

Household Production, Services and Monetary Policy*

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Abstract

Household production varies substantially across developed and less developed countries. In this paper, I first provide a VAR-based evidence that services are more interest-sensitive than nondurable goods. To match that differential, a standard two-sector sticky price model requires an implausibly high degree of sectoral heterogeneity in price stickiness. In this paper, I build a model that mimics the above empirical fact without relying on such heterogeneity. A key feature of the model is the inclusion of a household sector, which produces services at home (caring for children, cooking, cleaning, etc.), that are substitutes to a subset of market-provided services. Therefore, when fixing their prices (following an expansionary monetary policy for example), producers of market-services internalize the fact that households might decide to produce the services on their own, if they raise their prices "too much". This causes an endogenous downward shift of the "Augmented" New-Keynesian Phillips curve in the service sector, inducing a higher nominal rigidity in that sector. Conversely, firms in the nondurable goods sector do not face the direct competition of households who typically produce services. As a consequence, the real effects of monetary shocks are stronger in the service sector than in the nondurable goods sector, which is consistent with empirical evidence.

Keywords: Services, Nondurable Goods, Household Production, New-Keynesian Phillips Curve, Monetary Policy.

JEL Classification Codes: E12, E32, D13

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1 Introduction

From the purely descriptive evidence by Friedman and Schwartz (1963) to the more sophisticated VAR approach by Sims (1972, 1980, 1992), and more recently by Christiano, Eichenbaum and Evans (1999), a consensus has emerged among economists that monetary policy has real effects, at least in the short run. Macroeconomists have then devoted resources to building models of monetary non-neutrality. The most recent and major development in that area is the New Keynesian Dynamic Stochastic General Equilibrium (DSGE) framework, which has become the reference for monetary policy analysis in many central banks around the world.

How much of nominal rigidity is required by New Keynesian models in order to fit the data is a relevant empirical issue. Eichenbaum and Fisher estimate a DSGE model and find that the canonical Calvo (1983) model implies that firms re-optimize their prices nearly once every two years. Gali and Gertler (1999), estimate the New Keynesian Phillips curve and find an average price duration ranging from 6 to 8 quarters across their alternative specifications. These high values for price rigidity are at odd with micro evidence, which suggests that prices change quite frequently (see Bils and Klenow¹ (2004) and Nakamura and Steinsson² (2008), among many others).

To solve the apparent inability of the standard New Keynesian model to generate large real effects of monetary shocks, inflation inertia and output persistence (as suggested by empirical VARs), while relying on modest degree of nominal rigidity (as suggested by micro evidence), many solutions have been explored.

One solution is to combine nominal rigidities with real rigidities (factors that make firms reluctant to adjust their relative prices) of some kind. This idea was first introduced by Ball and Romer (1990), and has gained interest in light of the failure of models relying solely on nominal rigidities to fit the data. For example, Eichenbaum and Fischer (2004) make two key departures from the baseline Calvo model and obtain a more plausible estimate of price rigidity (2 quarters). They assume variable elasticity of demand of differentiated products as in Kimball (1995) and firm-specific capital. Christiano, Eichenbaum and Evans (2005) also estimate a DSGE model featuring staggered prices and wage contracts, along with four sources of real rigidities: habit formation in consumption, working capital, capital adjustment costs and variable capacity utilization and obtain an average duration of price and wage contracts of 3 quarters.

Another avenue is to exploit the sectoral heterogeneity in price stickiness inherent to micro data. Carvalho (2006) finds that this does indeed generate larger and more persistent real effects of monetary shocks. His simulations shows that, in order to reproduce the dynamics of a calibrated

¹The authors use micro data from the Bureau of Labor Statistics for 1995-97, and find a median price duration smaller than 4.3 months. Their sample includes 350 items which covered 70% of consumer spendings.

²Even after excluding sales, they obtain an average price duration of a year for the period 1988-2005.

heterogenous economy³, an identical-firms model requires a frequency of price adjustment that is up to three times lower than the average of the heterogenous economy.

While existing multi-sector models have mainly focused on the durability of goods⁴ (see Erceg et al.(2006), Carlstrom et al.(2006), Barsky et al.(2007), Bouakez et al.(2008), Monacelli (2009), among many others) this paper deals with the service sector instead. I first provide a VAR-based evidence that services are more interest-sensitive than nondurable goods. I also find that a standard two-sector (service sector and nondurable goods sector) sticky price model cannot generate that differential, unless one assumes an implausibly high degree of sectoral heterogeneity in price stickiness. I then ask the following question: can the inclusion of household production in an otherwise standard multi-sector New Keynesian model help explaining why monetary shocks have larger real effects on consumer services than nondurables? This question is relevant for at least two reasons:

First, the service sector has many distinctive features: (i) it is the largest sector in the US economy, accounting for nearly 60% of total consumption expenditures by 2005⁵; (ii) the Input-Output matrix reveals that it does supply substantial amount of intermediate inputs to every single sector of the economy⁶; (iii) it features more price rigidity than other sectors of the economy (see, e.g., Bils and Klenow (2004), and Nakamura and Steinsson (2008) for micro evidence); (iv) a subset of services have good substitutes at home (see Pissarides (2006), Lebergott (1993) and Reid (1934)). These features suggest a potential important role of the service sector in understanding how monetary policy actually affects the economy.

Second, the household sector is large. Eisner (1988) estimates the Gross Household Production (GHP) in the US at \$1,709 billion, which represents 37.5% of the extended GNP of \$4,560 billion. The American Time Use Survey also shows that people devote almost 22 hours of their discretionary time⁷ a week to home production (cooking, cleaning, caring for children, etc.)⁸.

³Heterogeneity in the sense of price rigidity.

⁴Two notable exceptions are Bouakez et al. (2007) who estimate a multisector DSGE model including 6 broad sectors of the US economy (agriculture, mining, construction, durable goods, nondurable goods and services), and Wolman (2008) who analyses the optimal rate of inflation when relative prices of services are trending.

⁵This is an interesting feature if we think of aggregate variables (inflation, output) as weight average of sectoral outcomes.

⁶74% of intermediate inputs used by the service sector comes from the service sector, and at least 30% of intermediate inputs used by any other sector is supplied by the service sector (see Bouakez et al. (2007, page 24, table 1))

⁷This excludes sleeping time.

⁸Many papers have previously pointed out the importance of the household sector for aggregate fluctuations (See, e.g., Rogerson et al. (1991), Benhabib et al. (1991), Mcgrattan et al. (1997), Chang et al. (2003)). But these studies tackle a different set of issues. Moreover, only Rogerson (2008) makes a particular treatment of the service sector. The author analyzes the performance of the European labor market vis à vis de US over the long run, which is far from the issue I deals with in this paper.

I develop a three-sector (market-nondurable goods sector, market-services sector, and household sector) sticky price model *à la* Calvo (1983) to examine how household production actually affects the way monetary policy influences the economy. I find that the price setting behavior in the market-service sector is heavily distorted once one accounts for household production. Following an expansionary (contractionary) monetary policy, the New Keynesian Phillips curve of the market-services sector shifts downward (upward), while that of the market-goods sector remains unchanged. The rationale for that is the following: contrary to market-nondurables, market-services have fairly good substitutes at home. This provides households with the option of substituting away from the market-services, which reduces the monopoly power of the firms in that sector. As a consequence, the real effects of monetary shocks are larger in the service sector than in the nondurable goods sector. Simulations show that, in order to generate such heterogeneity in sectoral responses to monetary shocks, a model without home production requires an extremely high degree of sectoral heterogeneity in price stickiness, which is at odds with micro data.

The next section provides a VAR-based evidence that services are more interest-sensitive than nondurable goods and documents that a subset of market-provided services have close substitutes at home. This is the motivation to the modeling approach adopted here, which is detailed in section 3. In section 4, the model is calibrated and simulated and section 6 draws concluding remarks.

2 Empirical evidence

2.1 Services vs. nondurables: a sectoral VAR

In this section I document that services are more interest-sensitive than nondurable goods. The procedure adopted here is closely related to Erceg and Levin (2006). These authors estimate a VAR model focusing on the durability of goods. They find that durable goods react more to monetary shocks than the remaining components of GDP which they aggregate into a single entity. They then examine how this affects the optimal monetary policy.

