000 simulations. We divide the discussion of results into three parts: we first analyze the dynamics of policy variables, we then discuss key allocation variables, and we close by analyzing how the asset values of search and active customer relationships vary under the Ramsey plan. As we mentioned above, for all of our dynamic experiments, we assume that the alternative tax instruments (the profit tax and the search taxes) are unavailable.

4.3.1 Ramsey Policies and Prices

The upper panel of Table 2 reports key first and second moments for Ramsey policy and price variables. The first row shows that the labor tax rate has a standard deviation of 0.1 percent around its mean of about 28 percent. The low volatility of the labor tax rate is in line with benchmark tax-smoothing findings in the Ramsey literature — for example, Chari and Kehoe (1999, p. 1737), Schmitt-Grohe and Uribe (2004a, p. 204), and Siu (2004, p. 595) all report very similar results. In search-based models, Arseneau and Chugh (2007a, p. 38) find substantially more volatility in labor tax rates in the presence of labor matching frictions, while Aruoba and Chugh (2006, p. 47) find about the same or even lower volatility in labor tax rates in the presence of frictions underlying monetary exchange. Also as in the basic LS/CCK environment, the labor tax rate inherits the serial correlation of the exogenous shocks; when we simulate a version of our model with zero persistence in TFP and government spending shocks, the first-order autocorrelation of τ^l is virtually zero. Furthermore, the serial correlation of real government debt obligations, defined as $b_t \equiv B_t/P_t$, also inherits from the assumed persistence of the exogenous shocks, again just as in a baseline LS/CCK model.

The second row of Table 2 displays our central result: the volatility of the optimal inflation rate, at 0.67 percent around a mean of 2.5 percent (all on an annual basis), is an order of magnitude lower than benchmark results in the Ramsey literature. Optimal inflation policy in our environment stands in sharp contrast to the extremely volatile optimal inflation rate first found by CCK in a flexible-price Ramsey model and recently verified in, among others, the flexible-price versions of the models of Schmitt-Grohe and Uribe (2004a, 2004b), Siu (2004), and Chugh (2006, 2007a, 2007b).[19]

In these flexible-price Ramsey models, unanticipated inflation does not distort relative prices of goods. It is easiest to understand this in the basic cash/credit economy absent the search frictions of our model. In a basic cash/credit economy, the nominal price of both cash and credit goods is P, and the relative price depends only on the nominal interest rate, reflecting the opportunity cost of the money used to purchase the cash good. In other words, given a nominal interest rate, dynamic fluctuations in the price level do not alter the relative price between cash and credit goods and therefore have little effect on equilibrium dynamics. In these baseline models, then, the driving force behind price-level dynamics is just the (desirable) ability of price-level fluctuations to tailor the real returns on nominal government debt, thus avoiding the need to change other distortionary taxes in the face of shocks to the government budget.

With search frictions, this result is overturned because inflation affects the relative price of search goods. To see this, recall expression (13), which we noted above contained our central hypothesis. The (binding) cash-in-advance constraint links realized inflation to the dynamics of the relative price, p_1, of search cash goods. As we discussed when we presented condition (13), fluctuations in π_t may potentially transmit into fluctuations in p_{1t}, which in turn may disrupt search markets. Our intuition is that disruption of search markets would not stem from fluctuations in p_{1t} *per se*, but rather, more precisely, from the extent to which those fluctuations alter expectations about future p_{1t+1} and the extent to which they are associated with fluctuations in goods-market tightness. We think that the reason that the transmission of movements in p_{1t} into anticipated movements in p_{1t+1} is important here is that p_{1t} itself plays no direct allocative role. As is well-known in search-based models, the actual realization of p_{1t} in and of itself has only a distributive role once period t begins. The Nash-bargained price divides the surplus between parties, here between customers and firms,

[19] From their simulation experiments, Chari and Kehoe (1999) report a mean inflation rate of -0.44 percent with a standard deviation of 19.93; Schmitt-Grohe and Uribe (2004a) report a mean inflation rate of -3.39 percent with a standard deviation of 7.47 percent; Siu (2004) reports a mean inflation rate of -2.59 percent with a standard deviation of 5.08 percent; and Chugh (2006) reports a mean inflation rate of -4.01 percent with a standard deviation of 6.96 percent. Each of these models is calibrated in a slightly differen way from the others, but the general result that comes through is clear: with flexible prices, the Ramsey inflation rate is quite volatile.

Variable	Mean	Std. Dev.	Auto corr.	Corr(x, Y)	Corr(x, Z)	Corr(x, G)
			Ramsey policies and prices			
τ^l	0.2776	0.0010	0.8854	-0.0586	0.6871	-0.6832
$\pi - 1$	2.4874	0.6744	-0.0433	-0.0942	-0.1446	-0.0001
$R - 1$	5.6567	0.0394	0.9556	0.1225	0.7478	-0.4788
$R^* - 1$	-3.4044	0.0595	0.9677	0.4344	0.9480	-0.2239
p_1	1.4534	0.0063	0.2577	0.4067	0.6892	-0.0546
p_2	1.4380	0.0067	0.2670	0.4051	0.6972	-0.0634
Ep'_1	1.4534	0.0029	0.9376	0.6108	0.9981	-0.0373
$\mu - 1$	2.4848	0.1059	0.1470	-0.0597	0.0747	-0.1449
			Ramsey allocations			
gdp	0.2734	0.0049	0.9335	1	0.6425	0.7358
l	0.2734	0.0038	0.9395	0.5159	-0.2705	0.9544
θ_1	1.1715	0.0190	0.9125	0.5983	0.9979	-0.0522
θ_2	1.0931	0.0180	0.9142	0.5977	0.9980	-0.0529
N_1	0.0248	0.0002	0.9203	0.3718	0.8806	-0.2501
N_2	0.0288	0.0003	0.9147	0.3821	0.8839	-0.2393
s_1	0.0133	0.0001	0.0788	-0.0629	0.3018	-0.3462
s_2	0.0160	0.0001	0.0377	-0.0240	0.3233	-0.3127
a_1	0.0156	0.0003	0.6903	0.4664	0.9211	-0.1632
a_2	0.0175	0.0004	0.6688	0.4671	0.9152	-0.1576
x_1	0.0599	0.0009	0.9342	0.4857	0.9787	-0.1815
x_2	0.0779	0.0014	0.9045	0.4999	0.9819	-0.1661

Table 2: Simulation-based moments in the Ramsey equilibrium.

but does not affect allocations, all else, including expectations of future prices, equal.

Absent a direct concern for distributions of gains between customers and firms, more important from the perspective of the Ramsey planner is that period-t search activity, on the part of both households and firms, is governed by expectations of period-$t+1$ prices. Indeed, the shopping conditions (9) and (10) and advertising conditions (20) and (21) depend on p_{it+1}, not on p_{it}; as we have already noted, shopping and advertising in our model are akin to investment decisions in that they are governed by expected future returns. To the extent that inflation-induced volatility of expected future prices disrupts search activity, keeping inflation volatility low is important.

