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Household Production, Services and Monetary Policy

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Household Production, Services and Monetary Policy[1]

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Abstract

A distinctive feature of market-provided services is that some of them have close substitutes at home. Households may therefore switch between consuming home and market services in response to changes in the real wage—the opportunity cost of working at home—and changes in the price of market services. In order to analyze and quantify the implications of this trade-off for monetary policy, I embed a household sector into an otherwise standard sticky price DSGE model, which I calibrate to the U.S. economy. The results of the model are twofold. At the sectoral level, household production augments the service sector's New Keynesian Phillips curve with a sizable extra component that co-moves negatively with the output gap term, lowering the incentive of service sector firms to change their prices. This mechanism endogenously amplifies the real effects of a monetary shock in that sector, unlike in the nondurable goods sector for which households cannot manufacture substitutes at home. At the aggregate level, household production also implies more sluggish prices and a stronger response of real macroeconomic variables to a monetary shock. Some empirical support for this theory is provided.

JEL Classification Numbers:E12, E32, D13.

Keywords: Consumer services, DSGE model, Household production, Monetary shock, Nondurable goods, New Keynesian Phillips curve.

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I. INTRODUCTION

One of the most striking macroeconomic features of the US—and most advanced economies—is the large size of its service sector, which now accounts for nearly 80 percent of the economy-wide value-added. In a recent paper, Buera and Kaboski (2009) document that the expansion of the service sector was mainly driven by consumer services, which went from one-third of total private consumption expenditures in 1950 to about two-thirds in 2008.[1]

A distinctive feature of consumer services is that a number of them have close substitutes at home, unlike nondurable goods (see, e.g., Lebergott (1993); Ngai and Pissarides (2008); Reid (1934); Vanek (1973)).[2] Consumers could therefore switch between market- and home-produced services in response to changes in economic conditions, which would endogenously amplify the real effects of monetary shocks in the service sector. Given that the service sector is large, aggregate real effects would also be stronger.

To assess the above conjecture, I embed a household sector into an otherwise standard two-sector (market services and nondurables) sticky price model. Consistently with the data, the model features an important source of asymmetry: services can be produced both by firms and at home, whereas nondurable goods are exclusively supplied in the market.

Qualitatively, it is reasonable to posit that accounting for household production may lead to improvements over the standard New Keynesian model in understanding the transmission of monetary shocks to the real economy, both at the aggregate and sectoral level. In fact, by affecting the real wage—the opportunity cost of working at home—and the price of market-provided goods and services, a monetary shock changes the incentives of households to choose market consumption over home' (and vice versa). Moreover, these effects are likely to be stronger in the service sector for which households are able to produce substitutes at home.

[1] There are two non-exclusive explanations as to why the service sector expands over the course of economic development, an empirical regularity which was first noted by Kuznets (1966). One explanation is that the service good feature an income elasticity of demand above unity (see Kongsamut, Rebelo, and Xie (2001) for a recent contribution). Ngai and Pissarides (2007) provide another rationale consistent with balanced growth. The authors show that a low (less than one) elasticity of substitution among goods is enough to drive labor away from the more productive sectors (e.g., agriculture and manufacturing) and towards the less productive ones (e.g., services).

[2] Examples of household activities that are substitutes for market services include cooking, cleaning, caring for children and other relatives, shopping, gardening, administration (dealing with bills, keeping bank accounts, etc.), repairs, etc. Buera and Kaboski (2009) also list medical activities such as checking blood sugar (pressure) and home dialysis as examples of previously exclusive market services that are now undertaken at home.

At the quantitative level, the implications for monetary policy of household production would depend on the size of the home sector, and most importantly on the degree of substitutability between market- and home-produced services. Eisner (1988) estimates U.S. Gross Household Production (GHP) at 37.5% of the extended Gross National Product (GNP), defined as the sum of GNP and GHP. In addition, the "American Time Use Survey" (ATUS) suggests that people devote a substantial amount of their discretionary time to home activities (nearly 26 hours a week). Moreover, as noted by Ngai and Pissarides (2008), the literature on household production has argued convincingly that household production and market production are close substitutes for each other, with the estimates of the elasticity of substitution ranging from 1.5 to 2.5 across studies (see Aguiar and Hurst (2007a); Chang and Schorfheide (2003); McGrattan, Rogerson, and Wright (1997); Rogerson, Rupert, and Wright (1995)).[3]

Although the implications of household production for real business cycles have been studied extensively (see, e.g., Benhabib, Rogerson, and Wright (1991); Greenwood and Hercowitz (1991); McGrattan, Rogerson, and Wright (1997)), its implications for monetary policy have not been examined yet. I show in this paper that when household production is accounted for, the degree of nominal rigidity in the *Augmented* New Keynesian Phillips curve (NKPC) of the service sector is no longer summarized by the output gap term. The NKPC features an additional term, which I find to be substantial for a reasonable calibration of parameters. This term increases with the degree of substitutability between market and home services, and comoves negatively with the output gap, therefore amplifying nominal rigidity in the service sector endogenously. Intuitively, a firm in the service sector is more reluctant to change its price in response to monetary shocks because it faces the household as an additional competitor, beyond traditional monopolistic competitors in the marketplace. In maximizing their profits, firms therefore tend to adjust quantities more than they would otherwise do, thus amplifying the real effects of monetary shocks in the service sector. This mechanism is not at play in the nondurable goods sector for which households cannot manufacture substitutes at home. Now, because the service sector is large, the aggregate response of output is stronger in my model, as the adjustment in aggregate inflation is relatively lower. These sectoral findings are consistent with evidence from a VAR that I estimate using U.S. quarterly data, where I find that consumer services are more interest-rate sensitive than consumer nondurable goods.

The remaining of the paper proceeds as follows. I end this section by a short review of the related literature. Section II provides an empirical support to the modeling approach adopted in

[3] These studies estimate the elasticity of substitution between a market aggregate of goods and services and home production. Given that home production consists of services, existing estimates are likely to provide a lower bound for the elasticity of substitution between market services and home production.

this paper. Section III presents the model and its main implications. In Section IV, I calibrate the model to the U.S. economy and analyze simulation results. Section V draws concluding remarks.

A. Related Literature

The standard New Keynesian model requires a very high degree of price rigidity in order to fit the data, at odds with micro-evidence which suggests that prices change quite frequently (see, e.g., Bils and Klenow (2004); Nakamura and Steinsson (2008)).[4] A solution in the literature has consisted in combining nominal rigidities with real rigidities (factors that make firms reluctant to adjust their relative prices) of some kind, as first introduced by Ball and Romer (1990). In that vein, Eichenbaum and Fisher (2004) assume a variable elasticity of demand for differentiated products, as in Kimball (1995), and firm-specific capital, and obtain a more plausible estimate of price rigidity of 2 quarters.[5] This paper complements that literature by showing that the inclusion of household production into an otherwise standard New Keynesian model amplifies the real effects of monetary policy for a given degree of nominal rigidity. Household production can therefore be seen as a way to induce additional price stickiness endogenously, which reduces the reliance on a higher exogenous degree of price rigidity to generate a strong response of real output to monetary shocks as observed in the data.

At a disaggregate level, several papers have attempted to explain differences in sectoral responses to a monetary shock. However, VAR-based evidence at the sectoral level, and multi-sector New Keynesian models have mainly distinguished goods according to their durability (see Barsky, House, and Kimball (2007); Carlstrom and Fuerst (2006); Erceg and Levin (2006); Monacelli (2009), among many others).[6] In this paper I make a distinction among goods by tangibility, that is service versus non-service goods. This is of interest given the

[4]For example, Gali and Gertler (1999) estimate the New Keynesian Phillips curve and obtain an average price duration ranging from 6 to 8 quarters across their alternative specifications. In the same vein, Eichenbaum and Fisher (2004) estimate a DSGE model and find that Calvo (1983) pricing implies that firms do re-optimize their prices nearly once every two years.

[5]Christiano, Eichenbaum, and Evans (2005) also estimate a DSGE model featuring staggered price 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 each.