In this paper, I focus on services instead, and disaggregate the real GDP into three major components: durables, nondurables and services. I consider a quarterly VAR (with 4 lags and a constant) for the US economy, over the sample period 1967:Q1-2007:Q4. The model is specified as follows:

$$\mathcal{X}_t = \Phi_0 + \sum_{j=1}^4 \Phi_j \mathcal{X}_{t-j} + \Omega \eta_t \quad (1)$$

Where η_t is a vector of contemporaneous disturbances. The vector \mathcal{X} contains the following variables: (i) real consumer durables, (ii) real consumer nondurables, (iii) real consumer services, (iv) price index of durables, (v) price index of nondurables, (vi) price index of services, (vii) capacity utilization (viii) commodity price index from CRB (Commodity Research Bureau), and

(iv) the federal funds rate. All the variables, except capacity utilization and the federal funds rate have been logged.

I follow the procedure in Christiano et al. (1999) in identifying the monetary policy shock, which is part of the vector of disturbances η_t . The estimated impulse response functions (IRF) of real variables to a one-standard-deviation innovation to the federal funds rate are portrayed in the figure below. The responses of sectoral prices and capacity utilization are shown in the appendix. The dotted lines represent the 95% confidence bands, which are built from 300 Monte Carlo replications.

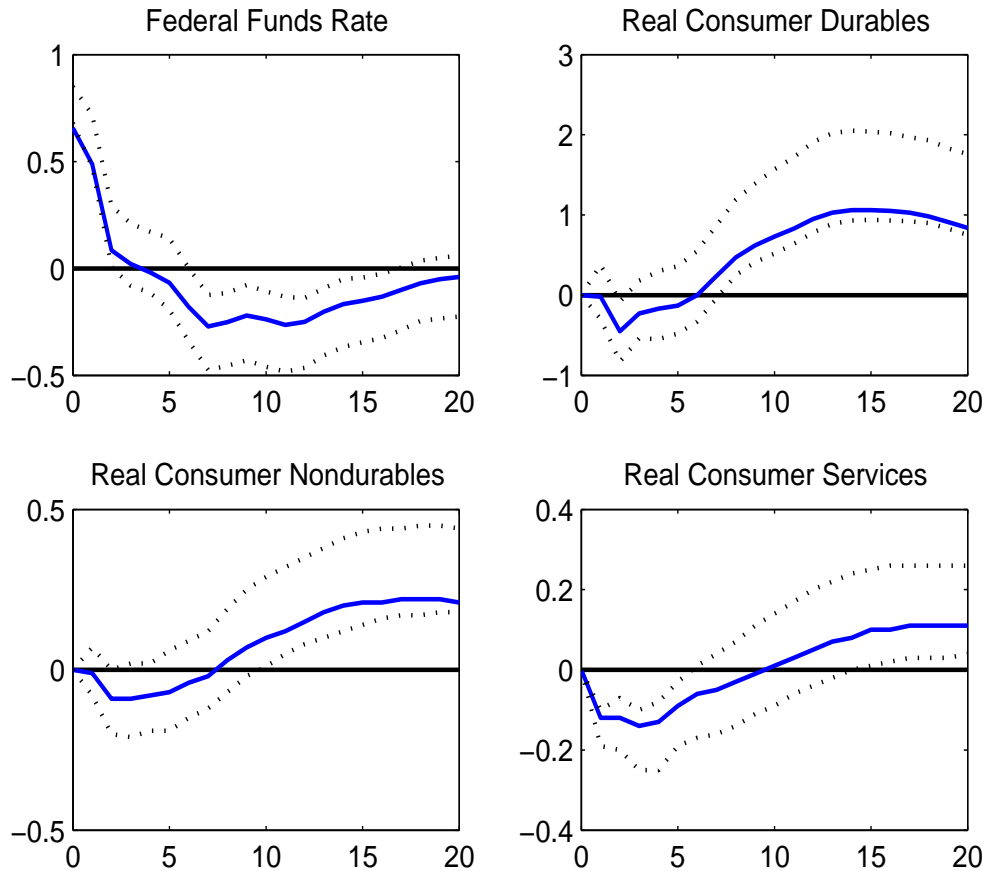


Figure 1: Estimated responses of sectoral consumption to a monetary policy tightening.

The service sector noticeably displays the strongest response during the first post-shock quarter. Its real spending drop by 0.12%, compared to marginal drops of 0.02 and 0.01% for durables and nondurables respectively. In the following quarters however, the response of durables catches up, and eventually exceeds that of services, reaching a maximum decline of 0.5% in the second quarter after the shock. But, services display a stronger response than nondurables in any quarter.

Moreover, the effects of the shock are more persistent in the service sector, lasting for 10 quarters, compared to 5 and 7 quarters for durables and nondurables respectively.

Interestingly, the results are robust to the re-ordering of variables. I run a similar VAR without capacity utilization and the results are roughly unchanged, with the only difference that the response of durables are now stronger in the first quarter. This partially highlights the importance of variable capacity utilization in understanding the behavior of the durable goods sector. It is also worth noticing that no clear evidence of "price puzzle" emerges from the responses of sectoral price indexes displayed in the appendix⁹.

2.2 The importance of home production

2.2.1 Home hours worked

Table 1: Time spent in household production, 2003 annual average

Activity	Weekly Hours		
	All	Men	Women
Housework	4.34	1.61	6.86
Food preparation and clean up	3.71	1.75	5.53
Lawn and garden care	1.4	1.82	0.98
Household management	0.91	0.77	1.05
Purchasing goods and services	5.67	4.76	6.58
Caring for household members	3.85	2.38	4.06
Caring for non-household members	2.03	1.82	2.17
Travel related to household activities	2.31	2.17	2.52
Other household activities	2.31	3.01	1.4
Total	26.39	20.09	31.15

Note: Data refer to persons aged 15 years and over, and include primary activities only.

Source: American Time Use Survey, Bureau of Labor Statistics.

This table shows the amount of time that people spent per week in different household activities. It only measures the amount of time spent on primary activities. For example, if you are preparing food while taking care of a child, only the activity that you declare as being your main occupation at that time is considered. While this simplification might not bear any consequence on the measure

⁹The inclusion of the commodity price index is argued (in the VAR literature) to partially solve the price puzzle, as it is likely to provide valuable information about the dynamics of prices in the economy. In fact, market participants can readily factor their expectations about inflation into commodity prices

of market hours worked, it is likely to bias the time devoted to household production downward. This is because many household tasks are usually performed simultaneously. Even some important forms of leisure, like watching TV or answering the phone are not incompatible with homework. Even though I see the above table as being conservative, it still conveys a clear message: people devote a substantial part of their time to home production¹⁰.

2.2.2 Home production as a substitute to market-provided services

To assess the importance of household production (as substitute to market-provided services), I focus on two key elements in this section: child care and food preparation¹¹. One would like to have a more comprehensive coverage of household production, but data is rather limited on that matter, at least for now.

I first consider child care, not only because of data availability, but also because it is a time consuming activity for households. Moreover it is an activity for which a clear market substitute does exist: day care centers. The Table below shows the importance of child care in family budgets. The table suggests that child care expenses account for 6 to 7% of the income of families with a

Table 2: Child care expenses by families with employed mothers, as percentage of monthly income, 1991-2005.

Date of survey	% of monthly income spent on child care		
	All	Below poverty	Above poverty
Fall 1991	7.1	26.6	6.9
Fall 1993	7.3	21.1	7.0
Spring 1997	6.9	20.0	6.6
Spring 1999	6.7	33.3	6.4
Winter 2002	7.1	25.7	6.9
Spring 2005	6.4	29.2	6.1

Source: Survey of Income and Program Participation (SIPP), U.S Census Bureau.

working mother (during the period 1991-2005), which is a quite large number. I also realize that child care is almost evenly divided between market and home, suggesting room for substitution.

Another market-provided service for which a close substitute clearly exists at home and for

¹⁰The table also reveals a big discrepancy in the amount of time devoted to homework by men and women, with men spending only 2/3 of the amount of time spent by women in household activities.