Another feature of search-based models that seems germane for understanding our dynamic results is that market tightness is the critical variable governing efficiency. Indeed, the Hosios (1990) notion of search efficiency is all about getting market tightness "right." Despite the problem of financing government purchases using available instruments, the Ramsey planner of course has a primitive concern for efficiency. Extending the centrality of market tightness in the usual static notion of search efficiency to a dynamic setting, it seems natural to conjecture that time-variation in market tightness would be undesirable from the Ramsey point of view. Well-known from search theory — see, for example, Pissarides (2000, Chapter 1) or Rogerson, Shimer, and Wright (2005) — is that p and θ are the two key endogenous variables in search markets.

To try to quantitatively assess the importance of the dynamics of θ_{1t}, θ_{2t}, and $E_t p_{1t+1}$ in shaping the dynamic Ramsey policy, we present in Table 3 a battery of median cross-correlations between policy and search-market variables from our simulated Ramsey equilibria, along with the same measures from a version of our model in which policy is exogenous and government financing concerns are absent. The way in which we construct the exogenous-policy simulations whose correlations are presented in the lower panel of Table 3 is the following. We assume independent AR(1) processes describe sufficiently-well the dynamics of the labor tax rate τ^l and the money growth rate μ, positing exogenous laws of motion $\ln \tau^l_t = (1-\rho_{\tau^l}) \ln \bar{\tau}^l + \rho_{\tau^l} \ln \tau^l_{t-1} + \epsilon^{\tau^l}_t$ and $\ln \mu_t = (1-\rho_\mu) \ln \bar{\mu} + \rho_\mu \ln \mu_{t-1} + \epsilon^\mu_t$. We set the means $\bar{\tau}^l = 0.2776$ and $\bar{\mu} = 1.0248$ and persistence parameters $\rho_{\tau^l} = 0.8854$ and $\rho_\mu = 0.147$ to match the corresponding values under the Ramsey equilibria shown in Table 2.[20] We use the same laws of motion and even the exact realizations of $\{z_t\}$ and $\{g_t\}$ used in computing the Ramsey equilibria. We then approximate decision rules for this exogenous-policy version of our model using our linear procedure, with which we conduct simulations.

Four main observations stand out to us in comparing the Ramsey equilibria in the upper panel of Table 3 with the exogenous-policy equilibria in the lower panel of Table 3.[21] First, the Ramsey-

[20] The assumption of independent laws of motion for μ_t and τ^l_t is justified by the fact that in the Ramsey equilibria, we found a median correlation between μ_t and τ^l_t of -0.011 and a mean correlation between μ_t and τ^l_t of -0.005.

[21] A caveat in all of our comparisons here is that the Ramsey policy cannot be fully captured by simple AR(1) rules

equilibrium correlations of π_t with θ_{1t}, θ_{2t}, p_{1t}, and p_{2t} are all negative, opposite in sign to the corresponding correlations under exogenous policy. Thus, the Ramsey policy engineers quite different cross-dynamics between inflation and key search-market variables than does an arbitrary policy. Second, while both are negative, the dynamic correlation between π_t and $E_t p_{1t+1}$ is much weaker in the Ramsey equilibrium (-0.07) than in the corresponding exogenous-policy equilibrium (-0.41). This result has the flavor of the often-made empirical argument that if policy successfully stabilizes a particular variable, there ought to be little observed correlation between them.[22] Because the Ramsey correlation between π_t and $E_t p_{1t+1}$ is the smallest between any policy variable and search-market variable, it may be the case that Ramsey adjustments in π_t are made with a primary concern for stabilizing $E_t p_{1t+1}$.[23] Third, under exogenous policy, the correlations of π_t with s_{1t} and a_{1t} are both negative, but the correlations of π_t with s_{2t} and a_{2t} are both positive. Thus, unanticipated inflation under exogenous policy directs household search away from the cash sector and towards the credit sector, just as in the exogenous-policy steady-state effects we documented in Figure 1. In contrast, the Ramsey policy maintains nearly symmetric correlations between π_t and s_{1t} and s_{2t} (approximately -0.92 in both cases) and between π_t and a_{1t} and a_{2t} (approximately -0.47 in both cases). These symmetric correlations seem a sensible goal of policy: given that all preference and technology parameters are symmetric across the cash-search and credit-search sectors, efficiency dictates that the two search markets move symmetrically. Fourth, interestingly, under exogenous policy, there is virtually zero correlation between p_{1t} and $E_t p_{1t+1}$, while this correlation, at 0.66, is substantially different from zero in the Ramsey equilibrium.

Another observation, regarding just the Ramsey equilibria, is that, as shown in the upper panel of Table 3, the Ramsey-equilibrium correlations of R_t, τ_t^l, and R_t^* with θ_{1t}, θ_{2t}, and $E_t p_{1t+1}$ are all very high. Again, if fluctuations in θ_{1t}, θ_{2t}, and $E_t p_{1t+1}$ are undesirable as we conjecture, it would seem that Ramsey policy should stabilize R_t, τ_t^l, and R_t^*. Referring back to the upper panel of Table 2, we see that indeed the volatility of R_t, τ_t^l, and R_t^* are all very small.

The low Ramsey volatility of R_t^* and R_t is quite different from what occurs under exogenous policy. We can compare the Ramsey-optimal policy dynamics in Table 2 with the corresponding

as we assume in the exogenous-policy case. Thus, some part of any differences we note here may be explained by "mis-specification" of the policy rules.

[22] The basic idea behind this argument is simple: if adjustments in a policy variable successfully completely stabilize a target variable, then by construction there is zero correlation between the policy and target variables (nor, of course, between *any* variable and the target variable). For a recent example of this kind of argument, see Kishor and Kochin (2007) and the references therein.

[23] Another subtle caveat is in order here. Properly speaking, a central bank of course does not directly set π, but rather μ or some relevant nominal interest rate. Under the Ramsey equilibrium, however, one can think of π as being set directly, with μ determined "residually" through equilibrium conditions, which allows us to speak here of π being the direct policy instrument.