[6]Two notable exceptions are Bouakez, Cardia, and Ruge-Murcia (2009) who estimate a multi-sector DSGE model including six broad sectors of the U.S. economy (agriculture, mining, construction, durable goods, non-durable goods and services), and Wolman (2009) who analyses the optimal rate of inflation when the relative price of services are trending.

large size of consumer services in aggregate consumption, and their substitutability with household services.

In parallel, a large literature has looked at the impact of home production on market outcomes, since the seminal paper by Becker (1965). Benhabib, Rogerson, and Wright (1991) show that accounting for household production improves the standard RBC model along several dimensions.[7] In particular, the fluctuations in market hours worked implied by their model is closer to the data than that of the standard model.[8] McGrattan, Rogerson, and Wright (1997) estimate a DSGE model with household production and find that it generates different predictions for tax changes than a similar model that abstracts from home production. These authors, however, consider a single market sector. I complement these studies by breaking the market into two distinct sectors (service and non-service), as in Rogerson (2008). This allows me to account for the fact that household production is almost exclusively made of services, a feature of the model that has important sectoral implications. Moreover, I focus on monetary policy which has not been studied yet in that literature.

II. Empirical Evidence

A. Services versus Nondurables: A Sectoral VAR

This section examines the sectoral responses of output and prices to a monetary policy shock. I depart from existing VAR models in that I focus particularly on consumer services, which is the category of goods for which substitutes exist at home. The procedure adopted here is closely related to Erceg and Levin (2006). These authors estimate a VAR model with an emphasis 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 subsequently examine the implication of this finding for optimal monetary policy. In this paper, I focus on services instead, and disaggregate real GDP into three major components: durables, nondurables and services. I consider a quarterly VAR (with 4 lags and a constant) for the U.S. economy, over the sample period from 1967:Q1 to 2007:Q4. The model is specified as fol-

[7] Other examples of models that takes into account household production include Freeman and Schettkat (2005); Greenwood and Hercowitz (1991); Greenwood, Seshadri, and Yorukoglu (2005); Rogerson (2008), to name only a few.

[8] The standard RBC model predicts very little fluctuations in hours worked as compared to the data.

lows:

$$\mathscr{X}_t = \Phi_0 + \sum_{j=1}^{4} \Phi_j \mathscr{X}_{t-j} + \Omega \eta_t \tag{1}$$

where η_t is a vector of contemporaneous disturbances. The vector $\mathscr{X}$ 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.

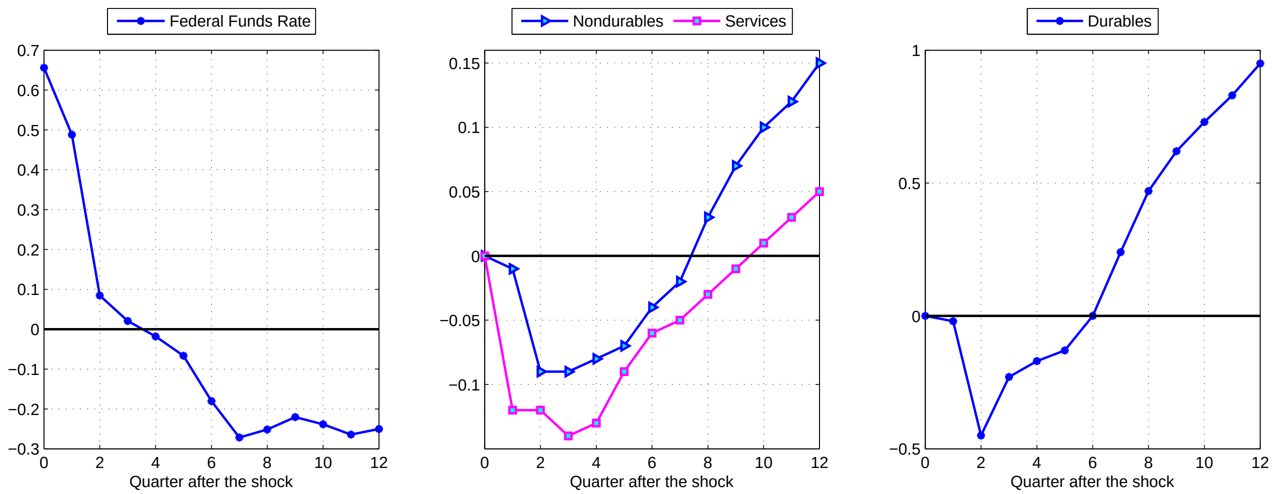
The commodity price index is included to control for supply shocks. In fact, Balke and Kenneth (1994) argue that during the 1960s and 70s, monetary policy would tighten in response to supply shocks, but not by enough to prevent inflation from rising. This counterfactually leads to a positive correlation between inflation and contractionary monetary policy, known as the "price puzzle". Commodity prices signal supply shocks and are therefore important in the VAR analysis. I also include the capacity utilization of the overall economy as some firms may respond to monetary shocks by simply changing how intensively they use their installed capital.

I follow the procedure in Christiano, Eichenbaum, and Evans (1997) 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 Figure 1. The service sector noticeably displays the strongest response during the first post-shock quarter. Real spending on services 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 even exceeds that of services, reaching a maximum decline of 0.5% in the second post-shock quarter.[9] However, services display a stronger response than nondurables in any quarter. Moreover, the effects of the shock last longer in the service sector, 9 quarters, compared to 6 and 7 quarters for durables and nondurables respectively.[10]

[9] As noted before, durable goods are known to respond more strongly to monetary shocks (see Barsky, House, and Kimball (2007) and Erceg and Levin (2006) for an empirical evidence, and Barsky, House, and Kimball (2007) for a theoretical explanation). I plot their response separately so as to highlight the difference between nondurables and services.

[10] Bouakez, Cardia, and Ruge-Murcia (2009) estimate a 6-sector DSGE model and find strong evidence of higher and more persistent responses of services to monetary shocks. Their estimates also imply a high degree of price rigidity in the service sector.

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



The results are robust to a wide range of variations such as the re-ordering of variables. I also run a VAR without capacity utilization and the results are roughly unchanged, with the only difference that the response of durables increases in the first quarter.

B. The Importance of Household Production

Household production is the production, usually at home, of goods and services for self consumption. However, some activities classified as household production are undertaken outside the house, shopping being the classic example. For household production to matter for aggregate market outcomes, it should first be the case that the home sector is quantitatively important. The objective of this section is to complement the existing literature on the size of the household sector.

1. Home hours worked

The amount of time that people spend on household chores is an indication of the importance of home production. This is because the opportunity cost of working at home is the real wage that one would earn while working in the market. An optimizing agent allocates his time between the market and home so as to equate the real wage and home productivity.[11]

Table 1. Time devoted to household production in the U.S. (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 hours of home production	**26.39**	**20.09**	**31.15**
Market hours worked	25.83	31.99	20.09
Leisure and Sports	33.46	35.00	32.06

Note: Data refers to persons aged 15 years and over, and includes primary activities only.
Source: American Time Use Survey, U.S. Bureau of Labor Statistics: http://www.bls.gov/tus/

Table 1 reports the amount of time that people spend per week in various household activities. I also display market hours worked and leisure time for the sake of comparison.[12] Only the amount of time spent on primary activities is reported. For example, if one is cooking while caring for a child, only the activity declared as the main occupation at the time is recorded. While this simplification may not distort the measurement of market hours worked, it is likely to bias the time devoted to household production downward. This is because many household chores are usually performed simultaneously. Even some important forms of leisure such as watching TV, surfing the internet or answering the phone are not incompatible with home production.[13] Nevertheless, Table 1 clearly indicates that people devote a substantial fraction

[11]The exactness of this relationship would, however, depend on how readily people can switch from home to market (and vice versa) in response to changes in market or home conditions. This in part depends on the extent of labor market frictions.

[12]Although I only report data for 2003, figures are of comparable magnitude for other years for which data do exist.