¹¹Shopping is also an activity which is worth looking at, given its relatively large share of time in household production as suggested by table 1.

which some forms of data might be available for comparison is food service. What makes restaurant an interesting case to look at is the fact that one can either go out for diner or prepare food at home. The figure below displays the HP-filtered annual expenditure shares of both food away from home and food at home for the period 1990 – 2007 ¹². Both series clearly move in opposite directions and have a negative correlation coefficient of -0.40. However, these series do have the same pattern over the long run. More precisely, and consistently with the Engel curve, expenditures share of food (either at home or away from home) is decreasing over time. However filtered series are more relevant for my analysis which is concerned with the short run (business cycle frequency).

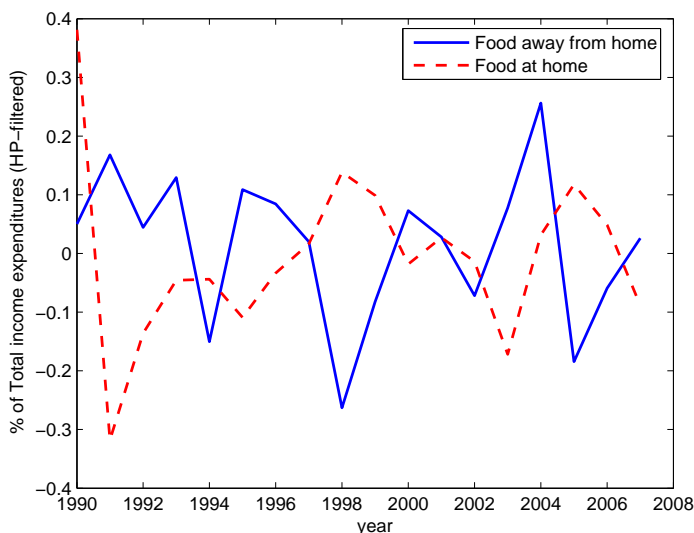


Figure 2: Food away from home and food at home as % of total household expenditures (HP-filtered series)

Source: author calculations from BLS data

3 The Model Economy

3.1 The Economic Environment

The economy is populated by a continuum of identical and infinitely-lived households of measure one. There are three broad sectors in the economy, of which two-market sectors and a home sector. At home, households produce services that cannot be sold on the market and are therefore used for self-consumption only. The two market sectors are a nondurable goods sector and a service sector,

¹²The average shares of food away from home and food at home in total household expenditures are respectively 8 and 5.6% for that period.

each of which is populated by a continuum of monopolistically competitive firms, who produce differentiated products. We assume that their prices are sticky *à la* Calvo (1983). Intermediate goods are further bundled into final consumption by perfectly competitive final good producers in each sector. There is also a monetary authority who obeys a Taylor rule and the only¹³ source of uncertainty in the model is a shock to monetary policy¹⁴. The following sections describe the behavior of all these entities in details.

3.2 The Representative Household

The representative household derives utility from the aggregate consumption index (C) and leisure (L), and seeks to maximize its expected lifetime:

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t (\log(C_t) + \Phi L_t) \right\} \quad (2)$$

Where $\Phi > 0$ and $\beta \in (0, 1)$ is the subjective discount factor. Consumption is a Cobb-Douglas aggregate of the nondurable good (labeled g) and the service (labeled s).

$$C = C_g^\omega C_s^{1-\omega}, \quad 0 < \omega < 1 \quad (3)$$

Wolman (2008) uses a similar specification to examine the optimal monetary policy when the relative price of services (compared to goods) is trending up. Many other papers, focusing on the durability nature of goods (durable vs. nondurable), also adopt the Cobb-Douglas calibration for the consumption aggregate (see Barsky et al. (2007), Monacelli (2008), Carlstrom et al. (2006) among many others). This specification allows me, as it will become clear later, to isolate the implications of the household sector for monetary policy¹⁵.

The service (s) is a CES aggregate of the market-provided services (C_s^m) and home-services (C_s^h).

$$C_s = \left[\gamma (C_s^h)^{\frac{\nu-1}{\nu}} + (1-\gamma) (C_s^m)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}, \quad \nu > 0, \quad 0 \leq \gamma < 1 \quad (4)$$

I choose the CES specification so that the parameter ν governing the elasticity of substitution between market-provided services and home-services be free¹⁶. This parameter will be key to the

¹³Strictly speaking, there is another source of uncertainty in the economy, which is the uncertainty faced by monopolistically competitive firms who do not know whether or not they will have the chance to re-optimize their prices in subsequent periods.

¹⁴Christiano et al. (2005), Barsky et al. (2007) and Monacelli (2009) also use that simplifying assumption. This allows one to focus solely on monetary policy. This poses no problem in calibrate models (which is the case here), but could potentially overstate the real effects of monetary shocks in the context of DSGE models.

¹⁵This, along with the logarithmic specification of the utility function, implies separability between goods and services: $U(C, L) = \omega \ln C_g + (1-\omega) \ln C_s + \phi L$.

¹⁶Rogerson (2008) adopts this modeling of the service sector when explaining the relative poor performance of the European labor market *vis à vis de* US.

analysis. To see why, considers the two following extreme cases: if market and home production are perfect complements, the consumption aggregate becomes $\min(C_s^m, C_s^h)$, which implies that households have no choice, but to consume the exact same quantity of both items. In that case, including the household production is likely to add nothing new to the standard model in terms of fluctuations of real market activities. In fact, people have no room to substitute away from the market in "bad times". In contrast, if both items are perfect substitutes, the aggregate is linear and households have the maximum margin for arbitrage, which is an additional source of fluctuations in market activities.

A more general specification of the consumption aggregate would be one in which I also allow for a non-unit elasticity of substitution between nondurable goods and the aggregate of services¹⁷. But, in that case two forces would be in play: the substitutability between the market-provided service and the market goods on one hand and the substitutability between home-services and market-provided services on the other hand. Though more general, this specification adds nothing to the understanding of the question treat in this paper, which focuses primarily on the relative sectoral responses and not in their level *per se*¹⁸.

The representative agent has four alternative uses of his unit discretionary time. He spends part of it working in the market (a fraction N_g in the goods-producing sector and a fraction N_s^m in the services-providing sector). The remaining time is allocated to household production (N_s^h), and leisure (L).

$$N_{s,t}^h + N_{s,t}^m + N_{g,t} + L_t = 1 \quad \forall t \quad (5)$$

The representative household faces two budget constraints. The first one is a standard budget constraint which requires that total spending (on market items) should not exceed total income. The household earnings come from wage income (W), interest payment on bonds (R) and dividends received from firms of which he owns shares (Π).

$$P_{g,t}C_{g,t} + P_{s,t}C_{s,t}^m + B_t \leq R_{t-1}B_{t-1} + W_t \underbrace{(N_{g,t} + N_{s,t}^m)}_{\text{Market Hours}} + \underbrace{\Pi_{g,t} + \Pi_{s,t}^m}_{\text{Total Profits}} \quad (6)$$

P_g and P_s are the price of the market good and market-provided service respectively¹⁹.

The second constraint is an intra-household resource constraint. It states that households cannot consume more home services than they actually produce. This is equivalent to saying that household production is for self-consumption exclusively, and can therefore not be sold on the

¹⁷ $C = \left[\omega C_g^{\frac{\rho-1}{\rho}} + (1-\omega) C_s^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}$ where $C_s = \left[\gamma (C_s^h)^{\frac{\nu-1}{\nu}} + (1-\gamma) (C_s^m)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}$

¹⁸I try the more general specification (mentioned above) in the simulations and the relative sectoral responses to monetary shocks are roughly unchanged.

¹⁹Note that one needs not to put the upper subscript m on P_g (nor on C_g) as there is no home counterpart of the market-good. Even for the market-service for which a home counterpart does exist, I ignore the subscript m on P_s because home-services are not priced. This considerably eases the notation and bears no risk of confusion.

market.

$$C_{s,t}^h \leq \Gamma(N_{s,t}^h) \quad (7)$$

Γ is the production function in the household sector, with labor as the only input.