	π	R	R^*	τ^l	Ep_1'	p_1	p_2	θ_1	θ_2	s_1	s_2	a_1	a_2
						Ramsey-policy cross-correlations							
π	1	0.25	0.05	-0.21	-0.07	-0.82	-0.81	-0.17	-0.16	-0.93	-0.91	-0.48	-0.47
R		1	0.92	0.86	0.79	0.28	0.29	0.78	0.79	0.06	0.12	0.65	0.66
R^*			1	0.83	0.96	0.53	0.54	0.96	0.96	0.19	0.26	0.85	0.86
τ^l				1	0.73	0.61	0.62	0.75	0.76	0.54	0.59	0.81	0.82
Ep_1'					1	0.66	0.67	0.99	0.99	0.26	0.34	0.91	0.92
p_1						1	1	0.70	0.69	0.87	0.90	0.90	0.89
p_2							1	0.70	0.70	0.87	0.90	0.91	0.90
θ_1								1	1	0.33	0.41	0.94	0.94
θ_2									1	0.32	0.40	0.93	0.94
s_1										1	0.99	0.65	0.64
s_2											1	0.72	0.70
a_1												1	0.99
a_2													1
						Exogenous-policy cross-correlations							
π	1	0.24	0.24	-0.05	-0.41	0.70	0.74	0.22	0.23	-0.51	0.68	-0.70	0.52
R		1	0.99	-0.09	-0.17	0.29	0.57	0.93	0.99	-0.90	0.72	-0.71	0.91
R^*			1	-0.09	-0.14	0.30	0.57	0.94	0.99	-0.90	0.72	-0.70	0.91
τ^l				1	0.21	-0.01	-0.07	-0.13	-0.10	0.12	-0.07	0.10	-0.09
Ep_1'					1	0.01	-0.09	0.21	-0.03	0.01	-0.26	0.22	-0.17
p_1						1	0.94	0.32	0.31	-0.64	0.84	-0.84	0.65
p_2							1	0.56	0.57	-0.84	0.97	-0.97	0.86
θ_1								1	0.97	-0.90	0.64	-0.64	0.85
θ_2									1	-0.92	0.70	-0.69	0.91
s_1										1	-0.90	0.91	-0.99
s_2											1	-0.99	0.94
a_1												1	-0.93
a_2													1

Table 3: Simulation-based cross-correlations. Upper panel: Ramsey policy. Lower panel: exogenous policy.

dynamics of the exogenous-policy model, which are presented in Table 4. The dynamics of τ^l and μ are the same in both cases by construction. The most apparent differences lie in the volatilities of R_t^*, R_t, and, to a lesser extent, π_t. Under the Ramsey equilibrium, R_t^* and R_t are one and two orders of magnitude less volatile, respectively, than under the exogenous-policy equilibrium. Stabilization of R_t^* is consistent with our conjecture that stabilizing the cash search/credit search margin (12) is a central goal of policy. The quantitative degree of stabilization of the standard static cash/credit margin (7) is similar to that found by Schmitt-Grohe and Uribe (2004a, 2004b) and Chugh (2007a). The fact that Ramsey-optimal fluctuations in π_t are *larger* than in the exogenous-policy case is consistent with the fact that state-contingent variations in inflation *are* desirable from the Ramsey point of view because they allow for shock absorption — just not nearly as desirable as in a basic LS/CCK environment. The larger Ramsey fluctuations in π_t are also evident in the larger fluctuations in p_{1t} under the Ramsey equilibria compared to the exogenous-policy equilibria. This result is consistent with our intuition regarding condition (13): fluctuations in π_t transmit into fluctuations in p_{1t}.

In sum, a number of volatilities in and correlations between policy and the key search-market variables θ_{1t}, θ_{2t}, and $E_t p_{1t+1}$ are quite different under the Ramsey policy than they are under exogenous policy. These observations of course do not prove our intuition that the key to understanding the optimality of stabilizing inflation in our model is inflation's effects on market tightness and expectations of future search-goods prices, but we think they are all consistent with it. If correct, this kind of motivation for stabilizing inflation is different from that articulated in a standard sticky-price model, in which distortions in static relative prices *per se*, rather than inflation's effects on the dynamics of expected future prices, is the typically-understood reason behind the optimality of inflation stability.

Figure 8 demonstrates this idea in a different way and displays the quantitative power of the search friction in shaping optimal policy. In Figure 8, we plot the standard deviation of the Ramsey inflation rate as a function of ϑ, which, recall from the specification of household preferences in (1), governs how valuable search goods are to the household; all other parameter values are held constant at their benchmark levels. In the absence of direct evidence, recall that we set as our baseline $\vartheta = 1$. In the limit, setting $\vartheta = 0$ collapses our model to a standard CCK model.

Figure 8 clearly shows that as we move our environment close to that of CCK (by lowering ϑ), their benchmark inflation volatility result re-emerges. As ϑ rises from very low values, optimal inflation volatility falls quickly, approaching a basic sticky-price model's prediction of near-zero inflation volatility for sufficiently-large ϑ. We encountered numerical difficulty in solving for very small and very large values of ϑ, hence we limit the results in Figure 8 to $\vartheta \in [0.1, 1.5]$, but the main message seems clear: as the importance of goods obtained in long-term relationships grows

Variable	Mean	Std. Dev.	Auto corr.	Corr(x, Y)	Corr(x, Z)	Corr(x, G)
			Policies and prices			
τ^l	0.2777	0.0011	0.8609	-0.0515	-0.0106	-0.0080
$\pi - 1$	2.4795	0.3409	0.2860	0.0849	0.2305	-0.0318
$R - 1$	5.6832	1.0461	0.9237	0.3592	0.9818	-0.1608
$R^* - 1$	-4.6915	0.5305	0.9233	0.3831	0.9867	-0.1358
p_1	1.4533	0.0023	-0.0056	0.2135	0.3106	0.0677
p_2	1.4634	0.0061	0.1393	0.2633	0.5744	-0.0372
Ep'_1	1.4533	0.0003	0.9282	0.8102	-0.0097	0.9740
$\mu - 1$	2.4795	0.1039	0.1449	-0.0034	-0.0034	0.0019
			Allocations			
gdp	0.2757	0.0047	0.9397	1	0.4991	0.8412
l	0.2755	0.0045	0.9386	0.5262	-0.4287	0.8919
θ_1	1.1719	0.0073	0.9240	0.6805	0.9661	0.1996
θ_2	1.0645	0.0183	0.9233	0.4962	0.9948	-0.0116
N_1	0.0254	0.0002	0.9237	-0.4357	-0.9175	0.0446
N_2	0.0279	0.0006	0.9229	0.3070	0.9019	-0.1833
s_1	0.0137	0.0002	0.6452	-0.4910	-0.9107	-0.0244
s_2	0.0157	0.0003	0.3132	0.1684	0.6921	-0.2192
a_1	0.0160	0.0001	0.2908	-0.2084	-0.6835	-0.1683
a_2	0.0168	0.0006	0.6289	0.3466	0.8981	-0.1330
x_1	0.0600	0.0009	0.9229	-0.3571	-0.9762	0.1680
x_2	0.0780	0.0026	0.9234	0.3661	0.9837	-0.1537

Table 4: Simulation-based moments in the exogenous-policy equilibrium.