[13]See Aguiar and Hurst (2007b) and Ramey and Neville (2009) for a comprehensive measurement of leisure.

of their time to home production, a fraction that is at least as large as that spent on market activities.[14]

2. Households and the production of services

Beside the overall quantitative importance of household production, several authors have documented that modern household production is exclusively made of services (see, e.g., Lebergott (1993); Ngai and Pissarides (2008); Reid (1934)). In fact, due to various transformations such as the enlargement of the production scale and the technology innovation that occurred in the market place, the production of home goods became relatively inefficient and was completely marketized by the second quarter of the twenty century. If household production has remained important (see Table 1) despite these marketization forces, it is simply because the disappearance of the home production of agricultural and manufacturing goods came along with an increasing need for home services. For example, modern houses require higher cleaning and management standards. Shopping is also one of these household activities that have gained interest overtime.

C. Household and Market Production Over the Business Cycle

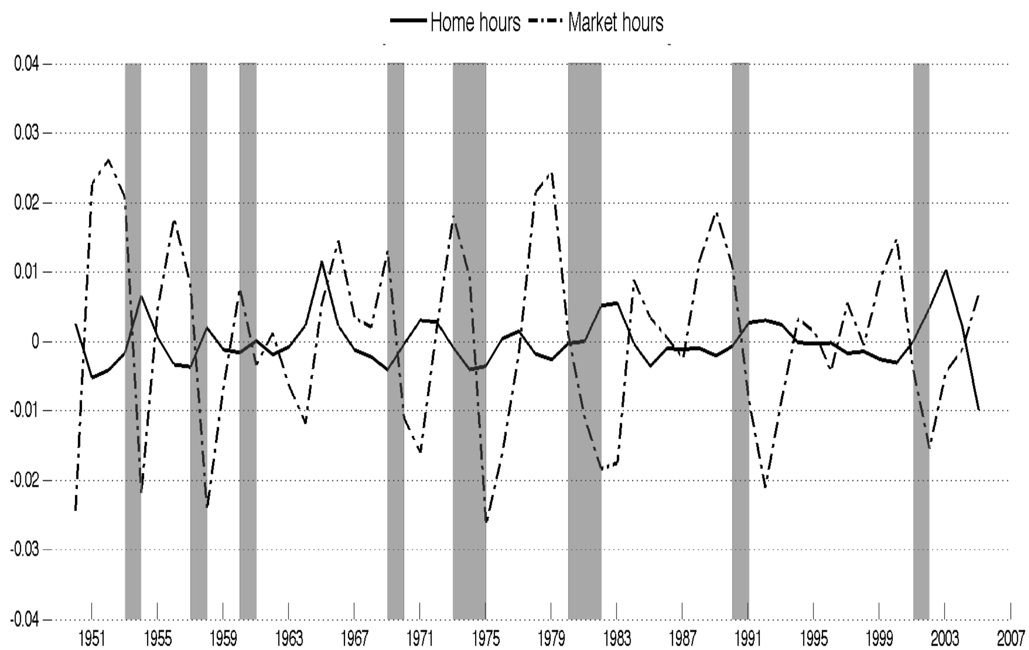
The previous section has highlighted the importance of household production in a long-run perspective. Another condition, yet necessary for household production to matter for monetary policy is that it be substitutable to market production (and vice versa) at the business cycle frequency. This section makes an empirical assessment of that requirement. I start with the allocation of time between the market and home.

1. Fluctuations of home and market hours worked

Figure 2 portrays the de-trended home and market hours worked for persons aged 14 years and over during the period from 1950 to 2005. Annual data on hours worked are from the Ramey and Neville's (2009) dataset. In order to focus exclusively on business cycle fluctuations, I have de-trended the series, using the HP-filter with smoothing parameter $\lambda =$

[14]Table 1 also shows a large discrepancy between the amount of time devoted to homework by men and women, with men spending only two-thirds of the amount of time spent by women.

Figure 2. Home and market hours worked (HP-de-trended series)



Note: Data refers to persons aged 14 years and over.
Source: Ramey and Neville's (2009) dataset, and NBER Business Cycle Dating Committee: www.nber.org/cycles.html

$1600^{1/4} \approx 6.25$, which Ravn and Uhlig (2002) show to perform better for annual observations.[15] However, qualitative results are robust to a wide range of filtering technics. The shaded regions in Figure 2 highlight the periods in which recessions occurred, as identified by the Business Cycle Dating Committee at the National Bureau of Economic Research.

During all the recessions of the sample period, but the 1973-75', home hours worked increased in the working-age population. Even though home hours worked did not increase for the entire working-age population during the 1973-75 recession, they did increase during the second-half of that recession for the group of persons aged 25-54 years. This group accounts for a substantial fraction of the labor force and is likely to include married couples with children. The counter-cyclicality of home hours worked extends well beyond recession episodes. This adds to the already well documented counter-cyclicality of leisure.

[15] 1600 is the standard value used at a quarterly frequency.

2. Substitutability between home and market services over the business cycle

A distinctive feature of household production is that it can be "outsourced", i.e. someone else can be paid to do it, and the resulting output still provide a similar utility, unlike leisure for which one has to spend one's own time to benefit from it. Beside the facts on home hours worked provided above, it would be interesting to have a measurement of the amount of services that are actually produced at home, and also to assess how substitutable they are to market services. This is because labor productivity in the home sector might be different from that of the market sector, so that hours worked do not provide a full picture of the relative importance (in terms of production) of market and home sectors. However, data is rather limited on that matter. Due to this constraint, I focus here on child care, food preparation and shopping to examine the substitutability between household production and market-provided services.

I first consider child care which is one of the most time consuming household activities. Recall from Table 1 that people spend a bit more than 6 hours per week on average caring for household and non-household members, most of which is accounted for by child care. Moreover, child care is an activity for which clearly distinguishable market substitutes do exist. These are organized facilities in the form of day care centers, nursery/preschool, and other forms of paid arrangements. Table 2 highlights the importance of child care in family budgets.

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), The U.S. Census Bureau, http://www.census.gov/population/www/socdemo/childcare.html, Historical Time Series Tables (Table C2)

It shows that child care expenses accounted for nearly 7% of the total income of families with a working mother during the period from 1991 to 2005, which is a quite large number. This is an argument about the levels.[16] On substitutability, a large empirical literature has assessed how child care costs affect child care payment and employment decisions of mothers (see, e.g., Anderson and Levine (1999), Blau and Robins (1988), and Tekin (2007), for U.S. based studies, and Cleveland, Gunderson, and Hyatt (1996) for a Canadian experience). These studies yield quite different estimates, stemming from differences in estimation methods, sample restrictions and datasets used.[17] However, as summarized by Anderson and Levine (1999), there does seem to be a clustering of estimates around an elasticity of about -0.3 and -0.4. These empirical studies thus consistently suggest that a higher price of childcare lowers the probability that a mother will work and pay for child care.

Another market-provided service for which a close substitute clearly exists at home and for which I could find some data for comparison is food service. What makes food service an interesting case to look at is the fact that one can readily decide whether to go out for dinner or prepare food at home. In addition, this is quantitatively important as food at home and food away from home account for up to $5,6\%$ and 8% respectively of total household expenditures on average over the sample period.