The first order conditions associated with the consumer problem are²⁰:

$$\frac{MU_{g,t}}{MU_{s,t}^m} = \frac{P_{g,t}}{P_{s,t}^m} \quad (8a)$$

$$MRS_{k,t} = \frac{\Phi}{MU_{k,t}} = \frac{W_t}{P_{k,t}}, \quad k = g, s^m \quad (8b)$$

$$\frac{W_t}{P_{k,t}} MU_{k,t} = \left(\frac{\partial \Gamma}{\partial N_s^h} \right) MU_s^h, \quad k = g, s^m \quad (8c)$$

$$\Lambda_t = \beta R_t \mathbb{E}_t(\Lambda_{t+1}) \quad (8d)$$

Where Λ_t is the lagrange multiplier associated to the date t budget constraint, and MU_i is the marginal utility of good i , $i = g, s^m, s^h$.

These are typically non-arbitrage conditions. For example, equation (8c) compares the benefits from two alternative uses of an extra unit of time. If the agent decides to work in the market-sector k , he earns the nominal wage income W . With each unit of money he can purchase $\frac{1}{P_k}$ units of consumption good or service k . Now each extra unit of consumption provides the marginal utility MU_k . So the left hand side of that equation summarizes the gain from working on the market and consuming the resulting revenue. The right hand side gives the benefits of devoting that extra unit of time to household production instead. $\frac{\partial \Gamma}{\partial N_s^h}$ is what the agent would produce if he was to work at home. Now, each unit of the home produced good provides the marginal utility MU_s^h . This equation thus simply suggests that the agent must be indifferent between those two options at the optimum.

3.3 Final Goods Producers

At each date t , the representative, competitive final good producer of the market-sector k ($k = g, s^m$), bundles intermediate products into the sector' final consumption good, using the following technology *à la* Dixit-Stiglitz:

$$Y_{k,t} = \left(\int_0^1 Y_{k,t}(z)^{\frac{\varepsilon_k - 1}{\varepsilon_k}} dz \right)^{\frac{\varepsilon_k}{\varepsilon_k - 1}} \quad (9)$$

Where $\varepsilon_k > 1$ is the constant elasticity of substitution between differentiated products. $Y_{k,t}(z)$ denotes the time t amount of intermediate input purchased from firm z by the final good producer of sector k .

²⁰after substituting for (7), which holds with equality at the optimum

The competitive firm takes its price as given and combines intermediate inputs such as to minimize production costs. This yields the following demand schedule for each intermediate good in each sector:

$$Y_{k,t}(z) = \left(\frac{P_{k,t}(z)}{P_{k,t}} \right)^{-\varepsilon_k} Y_{k,t}, \quad \forall z \in (0, 1) \quad (10)$$

The resulting price level in sector k is the lagrange multiplier of the cost minimization problem:

$$P_{k,t} = \left(\int_0^1 P_{k,t}^{1-\varepsilon_k}(z) dz \right)^{\frac{1}{1-\varepsilon_k}}, \quad k = g, s^m \quad (11)$$

3.4 Intermediate Goods producers

Besides final good producers, each sector is populated by a continuum of monopolistically competitive firms of measure one. The monopolistic firm z in sector $k = g, s^m$ produces output $Y_{k,t}(z)$ using a linear technology in labor:

$$Y_{k,t}(z) = AN_{k,t}(z) \quad (12)$$

Where A is a constant labor productivity parameter, which I normalize to one for simplicity. The demand for labor is determined by unit-cost minimization. Since I assume perfect mobility of labor, wages are equalized across sectors in equilibrium and one has:

$$\Psi_{k,t} = W_t/A \quad (13)$$

Where $\Psi_{k,t}$ is the nominal marginal cost in sector k , which, given the previous equation is sector-independent.

I assume price rigidity à la Calvo (1983). In each period, a firm z in sector k has a constant probability $1 - \theta_k$ of resetting its price if lucky enough. If not "selected" to change its price, the firm simply keep his previous period' price²¹.

The problem of a re-optimizing firm reads:

$$\begin{aligned} & \text{Max}_{P_{k,t}(z)} \left\{ \mathbb{E}_t \sum_{t=0}^{\infty} (\beta\theta_k)^i \frac{\Lambda_{t+i}}{\Lambda_t} [P_{k,t}(z) - \Psi_{k,t+i}] Y_{k,t+i}(z) \right\} \\ & \text{s.t} \quad Y_{k,t+i}(z) = \left(\frac{P_{k,t}(z)}{P_{k,t+i}} \right)^{-\varepsilon_k} Y_{k,t+i}, \quad \forall i \end{aligned} \quad (14)$$

Where $\Lambda_t = \frac{MU_{k,t}}{P_{k,t}}$ is the "price-adjusted" marginal utility of wealth. Ψ_t is the nominal marginal cost of production, which is equal to nominal wage, as noted previously.

²¹I do not assume price indexation. Price indexation has proven to be useful in explaining inflation persistence, which is not the focus in this paper. However, when I consider the zero-inflation steady state later, the setup becomes equivalent to one in which non-optimizing firms keep pace with the steady state inflation rate.

The solution to this problem is given by²²:

$$P_{k,t}^* = \left(\frac{\epsilon_k}{\epsilon_k - 1} \right) \frac{\mathbb{E}_t \sum_{i=0}^{\infty} (\beta \theta_k)^i MU_{k,t+i} \Psi_{k,t+i} P_{k,t+i}^{\epsilon_k - 1} Y_{k,t+i}}{\mathbb{E}_t \sum_{i=0}^{\infty} (\beta \theta_k)^i MU_{k,t+i} P_{k,t+i}^{\epsilon_k - 1} Y_{k,t+i}} \quad (15)$$

If $\theta_k = 0$, prices are fully flexible and:

$$P_{k,t}^* = \left(\frac{\epsilon_k}{\epsilon_k - 1} \right) \Psi_{k,t} \quad (16)$$

Using (11) and the probability of price adjustment, the price level in sector k simply becomes:

$$P_{k,t} = \left((1 - \theta_k)(P_{k,t}^*)^{1 - \epsilon_k} + \theta_k P_{k,t-1}^{1 - \epsilon_k} \right)^{1/(1 - \epsilon_k)} \quad (17)$$

3.5 Sectoral New Keynesian Phillips curves

Let π_g and π_s denote the inflation rate in the market-good and market-service sectors respectively. The following result holds.

Proposition 3.1 *In the presence of household production, the New Keynesian Phillips curve remains standard in the nondurable goods sector ($\pi_{g,t} = \kappa_g y_{g,t} + \beta \mathbb{E}_t(\pi_{g,t+1})$) whereas that of the service sector is "Augmented" as follows:*

$$\pi_{s,t} = \kappa_s y_{s,t}^m + \underbrace{(1 - 1/\nu) \kappa_s (y_{s,t} - y_{s,t}^m)}_{\text{Endogenous shift term}} + \beta \mathbb{E}_t(\pi_{s,t+1}) \quad (18)$$

Where $\kappa_j = (1 - \theta_j)(1 - \beta \theta_j)/\theta_j$, $j = g, s$ is a decreasing function of θ_j .

Note: The small letters in the proposition represents the deviation of capital letters variables from the deterministic steady state.

Proof. (See appendix)

The proof uses the first order conditions of the consumer problem (8)_s, the pricing equations of monopolistic firms (15)_s and the price aggregate (16), after a first order Taylor expansion.

As it is the case in most sticky price models, the dynamic effects of a shock to monetary policy in the model considered here are well captured through the New Keynesian Phillips Curve (NKPC thereafter). From the previous proposition, the inflation in the goods producing sector is entirely driven by the output gap, conditional on the degree of price stickiness.

Conversely, the NKPC in the service sector features an extra endogenous "shift term": $(1 - 1/\nu) \kappa_s (y_{s,t} - y_{s,t}^m)$. This term is key to understanding how household production actually affects

²²In a symmetric equilibrium, all re-optimizing firms actually charge the same price.

the transmission mechanism of monetary policy in the model. Its magnitude depends critically on the elasticity of substitution between household and market-services, ν .