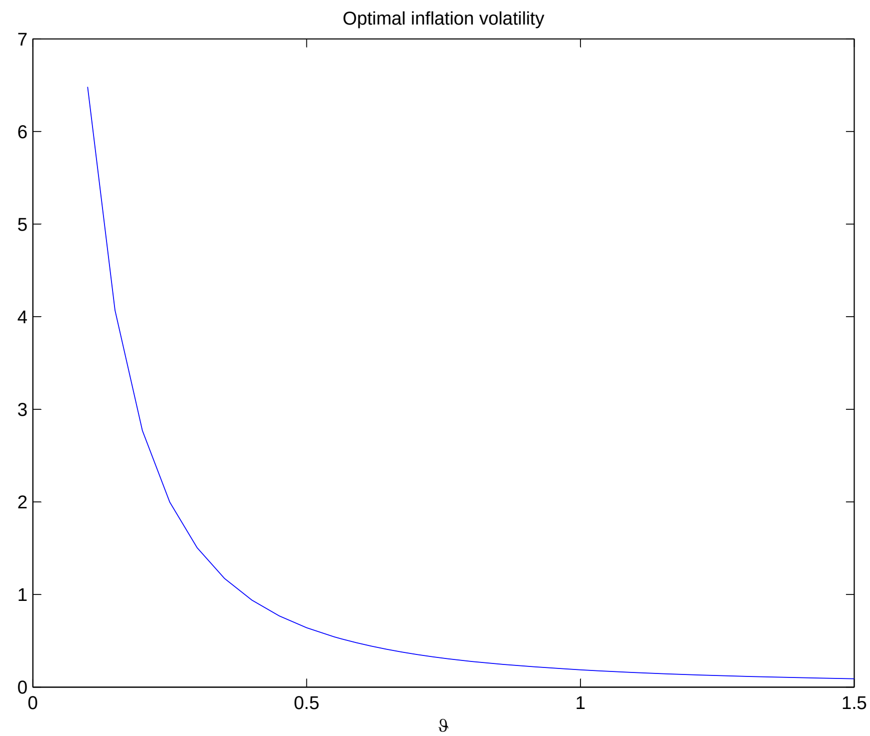

Figure 8: Optimal inflation volatility (standard deviation in annualized percentage points) as a function of ϑ.

(governed by increasing ϑ), stabilizing inflation becomes an ever-more important goal of policy.

4.3.2 Ramsey Allocations

In terms of the dynamics of allocations, the first row of the lower panel of Table 2 shows that the volatility of GDP, at about 1.8 percent, is in line with the empirical evidence for the U.S. economy presented in King and Rebelo (1999) and with many DSGE models, so there is nothing unusual about the macrodynamics of our model. Table 2 also shows, as was also suggested by the correlations presented in Table 3, that the dynamics of a_1 follow very closely the dynamics of a_2, the dynamics of s_1 follow very closely the dynamics of s_2, the dynamics of N_1 follow very closely the dynamics of N_2, and the dynamics of θ_1 follow very closely the dynamics of θ_2. These results all seem natural given the symmetry of our calibration across the cash search and credit search sectors. In the interest of at least some brevity, we leave our discussion of Ramsey allocations at that, but Table 2 presents some other moments calculated from our simulations.

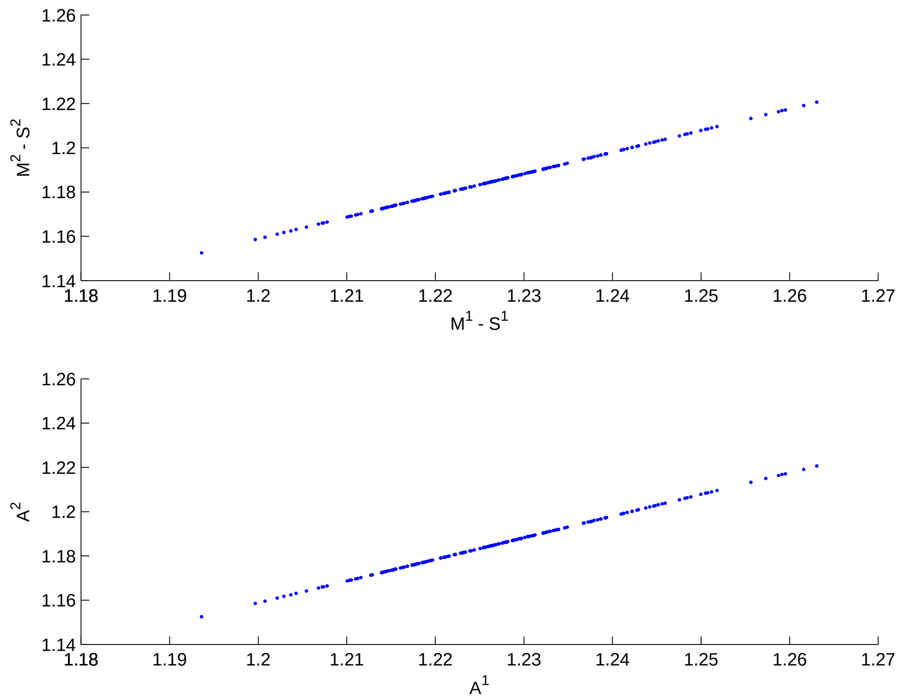

Figure 9: Dynamic realizations of cash-relationship and credit-relationship surpluses for households and firms.

4.3.3 Relationship Values

Finally, the structure of our model implies that there are "no-arbitrage" conditions between cash customer relationships and credit customer relationships for both households and firms. The household shopping conditions (9) and (10) and firm advertising conditions (20) and (21) suggest that household and firm surpluses across cash and credit relationships should be perfectly correlated over time. We can verify this from our Ramsey simulations.

Using notation that we define formally in Appendix B, the upper panel of Figure 9 plots dynamic realizations from a representative simulation of a household's surplus $\mathbf{M_t^1} - \mathbf{S_t^1}$ from entering into cash relationships against its surplus $\mathbf{M_t^2} - \mathbf{S_t^2}$ from entering into credit relationships. The lower panel plots dynamic realizations of a firm's surplus $\mathbf{A_t^1}$ from entering into cash relationships against its surplus $\mathbf{A_t^2}$ from entering into credit relationships. Under the Ramsey plan, the correlation between the surpluses from cash relationships and credit relationships is unity for both households and firms, which has the implication that both households and firms have incentives to direct search towards the cash and credit sectors in a perfectly-correlated manner. Indeed, as shown in Table 3, the correlation between s_{1t} and s_{2t} is virtually unity, as is that between a_{1t} and a_{2t}, confirming the no-arbitrage relationships across the cash and credit sectors.

5 Conclusion

The idea that unanticipated inflation is undesirable because it distorts relative prices is a well-established one. It is an idea articulated in basic undergraduate textbooks, and it is embedded in a very simple way – through the assumption of sticky prices — in the modern New Keynesian models that provide the basis for much of the model-based discussions of monetary policy issues. We show that deep-rooted frictions underlying goods-market trades lead to much the same effect. We adapted a standard cash/credit model, one that has been a workhorse in Ramsey studies of monetary policy, to include fundamental transactions frictions in what we view is at least one very natural way. With this simple extension, we show that achieving inflation stability is an important objective of policy precisely because unanticipated inflation distorts relative prices, even though there are no nominal rigidities of any sort. Our results thus challenge the standard view that sticky prices must be at the core of any practical DSGE model of monetary policy.