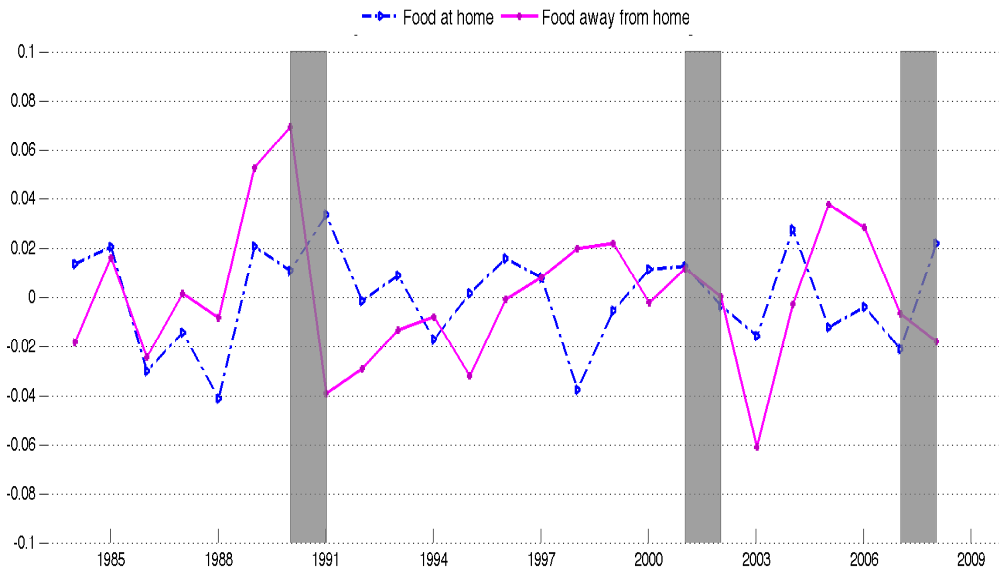
Figure 3 shows that food at home and food away from home co-move negatively over the business cycle. This is even more striking looking at the recession episodes, as represented by the shaded regions. The figure seems to suggest that, in bad times, people cut on spending on food out of their house and opt for having dinner at home instead. A notable exception is the 2001 recession during which spending on both items actually decreased. But overall, the figure suggests that households do switch between cooking at home and going out for dinner in response to changes in economic conditions.

Shopping is also a household activity that is worth examining, given its relatively large share of time in household production (see Table 1). Aguiar and Hurst (2007a) document a substantial heterogeneity in the prices that households pay at a given point in time for identical items in the same area. They find that doubling shopping frequency lowers the price of a good by 7 to 10%. That amounts to saying that households do indeed substitute time for money. The authors then use a Becker (1965) type of model and estimate elasticity of substitution between time and money due to shopping (home production) of nearly 1.8. In the same vein, Rogerson (2008) argues (see footnote 8, p. 244) that the service sector allows for substitution between employee time and consumer time, by having for example fewer cashiers and longer lines in stores, or letting customers bag their own groceries.

[16]Substantial disparities exist between households below and above the poverty line, with the former devoting more than a quarter of their monthly income to child care.

[17]The estimates vary substantially, from values just below zero to values slightly below -1.

Figure 3. Expenditures on food at home and food away from home (HP-de-trended series)



Source: author calculations from BLS data, Consumer Expenditure Survey
http://www.bls.gov/cex/data.htm.

I next build a New Keneysian DSGE model featuring the substitutability between market and household services, and subsequently examine its implications for monetary policy, both at the sectoral and aggregate level.

III. The Model Economy

A. The Economic Environment

The economy is populated by a continuum of identical and infinitely-lived households of measure one. There are three sectors in the economy, 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, 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 market sector. There is also a monetary authority who obeys a Taylor-type rule, and the only source of aggregate uncertainty in the model is a shock to monetary policy. The following sections describe the behavior of all these entities in details.

B. The Representative Household

The "unitary" representative household derives utility from the aggregate consumption index (C) and leisure (L), and seeks to maximize its expected lifetime utility:[18]

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left(\log(C_t) + \Phi L_t \right) \right\}, \quad \Phi > 0$$

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

$$C = C_g^{\omega} C_S^{1-\omega}, \quad 0 < \omega < 1. \tag{3}$$

Wolman (2009) uses a similar specification to examine optimal monetary policy when the relative price of services (compared to goods) is trending up, but with the service aggregate S made of market services only. This specification (which amounts to assuming a unit elasticity of substitution between nondurable and service aggregates) allows me, as will become clear later, to isolate the implications for monetary policy of the household sector.

The consumption of services (S) is a CES aggregate of market-provided services (C_s), and services that are produced at home (C_h):

$$C_S = \left[\gamma C_h^{\frac{\nu-1}{\nu}} + (1-\gamma) C_s^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}, \qquad \nu > 0, \quad 0 \leq \gamma < 1. \tag{4}$$

I choose the CES specification so that the parameter ν governing the elasticity of substitution between market-provided services and home-services is not constrained.[19] This parameter will be key to the analysis. To see why, consider the two following extreme cases: if market and home production are perfect complements, the consumption aggregate becomes

[18] Unitary household in the sense that the model does not distinguish between different members of the household (and between spouses in particular), which amounts to assuming that household members pool their resources together and make joint decisions. This is by opposition to the "collective" household type of model in which each spouse makes his (her) own decisions, taking (most likely) into account that of his (her) partner. Collective household models are suitable for addressing intra-household issues that involve strategic behavior, which is not the case here.

[19] Rogerson (2008) adopts this modelling of the service sector when explaining the relatively poor performance of the European labor market *vis à vis* the U.S.

$C_S = M\text{in}(C_s, C_h)$, which implies that households have no choice, but to consume the exact same quantity of both items. In that case, household production is likely to add nothing to standard models 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 channel through which shocks can impact 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 services.[20] But, in that case two forces would be in play: the substitutability between market-provided services and 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 examined in this paper.[21]

The representative agent has four alternative uses of his unit of 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 in the services-providing sector). The remaining time is allocated to household production (N_h), and leisure (L).

$$N_{h,t} + N_{s,t} + N_{g,t} + L_t = 1 \qquad \forall t. \tag{5}$$

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

$$P_{g,t}C_{g,t} + P_{s,t}C_{s,t} + B_t \leq R_{t-1}B_{t-1} + W_t\underbrace{(N_{g,t} + N_{s,t})}_{\text{Market hours}} + \underbrace{\Pi_{g,t} + \Pi_{s,t}}_{\text{Total profits}} \tag{6}$$

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

The second constraint is an intra-household resource constraint. It states that households cannot consume more home services than they actually produce. This amounts to assuming that

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

[21] In fact, beside the aggregate outcomes, the paper has more to say about the relative sectoral responses of macroeconomic variables, than about their level *per se*.

household production is for self-consumption, and can therefore not be sold on the market:

$$C_{h,t} \leq \Gamma(N_{h,t}) \tag{7}$$

where Γ is the production function in the household sector, which takes labor as the only input.

The household then chooses the optimal sequences of market goods, allocation of time to each sector (including the household sector), bond holdings - subject to the no-Ponzi game condition - and firm's shares. The corresponding first order conditions are:[22]

$$\frac{MU_{g,t}}{MU_{s,t}} = \frac{P_{g,t}}{P_{s,t}} \tag{8)a$$

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

$$\frac{W_t}{P_{k,t}} MU_{k,t} = \left(\frac{\partial \Gamma}{\partial N_h}\right) MU_h, \quad k \in \{g,s\} \tag{8)c$$

$$\Lambda_t = \beta R_t E_t(\Lambda_{t+1}). \tag{8)d$$

where Λ_t is the Lagrange multiplier associated to the date t budget constraint, and MU_i is the marginal utility of good i, $i \in \{g,h,s\}$.
These are optimality conditions. For example, Equation (8)c compares the benefits from two alternative uses of an extra unit of time. If the agent decides to work in the market, 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 in sector 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. $\frac{\partial \Gamma}{\partial N_h}$ 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_h. This equation thus simply suggests that the agent must be indifferent between those two options at the optimum.

[22]After substituting for Equation (7) which, given that the utility function is strictly increasing in C_h, holds with equality at the optimum.

C. Final Goods Producers

At each date t, the representative, competitive final good producer of the market-sector $k \in \{g,s\}$, bundles intermediate products into the sector final consumption good, using the following technology *à* la Dixit and Stiglitz (1977):

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

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.