When ν equals unity, the consumption aggregate (C) becomes Cobb-Douglas in market-services (C_s^m), home-services (C_s^h) and market-goods (C_g):

$$C = C_g^\omega (C_s^m)^{(1-\gamma)(1-\omega)} (C_s^h)^\gamma (1-\omega) \quad (19)$$

This, combined with the log utility yields a complete separability of home-services from market goods and services²³. The NKPC then reduces to the standard one in that case²⁴ and home production changes nothing to inflation dynamics. It follows that the real effects of a shock to monetary policy are identical to that obtained in a similar model without household production²⁵.

The higher the value of ν , everything else equal, the bigger the shift term. But everything else is not equal in this model because the expression $y_s - y_s^m$ is endogenous. Recall that $y_s = c_s$ is the aggregate of market-provided and home-produced services. It is hard to infer the behavior of the shift term analytically. I do rely on simulations to examine its relative contribution to inflation dynamics through the following exercise: for a given value of the parameter ν , I solve for the time path of both the output gap and the shift terms, following an expansionary monetary policy. The magnitude of those terms are portrayed in the figure below. The first thing to note is that the two terms are opposite and expand in different directions as ν rises from 1 to 5.

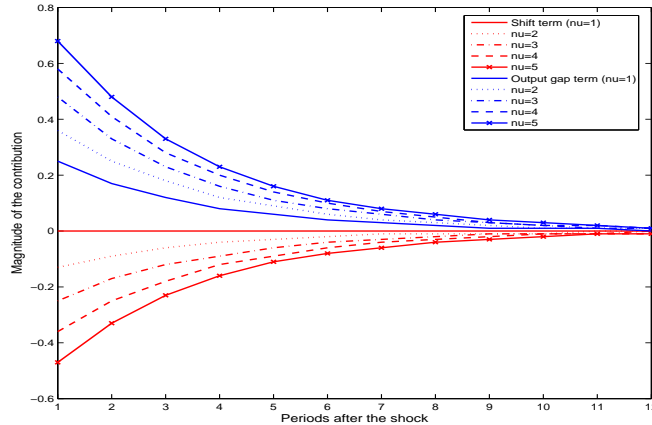


Figure 3: Contribution of the output gap term and the shift term (term related to home production) to inflation dynamics, following an expansionary monetary policy.

²³ $U(C, L) = \omega \ln c_g + (1 - \gamma)(1 - \omega) \ln C_s^m + \gamma(1 - \omega) C_s^h + \Phi L$

²⁴To see this, one simply has to replace ν by 1 in the NKPC of the service sector in the proposition above.

²⁵Benhabib et al.(1991) formally show (in a RBC framework) that home production changes nothing to aggregate fluctuations in the case of a log utility. But, this result couldn't be assumed blindly in this setup as one did not necessarily know (in advance) how home production would play out in the presence of price rigidity.

A high value of ν corresponds to a high output gap (see the figure below). In the absence of home production, this would induce a price increase, for a given level of price rigidity. In this model however, household production prevents that price increase from happening, by adding a negative term to the output gap term. As a consequence, firms in the service sector are able to produce more without further increase in their prices.

The general message conveyed by the proposition is that NKPC in the service sector is no longer summarized by the (only) term related to the output gap. Instead, home production adds substantial rigidity in the service sector. As a consequence, monetary policy will tend to have larger real effects in that sector as shown below.

3.6 Monetary Policy

I assume that the monetary authority sets the nominal interest rate according to the Taylor rule:

$$\frac{R_t}{\bar{R}} = \left(\frac{P_t}{P_{t-1}} \right)^{\phi_\pi} \left(\frac{Y_t}{\bar{Y}} \right)^{\phi_y} \xi_t, \quad \phi_\pi > 1, \quad \phi_y \geq 0 \quad (20)$$

where \bar{R} and \bar{Y} are respectively the gross nominal interest rate and the market-output associated with the zero inflation deterministic steady state.

ξ is a persistent shock such that:

$$\ln(\xi_t) = \rho_r \ln(\xi_{t-1}) + \zeta_t, \quad 0 < \rho_r < 1; \quad \text{with } \zeta_t \sim \text{iid}(0, \sigma_\zeta^2) \quad (21)$$

3.7 Aggregation

For a given market sector k ($k = g, s^m$), one has:

$$N_{k,t} = \int_0^1 N_{k,t}(z) dz \quad \text{for all } t, \quad (22)$$

and the aggregate production in that sector is given by:

$$Y_{k,t} = \Upsilon_{k,t} A N_{k,t} \quad (23)$$

where $\Upsilon_{k,t} = \left(\frac{P_{k,t}^*}{P_{k,t}} \right)^{-\varepsilon_k}$ is the "efficiency distortion". It is easy to show that:

$\Upsilon_{k,t} \leq 1$ and that: $\Upsilon_{k,t} = 1$ if $P_{k,t}(z) = P_{k,t}(z') \forall z, z'$.

Market clearing conditions reads:

$$C_{k,t} = Y_{k,t} \quad \text{for the market-goods and market-services,}$$

$$N_t = N_{g,t} + N_{s,t}^m \quad \text{for the labor market and}$$

$B_t = 0$ for the bonds market (as agents are identical).

One issue that arises in this setup is how to define aggregate market-output for which no direct expression exists in the model. In fact, the consumption aggregate mixes market and household items in a non-separable way. However, it turns out that one can actually get an expression for the deviation of real output from the steady state.

Let's define real output at date t as:

$$Y_t = \bar{P}_g Y_{g,t} + \bar{P}_s Y_{s,t}^m \quad (24)$$

where \bar{P}_i ($i = g, s$) are the sectoral price levels in steady state.

Linearizing the above expression, one gets:

$$y_t \bar{Y} = \bar{P}_g \bar{Y}_g y_{g,t} + \bar{P}_s \bar{Y}_s^m y_{s,t}^m \Rightarrow y_t = \chi y_{g,t} + (1 - \chi) y_{s,t}^m$$

where $\chi = \bar{P}_g \bar{C}_g / \bar{Y}$ can be inferred straightforwardly from the national accounts (see calibration).

The price level is simply defined as nominal over real output, that is:

$$P_t = \frac{P_{g,t} Y_{g,t} + P_{s,t} Y_{s,t}^m}{\bar{P}_g Y_{g,t} + \bar{P}_s Y_{s,t}^m} \quad (25)$$

which after linearization becomes:

$$p_t = \chi p_{g,t} + (1 - \chi) p_{s,t} \Rightarrow \pi_t = \chi \pi_{g,t} + (1 - \chi) \pi_{s,t}$$

4 Calibration

Consistently with the VAR-based evidence presented in section 1, the model is calibrated at a quarterly frequency. The discount factor β is set so as to imply an annualized real interest rate of 4% ($\beta = 1.04^{-1/4} = 0.99$). I set the elasticity of substitution between differentiated products ε_g and ε_s to imply an equal steady-state markup of 10% in both market sectors. This value is consistent with the findings in Basu and Fernald (1997).

The calibration of Φ and γ is based on household' time allocation. They are respectively set so that households devote one third of their discretionary time to market-work (which is standard in RBC models), and one fourth to homework (which is taken from the Michigan Time Use Survey²⁶). θ_g and θ_s are set such that prices last for 3 quarters on average in both sectors. But I also consider the cases of sticky services and flexible nondurables in the simulations. Many two-sector models perform a similar calibration of price stickiness²⁷.

²⁶The Time Use Survey by the BLS also suggests a time share of home production in that range.

²⁷See, e.g., Carlstrom et al.(2006), Barsky et al.(2007) and Monacelli (2009).

The coefficient of the inflation in the Taylor rule is fixed to 1.5 and the persistence of the shock to interest rate is $\rho_r = 0.7$. Those values are standard in the calibration of the simple Taylor rule (see, e.g., Carlstrom et al.(2006) and Monacelli (2009),). But I also consider the variant of the Taylor rule in which the weight of the output gap ϕ_y is different from zero. Because this weight is essentially small (especially at quarterly frequency), as suggested by estimations, the results are very similar qualitatively, and quantitatively close to those obtained with $\phi_y = 0$.