As we mentioned at the outset, our work builds on the theme begun in Arseneau and Chugh (2007b) and Aruoba and Chugh (2006) of studying optimal policy in environments with deep-rooted frictions in key markets. With the lessons learned by studying optimal policy in the face of fundamental trading frictions in labor markets (Arseneau and Chugh (2007b)), in one type of financial market (money markets — Aruoba and Chugh (2006)), and now here in product markets, an obvious interesting next step would be to characterize optimal policy in the presence of more than one of these frictions. Such a project would move this emerging second-generation of Ramsey-based optimal policy models even closer to the medium- and large-scale quantitative models favored by central banks as one input in their policy-making process. Some of the insights to be learned may be quite similar to those from existing models; some of the lessons are likely to be quite different.

A Household Problem

The representative household's problem in the baseline model is to choose state-contingent rules for l_t, x_{1t}, x_{2t}, M_t, B_t, N^h_{1t+1}, N^h_{2t+1}, s_{1t}, and s_{2t} to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u(x_{1t}, x_{2t}) + \vartheta v \left(\int_0^{N^h_{1t}} c_{i1t} di, \int_0^{N^h_{2t}} c_{i2t} di \right) + g(1 - l_t - s_t - N^h_t) \right] \tag{41}$$

subject to the sequence of flow budget constraints

$$\begin{aligned} &M_t - M_{t-1} + B_t - R_{t-1}B_{t-1} = \\ &\quad (1-\tau^l_{t-1})W_{t-1}l_{t-1} - P_{t-1}x_{1t-1} - P_{t-1}x_{2t-1} - \int_0^{N^h_{1t-1}} P_{i1t-1}c_{i1t-1}di - \int_0^{N^h_{2t-1}} P_{i2t-1}c_{i2t-1}di + P_{t-1}d_{t-1}, \end{aligned} \tag{42}$$

the sequence of cash-in-advance constraints

$$P_t x_{1t} + \int_0^{N^h_{1t}} P_{i1t}c_{i1t}di \leq M_t, \tag{43}$$

perceived laws of motion for the number of active cash relationships,

$$N^h_{1t+1} = (1-\rho^x)(N^h_{1t} + s_{1t}k^h(\theta_{1t})) \tag{44}$$

and credit relationships

$$N^h_{2t+1} = (1-\rho^x)(N^h_{2t} + s_{2t}k^h(\theta_{2t})), \tag{45}$$

as well as the identities

$$N^h_t = N^h_{1t} + N^h_{2t} \tag{46}$$

and

$$s_t = s_{1t} + s_{2t}. \tag{47}$$

Substitute the identities (46) and (47) directly into the utility function. Associate the sequence of multipliers ϕ_t/P_{t-1}, λ_t/P_t, μ^h_{1t}, and μ^h_{2t} to the remaining constraints, respectively. The first-order conditions with respect to l_t, x_{1t}, x_{2t}, M_t, B_t, N^h_{1t+1}, N^h_{2t+1}, s_{1t}, and s_{2t} are, respectively,

$$-g'_t + (1-\tau^l_t)w_t\beta E_t\phi_{t+1} = 0, \tag{48}$$

$$u_{1t} - \lambda_t - \beta E_t\phi_{t+1} = 0, \tag{49}$$

$$u_{2t} - \beta E_t\phi_{t+1} = 0, \tag{50}$$

$$-\frac{\phi_t}{P_{t-1}} + \frac{\lambda_t}{P_t} + \beta E_t\left(\frac{\phi_{t+1}}{P_t}\right) = 0, \tag{51}$$

$$-\frac{\phi_t}{P_{t-1}} + \beta R_t E_t\left(\frac{\phi_{t+1}}{P_t}\right) = 0, \tag{52}$$

$$\beta E_t\left\{\vartheta v_{1t+1}c_{1t+1}\right\}-\beta E_t g'_{t+1}-\mu^h_{1t}+\beta(1-\rho^x)E_t\mu^h_{1t+1}-\beta E_t\left\{\lambda_{t+1}\frac{P_{1t+1}}{P_{t+1}}c_{1t+1}\right\}-\beta E_t\left\{\beta\phi_{t+2}\frac{P_{1t+1}}{P_{t+1}}c_{1t+1}\right\}=0, \tag{53}$$

$$\beta E_t\left\{\vartheta v_{2t+1}c_{2t+1}\right\}-\beta E_t g'_{t+1}-\mu^h_{2t}+\beta(1-\rho^x)E_t\mu^h_{2t+1}-\beta E_t\left\{\beta\phi_{t+2}\frac{P_{2t+1}}{P_{t+1}}c_{2t+1}\right\}=0, \tag{54}$$

$$-g'_t+(1-\rho^x)\mu^h_{1t}k^h(\theta_{1t})=0, \tag{55}$$

$$-g'_t+(1-\rho^x)\mu^h_{2t}k^h(\theta_{2t})=0. \tag{56}$$

The first-order conditions (48) through (52) are completely standard in cash/credit models; they imply a standard consumption-leisure optimality condition

$$\frac{g'(1-l_t-s_t-N^h_t)}{u_{2t}}=(1-\tau^l_t)w_t, \tag{57}$$

a (Walrasian) cash-good/credit-good optimality condition

$$\frac{u_{1t}}{u_{2t}}=R_t, \tag{58}$$

and a pricing formula for a one-period nominally risk-free bond

$$1=R_tE_t\left[\frac{\beta u_{1t+1}}{u_{1t}}\frac{1}{\pi_{t+1}}\right], \tag{59}$$

where $\pi_t\equiv P_t/P_{t-1}$ is the gross inflation rate between periods $t-1$ and t.

Regarding the search markets, the first-order conditions (53) and (55) yield an optimal shopping condition for cash goods,

$$\frac{g'_t}{k^h(\theta_{1t})}=\beta(1-\rho^x)E_t\left\{c_{1t+1}\left[\vartheta v_{1t+1}-p_{1t+1}u_{1t+1}\right]-g'_{t+1}+\frac{g'_{t+1}}{k^h(\theta_{1t+1})}\right\}, \tag{60}$$

which is expression (9) in the text; and the first-order conditions (54) and (56) yield an optimal shopping condition for credit goods,

$$\frac{g'_t}{k^h(\theta_{2t})}=\beta(1-\rho^x)E_t\left\{c_{2t+1}\left[\vartheta v_{2t+1}-p_{2t+1}u_{2t+1}\right]-g'_{t+1}+\frac{g'_{t+1}}{k^h(\theta_{2t+1})}\right\}, \tag{61}$$

which is expression (10) in the text.