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

$$Y_{k,t}(z) = \left(\frac{P_{k,t}(z)}{P_{k,t}} \right)^{-\varepsilon_k} Y_{k,t}, \qquad \forall z \; \varepsilon \; (0,1). \tag{10}$$

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

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

D. 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 $k \in \{g,s\}$ produces output $Y_{k,t}(z)$ using a linear technology in labor:

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

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:

$$\Psi_{k,t} = W_t / A \tag{13}$$

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 its previous price.[23]

The problem of a re-optimizing firm then reads:

$$\underset{P_{k,t}(z)}{Max}\left\{E_t\sum_{t=0}^{\infty}(\beta\theta_k)^i\frac{\Lambda_{t+i}}{\Lambda_t}\left[P_{k,t}(z)-\Psi_{k,t+i}\right]Y_{k,t+i}(z)\right\}$$

$$\text{s.t.}\qquad Y_{k,t+i}(z)=\left(\frac{P_{k,t}(z)}{P_{k,t+i}}\right)^{-\varepsilon_k}Y_{k,t+i},\qquad \forall i$$

where $\Lambda_t=\frac{MU_{k,t}}{P_{k,t}}$ is the "price-adjusted" marginal utility of wealth.[24] Ψ_t is the nominal marginal cost of production, which is equal to the nominal wage (up to a constant), as noted previously. The solution to this problem is given by the following expression which does not depend on z as all re-optimizing firms set the same price:

$$P^{\star}_{k,t}=\left(\frac{\varepsilon_k}{\varepsilon_k-1}\right)\frac{E_t\sum_{i=0}^{\infty}(\beta\theta_k)^i MU_{k,t+i}\Psi_{k,t+i}P^{\varepsilon_k-1}_{k,t+i}Y_{k,t+i}}{E_t\sum_{i=0}^{\infty}(\beta\theta_k)^i MU_{k,t+i}P^{\varepsilon_k-1}_{k,t+i}Y_{k,t+i}}. \tag{16}$$

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

$$P^{\star}_{k,t}=\left(\frac{\varepsilon_k}{\varepsilon_k-1}\right)\Psi_{k,t}.$$

Using ((11)), and given the mass $1-\theta_k$ of firms that reset their price at each period, the aggregate price level in sector k simply becomes:

$$P_{k,t}=\left((1-\theta_k)(P^{\star}_{k,t})^{1-\varepsilon_k}+\theta_k P^{1-\varepsilon_k}_{k,t-1}\right)^{1/(1-\varepsilon_k)}. \tag{18}$$

E. Sectoral and Aggregate 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.

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[23]I therefore do not assume price indexation. In the zero-inflation steady state, however, the setup is obviously equivalent to one in which non-optimizing firms keep pace with the steady state inflation rate.

[24]Recall that Λ is the Lagrange multiplier associated to the budget constraint of the consumer problem.

PROPOSITION 1. *SECTORAL NEW KEYNESIAN PHILLIPS CURVES*
In the presence of household production, the New Keynesian Phillips curve remains standard in the nondurable goods sector $\left[\pi_{g,t} = \kappa_g y_{g,t} + \beta E_t(\pi_{g,t+1})\right]$*, whereas that of the service sector is "Augmented" as follows:*

$$\pi_{s,t} \quad = \quad \underbrace{\kappa_s y_{s,t}}_{\text{Standard output gap term}} \quad + \quad \underbrace{(1-1/\nu)\kappa_s(y_{S,t} - y_{s,t})}_{\text{Extra endogenous term}} \quad + \quad \beta E_t(\pi_{s,t+1}) \tag{19}$$

where small case letters denote deviations from the deterministic steady state. $y_S = c_S$ *is the aggregate of market and home services.* $\kappa_j = (1-\theta_j)(1-\beta\theta_j)/\theta_j$, $j \in \{g,s\}$*, is a decreasing function of* θ_j*.*

Proof. (see appendix) □

As in most sticky price models, the dynamic effects of a shock to monetary policy are well captured through the New Keynesian Phillips Curve (NKPC thereafter). From the above proposition, the inflation in the goods-producing sector is solely driven by the output gap, to an extent that decreases with the exogenous degree of price stickiness in that sector, which is standard in the literature. Conversely, in addition to the output gap term, the NKPC in the service sector features an extra endogenous term:

$$(1-1/\nu)\kappa_s(y_{S,t} - y_{s,t}).$$

This term, by augmenting the NKPC is key to understanding how household production actually affects the transmission mechanism of monetary policy to the economy. Its magnitude depends critically on the elasticity of substitution between household and market services, ν. The extra term vanishes when ν equals unity. This can be seen either by replacing ν by one in the previous expression, or by examining the utility function. Recall that for $\nu = 1$, the consumption aggregate (C) becomes Cobb-Douglas in market services (C_s), home services (C_h) and market goods (C_g):

$$C = C_g^{\omega} C_s^{(1-\gamma)(1-\omega)} C_h^{\gamma(1-\omega)}. \tag{21}$$

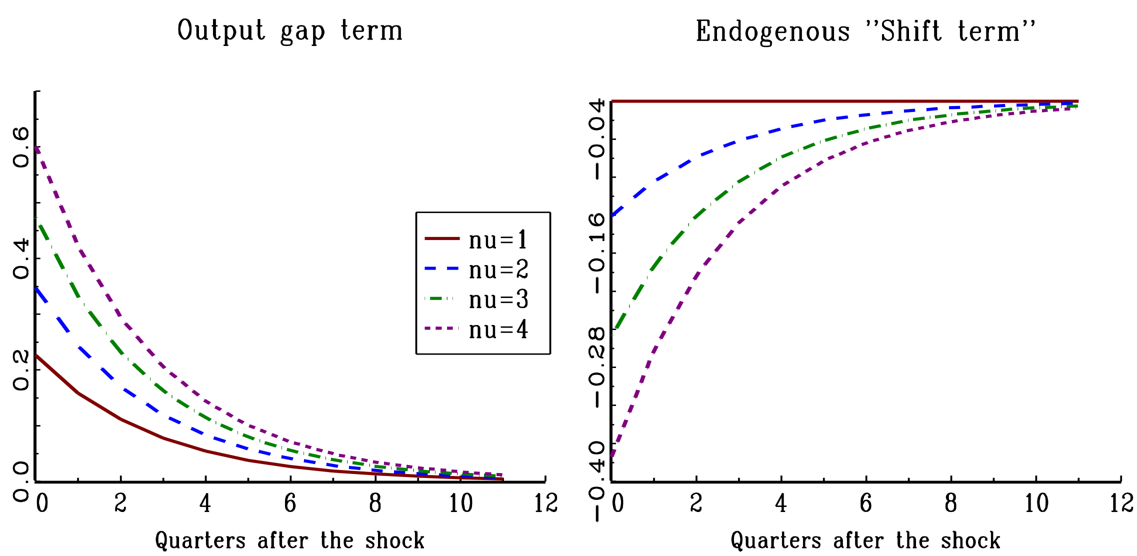
This, combined with log utility yields complete separability of home-services from market goods and services:

$$U(C,L) = \omega \ln C_g + (1-\gamma)(1-\omega)\ln C_s + \gamma(1-\omega)C_h + \Phi L.$$

The NKPC then reduces to the standard one and home production changes nothing about inflation dynamics.[25] It follows that the real effects of a shock to monetary policy are identical to that obtained in a similar model without household production.

Proposition 1 confirms the conjecture made in the introduction that household production matters qualitatively for monetary policy. Its quantitative importance in shaping inflation dynamics and thus impacting the real effects of monetary shocks lies in the magnitude of the extra endogenous term, relative to the output gap. This depends in particular on the size of the home sector, and most importantly on the substitutability between market-provided and home-produced services. The higher the elasticity of substitution between market and home services (ν), the bigger the additional term, all else equal. But everything else is not equal in this model, due to the endogeneity of the expression $y_S - y_s$. Recall that $y_S = c_S$ is the aggregate of market-provided and home-produced services. It is unfortunately hard to infer the behavior of the extra term analytically. I 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 extra terms, following an expansionary monetary policy. The magnitude of those two terms are portrayed in Figure 4.