The parameter ν is central to our analysis. Fortunately, many authors have estimated the elasticity of substitution between market and home produced goods as a whole²⁸. But, as documented in section 1, home production consists almost exclusively of services. This suggests that existing estimations, which range from 1.5 to 2.3, are likely to provide a downward biased estimate of the elasticity of substitution that we refer to in this paper. Recall that ν in the model considered here is the elasticity of substitution between market and home services. I choose $\nu = 2.3$, which is the estimate in Chang et al.(2003). Note that this is still conservative as I refer here to the substitution between market-provided and home services (which is a specific subset of products), whereas the previous authors estimate the elasticity of substitution between the single market and home good.

Finally, I fix χ to match the 2008 expenditure share of nondurables goods (in the aggregate of nondurables and services). This allows me to pin down ω , using a set of first order conditions from the optimization problem of consumers.

The following table summarizes the values of calibrated parameters.

β	ν	Φ	γ	χ	ω	ε_g	ε_s	θ_g	θ_s	ϕ_π	ϕ_y	ρ_r
0.99	2.3	1.62	0.5	0.4	0.24	11	11	2/3	2/3	1.5	0	0.7

Table 3: Parameter values

5 Results

I first linearize the system around the zero inflation deterministic steady state. I then solve the model, using the Blanchard-Kahn (1980) method. The impulse response functions of endogenous variables to a negative percentage point innovation in the interest rate are plotted below.

I consider 4 scenarios: (i) model without home production (which I label "No HP") and equally sticky prices across sectors (this is the benchmark scenario); (ii) model with home production and flexible prices in all sectors; (iii) model with home production, sticky prices of services and flexible prices of goods; (iv) model with home production and equally sticky prices across sectors.

²⁸See Rogerson et al.(1995), McGrattan et al.(1997), and Chang et al.(2003)

Simulations suggest that a model with household production does generate real effects of monetary shocks in the service sector that are nearly twice as large as the real effects obtained in the benchmark model without household production. Moreover, this happens without a further increase in prices, as it should become clear below. Conversely, home production adds no real (nor nominal) effects to the nondurable goods sector. As a consequence, real effects of monetary policy are larger in the service sector, which is consistent with the VAR-based evidence presented in section 1.

The intuition for these results is that a wide range of market-service producers in this model face additional competition from households, who can produce services at home that are substitutes to their products. This prevents them from raising their prices as much as they would otherwise do in a context without home production. They rather increase production as a way to generate profits. Recall that a monopolistic firm can adjust either (inclusively) its prices or quantities as a way to maximize its profits, which is a direct consequence of the demand schedule (see equation (10)) that it faces. In a standard New Keynesian model, rising production entails higher real marginal costs which are in turn factored into prices. This is not necessarily true in this model because of the extra competition from the household sector. That's why prices in the market-service sector remained unchanged compared to a model without household production, although quantities increase.

Finally, because services have a big expenditure share in aggregate output, the later also registers larger real effects, compared to the benchmark model without home production (see the impulse response functions below).

Figure 4: Responses of Real Sectoral Consumption to an interest rate cut.

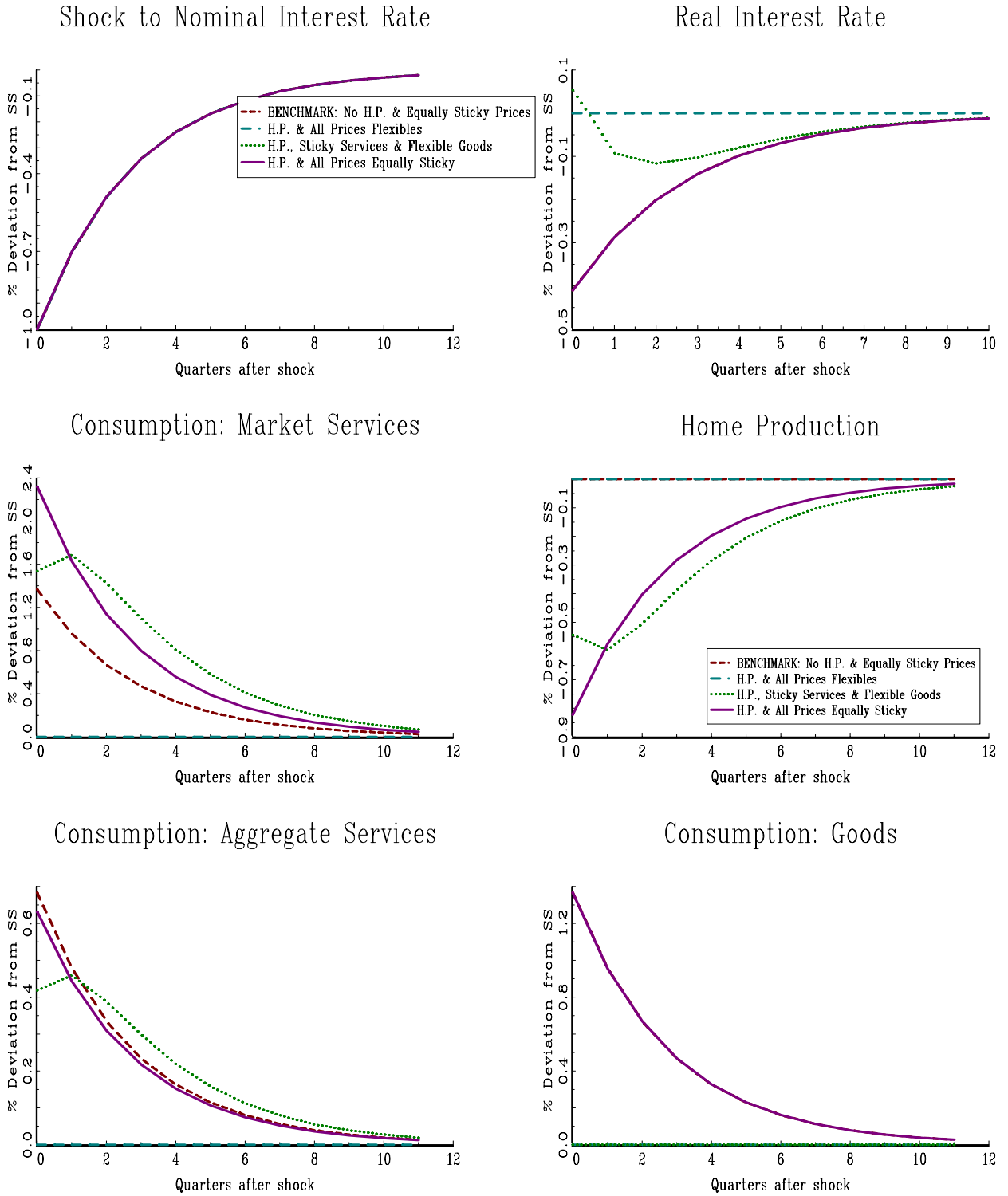
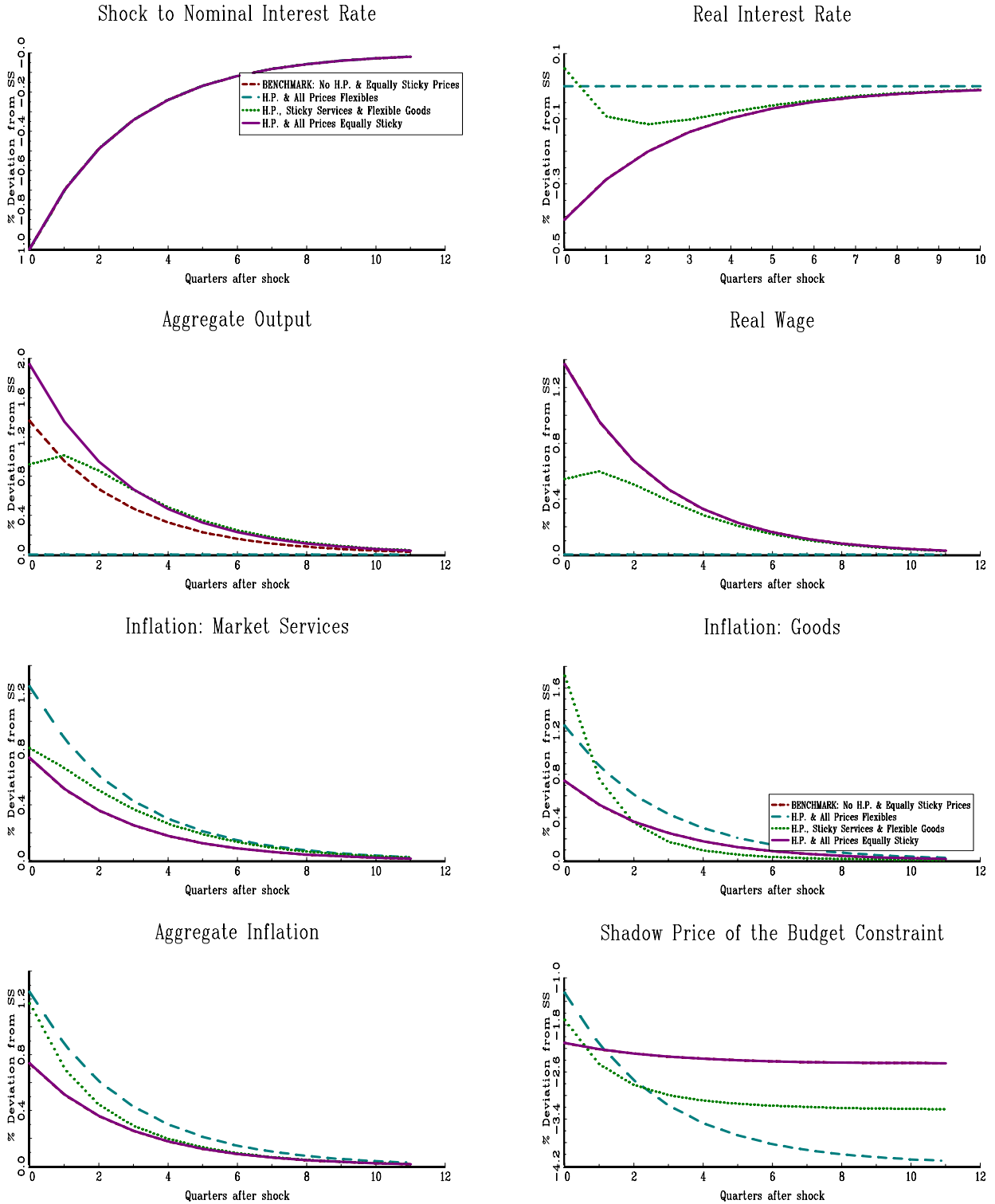