B Nash Bargaining

The marginal value to the household of a family member who is actively engaged in a cash relationship with a firm (in nominal terms):

$$\mathbf{M_t^1} = \frac{P_t \tilde{v}^1(c_{i1t})}{\beta E_t \phi_{t+1} + \lambda_t} - \frac{P_t g'(1 - l_t - s_t - N_t)}{\beta E_t \phi_{t+1} + \lambda_t} - P_{i1t} c_{i1t} + E_t \left[\left(\Xi_{t+1|t} \frac{P_t}{P_{t+1}} \right) ((1 - \rho^x) \mathbf{M_{t+1}^1} + \rho^x \mathbf{S_{t+1}^1}) \right]. \tag{62}$$

The marginal value to the household of a family member who is actively engaged in a credit relationship with a firm (in nominal terms):

$$\mathbf{M_t^2} = \frac{P_t \tilde{v}^2(c_{i2t})}{\beta E_t \phi_{t+1}} - \frac{P_t g'(1 - l_t - s_t - N_t)}{\beta E_t \phi_{t+1}} - P_{i2t} c_{i2t} + E_t \left[\left(\Xi_{t+1|t} \frac{P_t}{P_{t+1}} \right) ((1 - \rho^x) \mathbf{M_{t+1}^2} + \rho^x \mathbf{S_{t+1}^1}) \right]. \tag{63}$$

The function $\tilde{v}^1(.)$ is the marginal utility to the household of obtaining cash consumption from the i-th match, and $\tilde{v}^2(.)$ is the marginal utility to the household of obtaining credit consumption from the i-th match. Hence, $\tilde{v}^i(.) \equiv v_{it}(.)$, $i = 1, 2$. Captured in these Bellman equations is the assumption that if a given customer relationship survives separation, it continues to be a cash (credit) relationship if it was previously a cash (credit) relationship. Note that the discount used for $\mathbf{M_t^1}$ is different from the discount used for $\mathbf{M_t^2}$. Because of our assumption that a cash relationship is always a cash relationship and a credit relationship is always a credit relationship, the nominal interest rate needs to be taken account of in defining these two asset values. Because in equilibrium, $\beta E_t \phi_{t+1} = u_{2t}$, $\beta E_t \phi_{t+1} + \lambda_t = u_{1t}$, and $u_{1t}/u_{2t} = R_t$, defining the asset values this way does this.

For tractability and in line with our assumption that cash (credit) relationships are always cash (credit) relationships, we assume that a cash (credit) relationship can result only from purposeful search in the cash (credit) market. An extension one may want to later pursue is to allow crossover from search in one market into active relationships in the other market. The marginal value to the household of an individual searching for a cash relationship and an individual searching for a credit relationship thus are, respectively,

$$\mathbf{S_t^1} = -\frac{P_t g'(1 - l_t - s_t - N_t)}{\beta E_t \phi_{t+1} + \lambda_t} + E_t \left[\left(\Xi_{t+1|t} \frac{P_t}{P_{t+1}} \right) \left(\theta_{1t} k^f(\theta_{1t})(1 - \rho^x) \mathbf{M_{t+1}^1} + (1 - \theta_{1t} k^f(\theta_{1t})(1 - \rho^x)) \mathbf{S_{t+1}^1} \right) \right] \tag{64}$$

and

$$\mathbf{S_t^2} = -\frac{P_t g'(1 - l_t - s_t - N_t)}{\beta E_t \phi_{t+1}} + E_t \left[\left(\Xi_{t+1|t} \frac{P_t}{P_{t+1}} \right) \left(\theta_{2t} k^f(\theta_{2t})(1 - \rho^x) \mathbf{M_{t+1}^2} + (1 - \theta_{2t} k^f(\theta_{2t})(1 - \rho^x)) \mathbf{S_{t+1}^2} \right) \right]. \tag{65}$$

By the properties of the Cobb-Douglas matching function, $k^h(\theta_{it}) = \theta_{it} k^f(\theta_{it})$. Notice that in these formulations of $\mathbf{S_t^1}$ and $\mathbf{S_t^2}$, we make the assumption that if an individual is not successful in forming a lasting customer relationship, he is assigned back to search in the next period. In principle, a given atomistic individual unsuccessful in forming a customer relationship could be assigned by the household to labor or leisure in the next period, as well. Our specification is without loss of generality, however, because the household in every period optimally allocates its members between cash-search and credit-search. That is, as we allude to in the text, there is essentially a "no-arbitrage" condition between cash search and credit search a the household level, making the precise identities of those assigned to search in one sector versus the other irrelevant. Thus, without loss of generality, we can suppose that an individual who continues to search from one period to the next does so in the same sector.

The values to a firm of an existing cash customer and an existing credit customer are, respectively,

$$\mathbf{A_t^1} = P_{i1t}c_{i1t} - mc_t c_{i1t} + E_t\left[\left(\Xi_{t+1|t}\frac{P_t}{P_{t+1}}\right)(1-\rho^x)\mathbf{A_{t+1}^1}\right] \tag{66}$$

and

$$\mathbf{A_t^2} = P_{i2t}c_{i2t} - mc_t c_{i2t} + E_t\left[\left(\Xi_{t+1|t}\frac{P_t}{P_{t+1}}\right)(1-\rho^x)\mathbf{A_{t+1}^2}\right]. \tag{67}$$

Bargaining occurs every period between a given customer and the firm with which he is engaged in a relationship. For $i = 1, 2$, the firm and customer maximize the Nash product

$$(\mathbf{M_t^i} - \mathbf{S_t^i})^{\eta}\mathbf{A_t^i}^{1-\eta}, \tag{68}$$

where $\eta \in (0,1)$ is the fixed weight given to the customer's (equivalently, the household's) surplus and identical across cash and credit relationships. Make the following changes of variables: divide $\mathbf{M_t^i}$, $\mathbf{S_t^i}$, and $\mathbf{A_t^i}$ by P_t, define $p_{it} = P_{it}/P_t$ as the relative price of a search good, and re-interpret the asset values to be real, rather than nominal, asset values. With these changes, the first-order condition of the Nash product with respect to p_{it} is

$$\eta(\mathbf{M_t^i} - \mathbf{S_t^i})^{\eta-1}\left(\frac{\partial \mathbf{M_t^i}}{\partial p_{it}} - \frac{\partial \mathbf{S_t^i}}{\partial p_{it}}\right)\mathbf{A_t^i}^{1-\eta} + (1-\eta)(\mathbf{M_t^i} - \mathbf{S_t^i})^{\eta}\mathbf{A_t^i}^{-\eta}\frac{\partial \mathbf{A_t^i}}{\partial p_{it}} = 0, \tag{69}$$

which can be condensed as usual to

$$(1-\eta)(\mathbf{M_t^i} - \mathbf{S_t^i})\frac{\partial \mathbf{A_t^i}}{\partial p_{it}} = -\eta\mathbf{A_t^i}\left(\frac{\partial \mathbf{M_t^i}}{\partial p_{it}} - \frac{\partial \mathbf{S_t^i}}{\partial p_{it}}\right). \tag{70}$$

Using the value functions above and going through several tedious steps of algebra, all of which are identical to those in Arseneau and Chugh (2007b), we have

$$p_{1t}c_{1,t} = (1-\eta)\left(\frac{\tilde{v}^1(c_{1t})}{u_{1t}}\right) + \eta(mc_t c_{1,t} - \gamma\theta_{1t}) \tag{71}$$

and

$$p_{2t}c_{2,t} = (1-\eta)\left(\frac{\tilde{v}^2(c_{2t})}{u_{2t}}\right) + \eta(mc_t c_{2,t} - \gamma\theta_{2t}), \tag{72}$$

which are expressions (23) and (24) in the text.