Figure 4. Contribution of the output gap term and the extra term to inflation dynamics



Note: The shift term is the new term associated with household production: $(1-1/\nu)\kappa_s(y_{S,t}-y_{s,t})$, and the output gap term is standard and simply equals $\kappa_s y_{s,t}$.

[25] Benhabib, Rogerson, and Wright (1991) also show, using a RBC framework, that home production changes nothing about aggregate fluctuations in the case of a log utility. This paper therefore confirms that their result also holds with sticky prices.

One notable thing about Figure 4 is that the two terms are of opposite signs and co-move negatively as ν changes. In addition, these terms all expand in absolute value as ν rises (from 1 to 4 in the figure).[26]

A high value of ν corresponds to a high output gap, as people are more likely to switch between consuming home and market services. In the absence of the extra term, this would induce a price increase, for a given degree of price rigidity. In this model however, the extra term, by dampening the effect of the output gap, prevents this price increase from happening (recall that the extra term and the output gap term are of opposite signs). As a consequence, firms in the service sector are able to produce more without a further increase in their prices. Intuitively, this reluctance of service sector firms to increase their prices is due to the "extra competition" from household production. In fact, if the firms in the service sector decide to increase their prices, individuals may substitute away from the market and produce the services at their own house instead.

The general message conveyed by the proposition is that the degree of nominal rigidity in the NKPC of the service sector is no longer only summarized by 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, the effect of household production extends beyond the service sector.

Corollary 1. *Aggregate inflation dynamics are given by the following relationship when prices are equally sticky across sectors:*

$$\pi_t \quad = \quad \kappa y_t \quad + \quad \underbrace{(1-\chi)(1-1/\nu)\kappa(y_{S,t}-y_{s,t})}_{\text{Extra term induced by household production}} \quad + \quad \beta E_t(\pi_{t+1}) \tag{23}$$

where $1-\chi$ is the steady state share of services in total market consumption.
$\kappa = (1-\theta)(1-\beta\theta)/\theta$ is a decreasing function of θ, the constant probability (overtime and across sectors) that a firm does not reset its price in a given period.

Proof. (see appendix) □

Corollary 1 highlights the effect of household production on the aggregate economy. It shows that household production distorts the standard aggregate NKPC to an extent that increases with the size of the service sector (composition argument). This is because the model explicitly take into account the fact that nondurable goods, unlike services, do not have close sub-

[26] As explained above, the extra term vanishes when ν equals unity.

stitutes at home. My framework therefore nests a setup with only one market sector, as usually assumed in most household production models. Conceptually, a model with household production and only one market sector would generate a New Keynesian Phillips curve that resembles the one in Equation (23), with $\chi = 0$.

F. Monetary Policy

I assume that the monetary authority sets the nominal interest rate according to the Taylor (1993) rule:

$$\frac{R_t}{\bar{R}} = \left(\frac{P_t}{P_{t-1}}\right)^{\phi_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_y} \xi_t, \qquad \phi_\pi > 1, \quad \phi_y \geq 0 \tag{24}$$

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:

$$\ln(\xi_t) = \rho_r \ln(\xi_{t-1}) + \zeta_t, \quad 0 < \rho_r < 1; \quad \text{with } \zeta_t \sim \text{iid}(0, \sigma_r^2). \tag{25}$$

G. Aggregation

Since households are identical, bonds are in zero net supply in equilibrium.

For a market sector k one has:

$$N_{k,t} = \int_0^1 N_{k,t}(z)dz \quad \forall t. \tag{26}$$

It is useful to express the aggregate production in a market sector $k \in \{g, s\}$ as:

$$Y_{k,t} = \Upsilon_{k,t} Y_{k,t}^f \tag{27}$$

where $Y_{k,t}^f = \int_0^1 Y_{k,t}(z)dz = AN_{k,t}$ is the amount of goods that would be produced if all markets where perfectly competitive, and $\Upsilon_{k,t}$ is the efficiency loss incurred in sector k at time t, due to the fact that intermediate goods producers charge different prices (monopolistic competition).

It is easily shown that the "efficiency distortion" is given by:

$$\Upsilon_{k,t} = \left(\frac{P^{\star}_{k,t}}{P_{k,t}}\right)^{-\varepsilon_k}, \quad k \in \{g, s\} \tag{28}$$

where $P^{\star}_k$ and P_k are given respectively by Equations (14) and (18). Note that:

$$\begin{cases} \Upsilon_{k,t} = 1 \quad \text{if} \quad P_{k,t}(z) = P_{k,t}(z') \; \forall z, z' \\ \Upsilon_{k,t} \leq 1 \quad \text{in general.} \end{cases} \tag{29}$$

Market clearing also requires that $C_{k,t} = Y_{k,t}$ and $N_t = N_{g,t} + N_{s,t}$.

In this setup it is not as obvious to obtain an expression for the aggregate price level. The problem emerges from the fact that the consumption aggregate nests market variables (consumption of nondurable goods and market services) and the home production of services in a non-separable way. In fact, the aggregate services is a general CES function of market services and home services. It turns out that one can actually get an expression for the deviation of real output from the steady state, which is precisely the object of interest here.

I define real output at date t as:

$$Y_t = \bar{P}_g Y_{g,t} + \bar{P}_s Y_{s,t} \tag{30}$$

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

Linearizing the above expression, one obtains the following expression in which small case letters represent deviations from the steady state:

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

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

The aggregate price level in the economy is simply defined as nominal over real output, that is:

$$P_t = \frac{P_{g,t} Y_{g,t} + P_{s,t} Y_{s,t}}{\bar{Y}} \tag{32}$$

which after linearization becomes:

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

IV. Calibration and Results

A. Parameter Values

Consistent with the VAR-based evidence presented in section 1, the model is calibrated at 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 (1994).

The calibration of Φ and γ is based on households' time allocations in Table 1. This table implies that people spend 30% of their reported discretionary time on market work and 31% on homework.[27] θ_g and θ_s are set such that prices last for 3 quarters on average in each sector. In principle, allowing for a higher degree of price rigidity in the service sector would result in stronger real effects of monetary shocks in that sector. I shut down that channel in order to isolate the role of household production in amplifying the real effects of monetary shocks Many two-sector models perform a similar calibration of price stickiness.[28]

The coefficient on inflation in the Taylor rule is fixed at 1.5 and the persistence of the shock to the interest rate is $\rho_r = 0.7$. Those values are standard in the calibration of the simple Taylor rule (see, e.g., Carlstrom and Fuerst (2006), and Monacelli (2009)). I also consider variants 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 whole.[29] However, home production consists almost exclusively of services (see Section II.B.2). This suggests that existing estimations, which range from 1.5 to 2.5, are likely to provide a downward biased estimate of the elasticity of substitution that I refer to in this paper. Recall that ν in the model

[27] It is usually assumed in standard RBC models that people devote one-third of their discretionary time to market activities, which is very close to the 30% ratio implied by Table 1. Data from the Michigan Time Use Survey suggest that people spend 28% of their discretionary time to household activities, which is also close to the corresponding value in Table 1 (31%). I re-compute Φ and γ with these alternative figures and the resulting values are very similar to those reported in Table 3.

[28] See, e.g., Carlstrom and Fuerst (2006), Barsky, House, and Kimball (2007) and Monacelli (2009).

[29] See Rogerson, Rupert, and Wright (1995), McGrattan, Rogerson, and Wright (1997), Chang and Schorfheide (2003), and Aguiar and Hurst (2007a).

considered here is the elasticity of substitution between market and home services. I choose $\nu = 2.3$, which is the estimate in Chang and Schorfheide (2003). Note that this is still conservative as I refer here to the substitution between market and home services (which constitute a specific subset of products), whereas the previous authors have estimated the elasticity of substitution between a single aggregate of market goods and a single aggregate of home goods.

Finally, I fix χ to match the 2008 expenditure share of nondurable 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.

Table 3. Parameter values

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

I linearize the system around the zero inflation deterministic steady state and solve the model using Blanchard and Kahn's (1980) method. The simulation results follow.