Figure 5: Responses of Sectoral inflation and Real Aggregates to an interest rate cut.



6 Conclusion

In this paper, I first document three facts: (i) the service sector is more interest-sensitive than the nondurable goods sector; (ii) a subset of market-provided services has good substitutes at home; (iii) in order to replicate the first fact, a standard two-sector sticky price model requires an extremely high degree of sectoral heterogeneity in price stickiness, which is at odd with micro evidence.

I then ask the following question: can the inclusion of a household sector in an otherwise standard sticky price model rationalize the first fact? Or put in a different way, what are the implications of home production for sectoral responses of the economy to monetary shocks?

To provide an answer to that question, I build a multi-sector model, based on the second fact in the sense that households are allowed to produce services at home, that are fairly good substitutes to market-provided services. The model is calibrated to the US economy and two sets of results emerged, that can be summarized as follows:

First, if prices are flexible, home production does not induce real effects to monetary shocks, independently on how high is the elasticity of substitution between home-made and market-provided services. This seems to be a common feature to "real rigidities", which typically contribute to strengthening nominal rigidities that already exist.

Second, and most importantly, when prices are sticky (as suggested by micro evidence), the model does a good job in mimicking the first fact. In the presence of the home sector, nominal rigidity in the service sector is no longer summarized by the coefficient of the output gap in the "Augmented" New Keynesian Phillips curve, which now features an endogenous shift term. This term materializes the fact that households can shift away from the market-services if firms raise their price "too much" in the service sector. The larger the elasticity of substitution between home-made services and market-provided services, the bigger that term. With the calibrated elasticity of substitution of 2.3 -which is somehow conservative -, the real effects in the service sector, of an interest rate cut are roughly as twice as large as those obtained in a similar model without household production. Such differential doesn't exist in the nondurable goods sector for which the real effects of monetary shocks remain unchanged, compared to the baseline model without household production. In fact, contrary to services, there are no home substitutes to nondurable goods. As a consequence, the service sector is more interest-sensitive than the nondurable goods sector.

The results obtained in this paper suggest that home production is an important source of monetary non-neutrality, and particularly in the service sector. As a consequence, an estimated DSGE model that doesn't account for household production is likely to overestimate the exogenous degree of price stickiness in the service sector. This would be misleading on the sources and

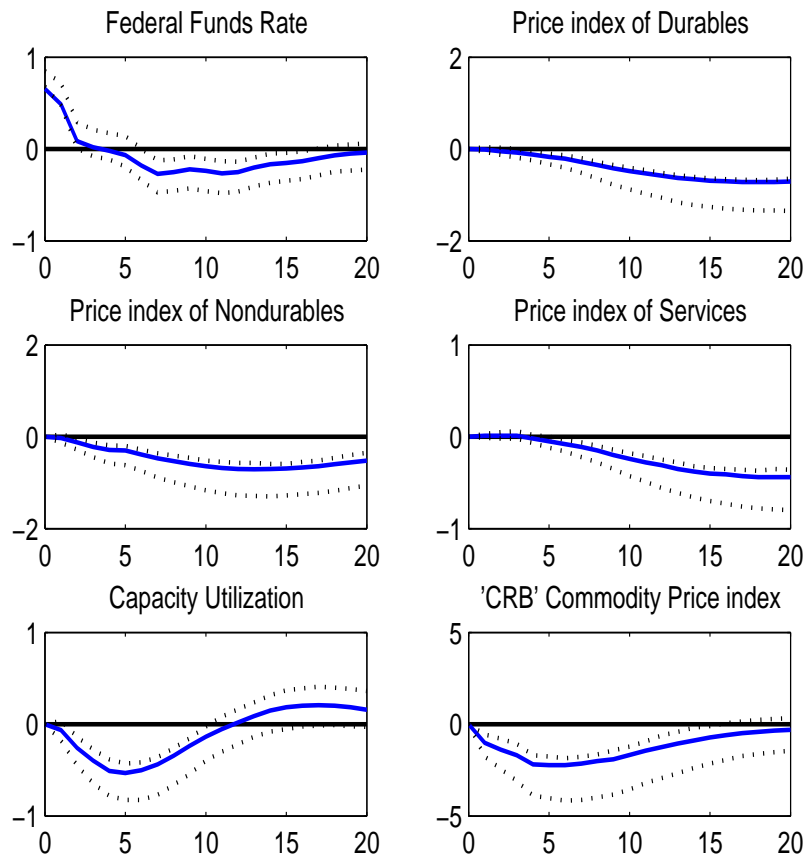
magnitudes of rigidities in the economy, which is key in understanding the transmission mechanism of monetary policy. A natural follow up to this work would then be to jointly estimate home and market-related parameters, including sectoral degrees of price stickiness.

Finally, although the model is calibrated to the US, the setup that presented in this paper is more general and can be readily applied to any country. This is particularly true for less developed country for which the household sector is even larger.

A. Appendix

A.1 IRF prices

Figure 6: Estimated responses of sectoral prices to a monetary policy tightening in a VAR model: services vs. nondurable



A.2 Proof of Proposition (3.1)

This proof uses the pricing equation of re-optimizing monopolistically competitive firms, the first order conditions of the consumer problem, along with some equilibrium conditions. As it is the case for the standard New Keynesian Phillips Curve (NKPC), the result is obtained by a first order Taylor expansion around the deterministic steady state.

Let \bar{X} denotes the value of the variable X in the deterministic steady state and x its deviation around that steady state.