C Private-Sector Equilibrium

Here, we collect the conditions characterizing a symmetric search equilibrium defined in Section 2.8. They are:

- Resource constraint:

$$x_{1t} + x_{2t} + N_{1t}c_{1t} + N_{2t}c_{2t} + g_t + \gamma(a_{1t} + a_{2t}) = z_t l_t \tag{73}$$

- The standard (Walrasian) cash-credit optimality condition:

$$\frac{u_{1t}}{u_{2t}} = R_t \tag{74}$$

- The standard consumption-leisure optimality condition:

$$\frac{g'_t}{u_{2t}} = (1 - \tau^l_t)w_t \tag{75}$$

- The standard bond Euler equation (pricing formula for a one-period nominally risk-free bond):

$$1 = R_t E_t \left[\frac{\beta u_{1t+1}}{u_{1t}} \frac{1}{\pi_{t+1}} \right] \tag{76}$$

- The (two different) shopping conditions for cash relationships and credit relationships:

$$\frac{g'_t}{k^h(\theta_t)} = (1 - \rho^x)E_t \left\{ c_{1t+1}\left[\vartheta v_{1t+1} - p_{1t+1}u_{1t+1}\right] - g'_{t+1} + \frac{g'_{t+1}}{k^h(\theta_{t+1})} \right\} \tag{77}$$

$$\frac{g'_t}{k^h(\theta_t)} = (1 - \rho^x)E_t \left\{ c_{2t+1}\left[\vartheta v_{2t+1} - p_{2t+1}u_{2t+1}\right] - g'_{t+1} + \frac{g'_{t+1}}{k^h(\theta_{t+1})} \right\} \tag{78}$$

- The (two different) advertising conditions for cash relationships and credit relationships:

$$\frac{\gamma}{k^f(\theta_t)} = \beta(1 - \rho^x)E_t \left\{ \Xi_{t+1|t} \left(p_{1t+1}c_{1t+1} - mc_{t+1}c_{1t+1} + \frac{\gamma}{k^f(\theta_{t+1})} \right) \right\} \tag{79}$$

$$\frac{\gamma}{k^f(\theta_t)} = \beta(1 - \rho^x)E_t \left\{ \Xi_{t+1|t} \left(p_{2t+1}c_{2t+1} - mc_{t+1}c_{2t+1} + \frac{\gamma}{k^f(\theta_{t+1})} \right) \right\} \tag{80}$$

- Nash-pricing equations to pin down p_{1t} and p_{2t}:

$$p_{1t}c_{1,t} = (1 - \eta)\left(\frac{\tilde{v}^1(c_{1t})}{u_{1t}} \right) + \eta(mc_t c_{1,t} - \gamma\theta_{1t}) \tag{81}$$

$$p_{2t}c_{2,t} = (1 - \eta)\left(\frac{\tilde{v}^2(c_{2t})}{u_{2t}} \right) + \eta(mc_t c_{2,t} - \gamma\theta_{2t}) \tag{82}$$

- Aggregate laws of motion for active cash and credit customer relationships:

$$N_{1t+1} = (1-\rho^x)(N_{1t} + m(s_{1t}, a_{1t})) \tag{83}$$

$$N_{2t+1} = (1-\rho^x)(N_{2t} + m(s_{2t}, a_{2t})) \tag{84}$$

- Condition describing nominal price inflation:

$$\pi_t \left[\frac{x_{1t} + p_{1t} N_{1t} c_{1t}}{x_{1t-1} + p_{1t-1} N_{1t-1} c_{1t-1}} \right] = \mu_t, \tag{85}$$

- Efficient labor market:

$$w_t = z_t \tag{86}$$

D Derivation of PVIC

The derivation of the Ramsey present-value implementability constraint (PVIC) proceeds quite similarly to derivations in standard flexible-price Ramsey models. Unlike standard flexible-price Ramsey models, and as we mentioned in Section 3, the PVIC in our model does not encode all of the equilibrium conditions of the economy; in particular, it does not encode the conditions describing search and pricing activity in the cash and credit search markets.

To derive the PVIC, start as usual with the household flow budget constraint in symmetric equilibrium. Diving each term through by P_{t-1}, multiplying each term by $\beta^t \phi_t$, and summing from $t = 0$ to infinity gives

$$\begin{aligned}
&\sum_{t=0}^{\infty} \beta^t \phi_t x_{1t-1} + \sum_{t=0}^{\infty} \beta^t \phi_t x_{2t-1} + \sum_{t=0}^{\infty} \beta^t \phi_t p_{1t-1} N_{1t-1} c_{1t-1} + \sum_{t=0}^{\infty} \beta^t \phi_t p_{2t-1} N_{2t-1} c_{2t-1} + \sum_{t=0}^{\infty} \beta^t \phi_t \frac{M_t}{P_{t-1}} \\
&+ \sum_{t=0}^{\infty} \beta^t \phi_t \frac{B_t}{P_{t-1}} = \sum_{t=0}^{\infty} \beta^t \phi_t (1-\tau^l_{t-1}) w_{t-1} l_{t-1} + \sum_{t=0}^{\infty} \beta^t \phi_t \frac{M_{t-1}}{P_{t-1}} + \sum_{t=0}^{\infty} \beta^t \phi_t R_{t-1} \frac{B_{t-1}}{P_{t-1}} + \sum_{t=0}^{\infty} \beta^t \phi_t d_{t-1}.
\end{aligned}$$

Use the household first-order condition (51) to substitute into the last term on the first line and use the household first-order condition (52) to substitute into the first term on second line; this yields

$$\begin{aligned}
&\sum_{t=0}^{\infty} \beta^t \phi_t x_{1t-1} + \sum_{t=0}^{\infty} \beta^t \phi_t x_{2t-1} + \sum_{t=0}^{\infty} \beta^t \phi_t p_{1t-1} N_{1t-1} c_{1t-1} + \sum_{t=0}^{\infty} \beta^t \phi_t p_{2t-1} N_{2t-1} c_{2t-1} \\
&+ \sum_{t=0}^{\infty} \beta^t \lambda_t \frac{M_t}{P_t} + \sum_{t=0}^{\infty} \beta^t \beta \phi_{t+1} \frac{M_t}{P_t} + \sum_{t=0}^{\infty} \beta^t \beta \phi_{t+1} R_t \frac{B_t}{P_t} \\
&= \sum_{t=0}^{\infty} \beta^t \phi_t (1-\tau^l_{t-1}) w_{t-1} l_{t-1} + \sum_{t=0}^{\infty} \beta^t \phi_t \frac{M_{t-1}}{P_{t-1}} + \sum_{t=0}^{\infty} \beta^t \phi_t R_{t-1} \frac{B_{t-1}}{P_{t-1}} + \sum_{t=0}^{\infty} \beta^t \phi_t d_{t-1}.
\end{aligned}$$