B. Simulation Results

I consider three scenarios. The first scenario consists of a baseline model without household production and with equally sticky prices across sectors (labeled "No H.P."). The two remaining scenarios feature household production (labeled "H.P."), subsequently with flexible prices in each sector, and with equally sticky prices across sectors (the preferred specification). The impulse response functions of endogenous variables to a negative percentage point innovation in the interest rate are portrayed in appendix. The results can be summarized as follows.

Household production, as one would expect, has no implications for monetary policy when prices are flexible. The impulse response functions of real macroeconomic variables in that scenario therefore simply coincide with the horizontal axis. This result holds independently of the size of the household sector and the degree of substitutability between home and market services. Flexible prices adjust instantaneously so as to completely offset the shock. As a consequence, the real wage remains unchanged, and individuals therefore have no incentive to reallocate their time between the market and home.

The most relevant scenarios are those with sticky prices. Simulations indicate that the real effects of a monetary shock are substantially larger in the service sector when household production is accounted for. The initial responses of consumption of market-provided services to a 1% cut in the nominal interest rate are 2.4% in the model with home production and only 1.4% in the baseline model.[30] Conversely, home production does not augment the real effects of a monetary shock in the nondurable goods sector. The initial response of real spending on nondurables is therefore the same as in the baseline model (1.4%), reflecting the fact there is no home substitutes to nondurable goods.

The rationale behind the above results is as follows. An expansionary monetary policy, by raising the overall demand in the economy, increases the production costs (the nominal wages) incurred by firms. Since prices are rigid (only a fraction $1-\theta$ of firms get to re-optimize their prices in a given period), they do not rise as much as nominal wages. As a consequence, the real wage increases (by 1.4% initially in the simulations). In the baseline model, economic agents only decrease leisure as a way to take advantage of the increased real wage. Accounting for the household sector provides individuals with an additional margin they can operate on, namely the reallocation of time between home and market activities. This explains why market hours worked increases more in a model with home production following a monetary expansion.[31] Now, why is it that all the increase in market hours is allocated to the service sector? The answer to this question lies in the substitutability differential among goods and services. Recall that market services are closer substitutes to home services than market nondurables are. In order to keep pace with the aggregate level of services consumption (an object of interest in the utility function), households replace their lost consumption of home services (due to the shift of hours worked toward the market) by consuming more market services. The model's prediction that monetary shocks have stronger real effects in the service sector compared with the nondurable goods sector is consistent with VAR-based evidence presented in the paper that services are more interest-rate sensitive than nondurable goods.

As for prices, the increased response of market services happens without further increase in their prices as compared to the baseline model without home production. The rationale behind this result is that market-service producers in this model face an extra competition from household production, making them more reluctant to increase their prices. They therefore increase their quantities more than they would otherwise do. The fact that market services'

[30] These values all subsequently return to their steady state level asymptotically.

[31] Given that technology is linear in labor, the dynamics of hours worked mimic the dynamics of the corresponding consumption variables in the model, and are therefore not portrayed in the figures in appendix.

prices do not increase further despite the increase in production (output gap) suggests that household production does generate additional price rigidity in the service sector.

The model also has important aggregate implications, given that aggregate responses are weighted averages of sectoral responses. Since services account for a very large share of aggregate output, the behavior of aggregate variables is closer to that of services (composition argument). When household production is accounted for, the real effect of a monetary shock on aggregate output is about 50% larger compared to the benchmark model without household production.

V. Conclusion

This paper embeds a household sector into an otherwise standard two-sector (service sector and nondurable goods sector) sticky price model, and examines its implications for monetary policy, both at the sectoral and aggregate level. Consistent with the data, households are allowed to produce services at home, whereas nondurable goods are exclusively supplied in the market. I find that the inclusion of household production substantially amplifies the real effects of a monetary shock in the service sector, which translates into a stronger response of real macroeconomic aggregates. The mechanism operates through two main channels:

On the supply side, I show that the degree of nominal rigidity in the *Augmented* New Keynesian Phillips curve of the service sector is no longer summarized by the output gap. It now features an additional endogenous component which is substantial for a reasonable calibration of parameters. Moreover, the higher the elasticity of substitution between home-produced and market-provided services, the larger the extra component. This new term, by reducing the incentives of service sector firms to change their prices, captures the extra competition from household production. Monopolistically competitive firms in the service sector therefore adjust to monetary shocks by changing quantities more than they would otherwise do, which is not the case in the nondurable goods sector for which households cannot manufacture substitutes at home.

On the demand side, an expansionary monetary shock, by increasing the real wage—the opportunity cost of working at home—increases the incentive of individuals to substitute away from home production and towards market services, thus amplifying the real effects of a monetary shock in the service sector. My model therefore generates a stronger response of services to monetary shocks, compared with the response of nondurable goods, consistent with a VAR-based evidence presented in the paper.

Finally, because the service sector is large, the response of real macroeconomic aggregates is also stronger than in a model without household production. These findings suggest that household production is an important source of real rigidity. Accounting for it may therefore contribute to our understanding of the transmission of monetary policy to the economy.

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Appendix A. Proof of Proposition 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 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:

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

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, and ε_s is the constant elasticity of substitution among varieties produced in that sector.[32]

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

$$\frac{P^{\star}_{s,t}}{P_{s,t}} = \left(\frac{1-\theta_s \Pi_{s,t}^{\varepsilon_s - 1}}{1-\theta_s}\right)^{\frac{1}{1-\varepsilon_s}} \tag{35}$$

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:

$$P^{\star}_{s,t} = \left(\frac{\varepsilon_s}{\varepsilon_s - 1}\right) \frac{E_t \sum\limits_{i=0}^{\infty} (\beta\theta_s)^i MU_{s,t+i} \Psi_{s,t+i} P_{s,t+i}^{\varepsilon_s - 1} Y_{s,t+i}}{E_t \sum\limits_{i=0}^{\infty} (\beta\theta_s)^i MU_{s,t+i} P_{s,t+i}^{\varepsilon_s - 1} Y_{s,t+i}}. \tag{36}$$

Since 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: $\Psi_{s,t} = \Psi_t = W_t/A \quad \forall t$.

[32] θ_s also corresponds to the fraction of service sector firms that do not adjust their price in a given period (in a symmetric equilibrium).

Now, the following relation holds from the consumer optimization problem, where MU is the marginal utility of consumption, and MRS is the marginal rate of substitution between consumption and leisure:

$$MRS_{s,t} = \Phi / MU_{s,t} = W_t / P_{s,t}$$

It follows that:

$$MU_{s,t+i} \Psi_{s,t+i} = \Phi P_{s,t+i} / A \quad \text{for all } i. \tag{38}$$

It is interesting to note that the numerator of $P^{\star}_{s,t}$ then has the same form as in a standard New Keynesian model. The difference with a standard model lies in the denominator. More precisely, because the CES aggregate of services ($C_S = \left[\gamma C_h^{\frac{\nu-1}{\nu}} + (1-\gamma) C_s^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}}$) nests household production, the marginal utility of consuming the market-services (MU_s) now depends on the amount of household-services that the agent consumes. In fact, by chained derivation, $MU_s = \partial U / \partial C_s = (\partial U / \partial C_S)(\partial C_S / \partial C_s)$. Now, taking into account the functional form of the utility, and combining the expression of $P^{\star}_{s,t}$ above with Equation (35), one gets the following equation after some manipulations:

$$\frac{\varepsilon_s}{\varepsilon_s - 1} \frac{\Phi}{(1-\omega)(1-\gamma)} \frac{V_{1,t}}{V_{2,t}} = \left(\frac{1 - \theta_s \Pi_{s,t}^{\varepsilon_s - 1}}{1 - \theta_s} \right) \tag{39}$$

where V_1 and V_2 have the following recursive representation:

$$V_{1,t} = A^{-1} C_{s,t} + \beta \theta_s E_t \left(\Pi_{s,t+1}^{\varepsilon_s} V_{1,t+1} \right)$$

and

$$V_{2,t} = \left(\frac{C_{s,t}}{C_{S,t}} \right)^{1-1/\nu} + \beta \theta_s E_t \left(\Pi_{s,t+1}^{\varepsilon_s - 1} V_{2,t+1} \right)$$

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

$$v_{1,t} = (1 - \beta\theta_s) c_{s,t} + \beta\theta_s \varepsilon_s E_t(\pi_{s,t+1}) + \beta\theta_s E_t(v_{1,t+1}) \tag{41a}$$

$$v_{2,t} = (1 - 1/\nu)(1 - \beta\theta_s)\left(c_{s,t} - c_{S,t}\right) + \beta\theta_s(\varepsilon_s - 1) E_t(\pi_{s,t+1}) + \beta\theta_s E_t(v_{2,t+1}). \tag{41b}$$

Recall that:

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

where C_h is the amount of services which are produced at home.