The aggregate price in the market-service sector reads:

$$P_{s,t} = \left[(1 - \theta_s) P_{s,t}^{\star \varepsilon_s - 1} + \theta_s P_{s,t-1}^{\varepsilon_s - 1} \right]^{\frac{1}{1 - \varepsilon_s}}$$

where θ_s is the exogenous probability that a monopolistically competitive firm in the market-service sector does not re-optimize its price in a given period t ²⁹, and ε_s is the constant elasticity of substitution among varieties produced in that sector.

Dividing both sides of the previous equation by $P_{s,t-1}$ one gets:

$$\frac{P_{s,t}^{\star}}{P_{s,t}} = \left(\frac{1 - \theta_s \Pi_{s,t}^{\varepsilon_s - 1}}{1 - \theta_s} \right)^{\frac{1}{1 - \varepsilon_s}} \quad (26)$$

where $\Pi_{s,t} = \frac{P_{s,t}}{P_{s,t-1}}$ is the gross inflation rate in the market-service sector.

Recall from the text that firms in the market-service sector that have the opportunity to reset their price at date t do so according to the following pricing rule (see equation 15 in the text):

$$P_{s,t}^{\star} = \left(\frac{\varepsilon_s}{\varepsilon_s - 1} \right) \frac{\mathbb{E}_t \sum_{i=0}^{\infty} (\beta \theta_s)^i MU_{s,t+i}^m \Psi_{s,t+i}^m P_{s,t+i}^{\varepsilon_s - 1} Y_{s,t+i}^m}{\mathbb{E}_t \sum_{i=0}^{\infty} (\beta \theta_s)^i MU_{s,t+i}^m P_{s,t+i}^{\varepsilon_s - 1} Y_{s,t+i}^m} \quad (27)$$

Note that because I assume a linear technology in labor, the nominal marginal cost is not sector-specific and is simply equal to the nominal wage up to a constant, namely the labor productivity parameter: $\Psi_{s,t}^m = \Psi_t = W_t/A \quad \forall t$.

Now, $MRS_{s,t}^m = \Phi/MU_{s,t}^m = W_t/P_{s,t}$ from the consumer optimization problem. It follows that:

$$MU_{s,t+i}^m \Psi_{s,t+i}^m = \Phi P_{s,t+i}/A \quad \text{for all } i. \quad (28)$$

It is interesting to note that the numerator of $P_{s,t}^{\star}$ then has the same form as that one would get for $P_{g,t}^{\star}$ (which is standard). The difference here comes from the denominator. More precisely,

²⁹This also corresponds to the fraction of firms who do not adjust their price in period t . Note that we are implicitly considering the symmetric equilibrium here, which implies that all re-optimizing firms (in fraction $1 - \theta_s$) actually charge the same price P_t^{\star}

because of the CES aggregate $C_s = \left[\gamma(C_s^h)^{\frac{\nu-1}{\nu}} + (1-\gamma)(C_s^m)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}$ materializing the presence of household production, the marginal utility of consuming the market-services (MU_s^m) now depends on how much of household-services the agent actually consumes. In fact, by chained derivation,

$$MU_s^m = \partial U / \partial C_s^m = (\partial U / \partial C_s)(\partial C_s / \partial C_s^m)$$

Now, taking into account the functional form of the utility and combining the expression of $P_{s,t}^*$ above with equation (26), one gets the following equation after some manipulations:

$$\frac{\varepsilon_s}{\varepsilon_s - 1} \frac{\Phi}{(1-\omega)(1-\gamma)} \frac{V_{1,t}}{\bar{V}_{2,t}} = \left(\frac{1 - \theta_s \Pi_{s,t}^{\varepsilon_s - 1}}{1 - \theta_s} \right) \quad (29)$$

Where V_1 and V_2 have the following recursive representation:

$$V_{1,t} = A^{-1} C_{s,t}^m + \beta \theta_s \mathbb{E}_t \left(\Pi_{s,t+1}^{\varepsilon_s} V_{1,t+1} \right) \quad (30a)$$

and

$$V_{2,t} = \left(\frac{C_{s,t}^m}{C_{s,t}} \right)^{1-1/\nu} + \beta \theta_s \mathbb{E}_t \left(\Pi_{s,t+1}^{\varepsilon_s - 1} V_{2,t+1} \right) \quad (30b)$$

which admitted the following linearization forms (after solving for \bar{V}_1 and \bar{V}_2):

$$v_{1,t} = (1 - \beta \theta_s) c_{s,t}^m + \beta \theta_s \varepsilon_s \mathbb{E}_t(\pi_{s,t+1}) + \beta \theta_s \mathbb{E}_t(v_{1,t+1}) \quad (31a)$$

$$v_{2,t} = (1 - 1/\nu)(1 - \beta \theta_s) (c_{s,t}^m - c_{s,t}) + \beta \theta_s (\varepsilon_s - 1) \mathbb{E}_t(\pi_{s,t+1}) + \beta \theta_s \mathbb{E}_t(v_{2,t+1}) \quad (31b)$$

Recall that:

$$C_s = \left[\gamma(C_s^h)^{\frac{\nu-1}{\nu}} + (1-\gamma)(C_s^m)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} \Rightarrow c_{s,t} = \gamma \left(\bar{C}_s^h / \bar{C}_s \right)^{1-1/\nu} c_s^h + (1-\gamma) \left(\bar{C}_s^m / \bar{C}_s \right)^{1-1/\nu} c_s^m$$

where C_s^h is the amount of services which are produced at home.

After linearization, equation (29) becomes:

$$v_{1,t} - v_{2,t} = \frac{\theta_s}{1 - \theta_s} \pi_{s,t} \quad (32)$$

Iterating the above equation one step forward and evaluating the expression $(v_{1,t} - v_{2,t})$ from equations (31a) and (31b), one obtains the following "Augmented" NKPC after some straightforward algebra:

$$\pi_{s,t} = \kappa_s y_{s,t}^m + (1 - 1/\nu) \kappa_s (y_{s,t} - y_{s,t}^m) + \beta \mathbb{E}_t(\pi_{s,t+1}); \text{ with } \kappa_s = \frac{(1 - \theta_s)(1 - \beta \theta_s)}{\theta_s} \quad (33)$$

where I've used the market clearing condition $c_s^m = y_s^m$ and define $y_s = c_s$. ■

A.3 Reduced set of equations for the linearized model

$$\begin{aligned}
c_{i,t} &= \mathbb{E}_t c_{i,t+1} - (r_t - \mathbb{E}_t \pi_{i,t+1}), \quad i = g, s^m \\
c_i &= y_i, \quad i = g, s, s^m \\
\pi_{g,t} &= \kappa_g y_{g,t} + \beta \mathbb{E}_t (\pi_{g,t+1}), \quad \kappa_g = (1 - \theta_g)(1 - \beta \theta_g) / \theta_g \\
\pi_{s,t} &= \kappa_s y_{s,t}^m + (1 - 1/\nu) \kappa_s (y_{s,t} - y_{s,t}^m) + \beta \mathbb{E}_t (\pi_{s,t+1}), \quad \kappa_s = (1 - \theta_s)(1 - \beta \theta_s) / \theta_s \\
r_t &= \phi_\pi \pi_t + \phi_y y_t + \ln \xi_t \\
\ln \xi_t &= \rho_r \ln \xi_{t-1} + \zeta_t \\
y_t &= \chi y_{g,t} + (1 - \chi) y_{s,t}^m \\
\pi_t &= \chi \pi_{g,t} + (1 - \chi) \pi_{s,t} \\
c_{s,t} &= \gamma \left(\bar{C}_s^h / \bar{C}_s \right)^{1-1/\nu} c_s^h + (1 - \gamma) \left(\bar{C}_s^m / \bar{C}_s \right)^{1-1/\nu} c_s^m \\
c_{s,t}^h &= (1 - \nu) c_{s,t} \\
\lambda_t &= (r_t - \mathbb{E}_t \pi_{t+1}) + \mathbb{E}_t \lambda_{t+1} \\
w_t &= -\lambda_t - p_t = c_{g,t} + p_{g,t}
\end{aligned}$$

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