Canceling like summations, pulling out the $t = 0$ terms from several summations, and adjusting indices of summation yields

$$
\begin{aligned}
&\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}x_{1t}+\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}x_{2t}+\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}p_{1t}N_{1t}c_{1t}+\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}p_{2t}N_{2t}c_{2t}+\sum_{t=0}^{\infty}\beta^t\lambda_t\frac{M_t}{P_t}\\
&= \sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}(1-\tau_t^l)w_tl_t+\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}d_t\\
&+ \phi_0\left[\frac{M_{-1}+R_{-1}B_{-1}}{P_{-1}}+(1-\tau_{-1}^l)w_{-1}l_{-1}-x_{1,-1}-x_{2,-1}-p_{1,-1}N_{1,-1}c_{1,-1}-p_{2,-1}N_{2,-1}c_{2,-1}+d_{-1}\right].
\end{aligned}
$$

Define

$$
A_0=\phi_0\left[\frac{M_{-1}+R_{-1}B_{-1}}{P_{-1}}\right]+\phi_0\left[(1-\tau_{-1}^l)w_{-1}l_{-1}-mc_{-1}N_{1,-1}c_{1,-1}-mc_{-1}N_{2,-1}c_{2,-1}-\gamma(a_{1,-1}+a_{2,-1})-x_{1,-1}-x_{2,-1}\right]. \tag{87}
$$

With this definition, substitute into the previous expression the symmetric equilibrium expression for real dividend payments of the firm, $d_t = (p_{1t} - mc_t)N_{1t}c_{1t} + (p_{2t} - mc_t)N_{2t}c_{2t} - \gamma(a_{1t} + a_{2t})$, which gives

$$
\begin{aligned}
&\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}x_{1t}+\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}x_{2t}+\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}p_{1t}N_{1t}c_{1t}+\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}p_{2t}N_{2t}c_{2t}+\sum_{t=0}^{\infty}\beta^t\lambda_t\frac{M_t}{P_t}\\
&= \sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}(1-\tau_t^l)w_tl_t+\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}(p_{1t}-mc_t)N_{1t}c_{1t}\\
&+ \sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}(p_{2t}-mc_t)N_{2t}c_{2t}-\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}\gamma(a_{1t}+a_{2t})+A_0.
\end{aligned}
$$

Using the cash-in-advance constraint holding with equality, $\frac{M_t}{P_t} = x_{1t} + p_{1t}N_{1t}c_{1t}$, to substitute out the term involving $\frac{M_t}{P_t}$ yields

$$
\begin{aligned}
&\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}x_{1t}+\sum_{t=0}^{\infty}\beta^t\lambda_tx_{1t}+\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}x_{2t}+\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}p_{1t}N_{1t}c_{1t}+\sum_{t=0}^{\infty}\beta^t\lambda_tp_{1t}N_{1t}c_{1t}\\
&+ \sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}p_{2t}N_{2t}c_{2t}=\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}(1-\tau_t^l)w_tl_t+\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}(p_{1t}-mc_t)N_{1t}c_{1t}\\
&+ \sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}(p_{2t}-mc_t)N_{2t}c_{2t}-\sum_{t=0}^{\infty}\beta^t\beta\phi_{t+1}\gamma(a_{1t}+a_{2t})+A_0.
\end{aligned}
$$

Next, using the household first-order conditions $\beta E_t\phi_{t+1} = u_{2t}$ and $\beta E_t\phi_{t+1} + \lambda_t = u_{1t}$, we have

$$
\begin{aligned}
&\sum_{t=0}^{\infty}\beta^tu_{1t}x_{1t}+\sum_{t=0}^{\infty}\beta^tu_{2t}x_{2t}+\sum_{t=0}^{\infty}\beta^tu_{1t}p_{1t}N_{1t}c_{1t}+\sum_{t=0}^{\infty}\beta^tu_{2t}p_{2t}N_{2t}c_{2t}\\
&= \sum_{t=0}^{\infty}\beta^tu_{2t}(1-\tau_t^l)w_tl_t+\sum_{t=0}^{\infty}\beta^tu_{2t}(p_{1t}-mc_t)N_{1t}c_{1t}+\sum_{t=0}^{\infty}\beta^tu_{2t}(p_{2t}-mc_t)N_{2t}c_{2t}-\sum_{t=0}^{\infty}\beta^tu_{2t}\gamma(a_{1t}+a_{2t})+A_0.
\end{aligned}
$$

Finally, use the consumption-leisure optimality condition to substitute $g_t' = u_{2t}(1 - \tau_t^l)w_t$ and rearrange terms to arrive at the PVIC,

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u_{1t} x_{1t} + u_{2t} x_{2t} - g_t' l_t + (u_{1t} - u_{2t}) p_{1t} N_{1t} c_{1t} + u_{2t} mc_t N_{1t} c_{1t} + u_{2t} mc_t N_{2t} c_{2t} + u_{2t} \gamma (a_{1t} + a_{2t}) \right] = A_0, \tag{88}$$

which is expression (32) in the text.

When we allow for the profit tax and search taxes, the household flow budget constraint is modified to

$$M_t - M_{t-1} + B_t - R_{t-1} B_{t-1} = \tau_{t-1}^{s_1} s_{1t-1} + \tau_{t-1}^{s_2} s_{2t-1} \tag{89}$$

$$+ \quad (1 - \tau_{t-1}^{l}) W_{t-1} l_{t-1} - P_{t-1} x_{1t-1} - P_{t-1} x_{2t-1} \tag{90}$$

$$- \quad \int_0^{N_{1t-1}^h} P_{i1t-1} c_{i1t-1} di - \int_0^{N_{2t-1}^h} P_{i2t-1} c_{i2t-1} di + (1 - \tau_{t-1}^{pr}) P_{t-1} d_{t-1}.$$

Proceeding just as before, except refraining from combining the equilibrium expression for d_t as we did above, we have that the PVIC is

$$\sum_{t=0}^{\infty} \beta^t \left[u_{1t} x_{1t} + u_{2t} x_{2t} + u_{1t} p_{1t} N_{1t} c_{1t} + u_{2t} p_{2t} N_{2t} c_{2t} - g_t' l_t - u_{2t} \tau^{s_1} s_{1t} - u_{2t} \tau^{s_2} s_{2t} \right] \tag{91}$$

$$- \quad \sum_{t=0}^{\infty} \beta^t \left[(1 - \tau_t^{pr}) \left(u_{2t} (p_{1t} - mc_t) N_{1t} c_{1t} + u_{2t} (p_{2t} - mc_t) N_{2t} c_{2t} - u_{2t} \gamma (a_{1t} + a_{2t}) \right) \right] = A_0. \tag{92}$$

Setting $\tau_t^{s_1} = \tau_t^{s_2} = \tau_t^{pr} = 0 \ \forall t$ and combining several terms collapses this modified PVIC back to expression (32).

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