After linearization, Equation (39) becomes:

$$v_{1,t} - v_{2,t} = \frac{\theta_s}{1-\theta_s} \pi_{s,t}. \tag{43}$$

Iterating the above equation one step forward, and using Equations (41)a and (41)b to evaluate the expression $(v_{1,t} - v_{2,t})$, one obtains the following *"Augmented"* NKPC after some straightforward algebra:

$$\pi_{s,t} = \kappa_s y_{s,t} + (1 - 1/\nu)\kappa_s (y_{S,t} - y_{s,t}) + \beta E_t(\pi_{s,t+1}), \quad \kappa_s = \frac{(1-\theta_s)(1-\beta\theta_s)}{\theta_s}$$

where I use the market clearing condition $c_s = y_s$ and define $y_S = c_S$.

Appendix B. Proof of Corollary 1

After linearizing the aggregate price Equation (32), aggregate inflation is given by $\pi_t = \chi \pi_{g,t} + (1-\chi)\pi_{s,t}$, where $\chi = \bar{P}_g \bar{C}_g / \bar{Y}$. Applying the sectoral inflation formulaes from Proposition 1, and using the assumption that prices are equally sticky across sectors, that is $\theta_g = \theta_s = \theta$, which implies that $\kappa_g = \kappa_s = \kappa$, one gets:

$$\pi_t = \kappa(\chi y_{g,t} + (1-\chi) y_{s,t}) + (1-\chi)(1-1/\nu)\kappa(y_{S,t} - y_{s,t}) + \beta E_t(\pi_{t+1})$$

The result then follows from the fact that $y_t = \chi y_{g,t} + (1-\chi) y_{s,t}$.

Appendix C. Reduced Set of Equations for the Linearized Model

$$c_{i,t} = E_t c_{i,t+1} - (r_t - E_t \pi_{i,t+1}), \quad i \in \{g, s\}$$

$$c_i = y_i \quad i \in \{g, h, s, S\}$$

$$\pi_{g,t} = \kappa_g y_{g,t} + \beta E_t(\pi_{g,t+1}), \quad \kappa_i = (1-\theta_i)(1-\beta\theta_i)/\theta_i, i \in \{g, s\}$$

$$\pi_{s,t} = \kappa_s y_{s,t} + (1-1/\nu)\kappa_s(y_{S,t} - y_{s,t}) + \beta E_t(\pi_{s,t+1})$$

$$r_t = \phi_\pi \pi_t + \phi_y y_t + \ln\xi_t$$

$$\ln\xi_t = \rho_r \ln\xi_{t-1} + \zeta_t$$

$$y_t = \chi y_{g,t} + (1-\chi) y_{s,t}$$

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

$$c_{S,t} = \gamma \left(\bar{C}_h/\bar{C}_S\right)^{1-1/\nu} c_{h,t} + (1-\gamma)\left(\bar{C}_s/\bar{C}_S\right)^{1-1/\nu} c_{s,t}$$

$$c_{h,t} = (1-\nu) c_{S,t}$$

$$w_t - p_{g,t} = c_{g,t}$$

Appendix D. Dynamic Response of Macroeconomic Variables to an Expansionary Monetary Shock

Figure 5. Responses of real sectoral consumption to a 1% interest-rate cut.

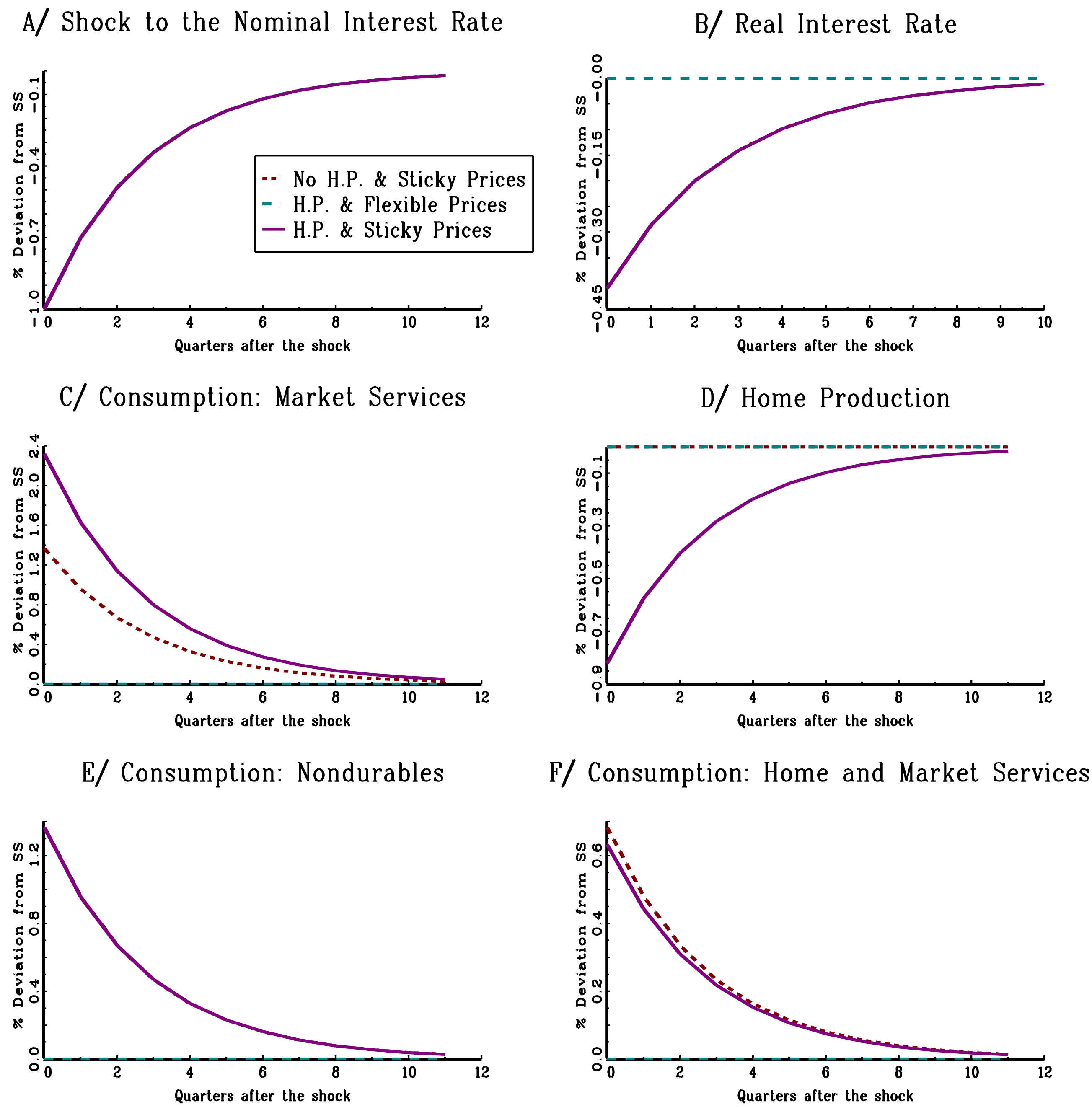

Figure 6. Responses of sectoral inflation and real aggregates to a 1% interest-rate cut.