

# Deep habits and the macroeconomic effects of government debt

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Discussion Paper  
Series 1: Economic Studies  
No 22/2010

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ISBN 978-3-86558-654-4 (Printversion)

ISBN 978-3-86558-655-1 (Internetversion)

**Abstract:**

In this paper, we study the effects of government debt on macroeconomic aggregates in a non-Ricardian framework. We develop a micro-founded framework which combines time-varying markups, endogenous labor supply and overlapping generations based on infinitely-lived families. The main contribution of this paper is to provide a new transmission mechanism of public debt through the countercyclical markup movements induced by external deep habits. We analyze the effects of debt-financed tax cuts. We show that the interest rate rises, entailing higher markups, which imply a fall in employment and consumption. It is particularly noteworthy that, even without capital, a crowding out effect of government debt is obtained in the long run. However, the short-run expansionary effect of debt-financed tax cuts, which would eventually be expected in a non-Ricardian framework, fails to occur. This is due to our flexible-price framework. On the other hand, we show that incorporating sticky prices in our model causes debt-financed tax cuts to have a short-run expansionary effect while preserving the long-run contractionary effect.

*JEL Codes* : E63; E52

*Keywords* : Wealth Effects, Fiscal Policy, Public Debt Shock, Deep Habits, Overlapping Generations, Monopolistic Competition.

## **Non-technical summary**

The recent economic crisis in Europe and United States has induced many governments to intervene to fight the recession. The active use of fiscal policy has revived the old debate on the impact of government spending and debt on economic activity. In order to analyze this issue the failure of Ricardian equivalence is required, as otherwise fiscal policy is neutral and government debt has no effect on macroeconomic aggregates. In this paper, the Ricardian equivalence breaks down because of the overlapping generations structure of our model.

Traditionally it is suggested that an expansionary fiscal policy has a positive effect on aggregate demand in the short run but negative effects in the long run due to the crowding-out effects on investment. From the theoretical point of view, can we have a model, without capital and default risk, capable of reproducing the short-run expansionary effect of public debt, while preserving the long-run negative effects?

In this paper we analyze the effects of public debt change in a non-Ricardian framework without capital, with endogenous labor supply and time-varying markups. We find that a tax cut financed by government debt entails a fall in consumption and employment both in the short run and in the long run when prices are flexible. Notice that the long-run crowding out effect on output is preserved even without capital. However, we do not find the traditional short-run expansionary effect on output and consumption. On the other hand, when prices are sticky, the short-run expansionary effect is obtained. So this paper offers a micro-founded general equilibrium model, where government debt has a short-run expansionary effect and long-run contractionary effect which is not related to the capital. The novelty in this paper is the introduction of external deep habits in a non-Ricardian framework, which offers a new transmission mechanism of government debt through the countercyclical markup movements induced by external deep habits.

## Nichttechnische Zusammenfassung

Die jüngste Wirtschaftskrise in Europa und den Vereinigten Staaten veranlasste viele Staaten, Maßnahmen zur Bekämpfung der Rezession zu ergreifen. Durch den aktiven Einsatz der Fiskalpolitik wurde die alte Diskussion über die Auswirkungen von Staatsausgaben und Staatsverschuldung auf die Konjunktur wiederbelebt. Will man diese Fragen untersuchen, so muss die Ricardianische Äquivalenz außer Kraft gesetzt werden, da die Fiskalpolitik ansonsten neutral wäre und die Staatsverschuldung keinen Effekt auf die gesamtwirtschaftlichen Aggregate hätte. In der vorliegenden Arbeit wird die Ricardianische Äquivalenz dadurch aufgehoben, dass wir ein Modell mit einer sich überlappenden Generationenstruktur verwenden.

In der traditionellen Auffassung wirkt sich eine expansive Fiskalpolitik kurzfristig positiv auf die gesamtwirtschaftliche Nachfrage aus, auf lange Sicht, aufgrund der Verdrängungseffekte auf Investitionen und Kapital, jedoch negativ. Aus theoretischer Sicht stellt sich die Frage, ob es auch ein Modell gibt, das auf Kapital und Ausfallrisiko verzichtet und das dennoch den kurzfristig expansiven und den negativen langfristigen Effekt zeigt.

Im vorliegenden Beitrag untersuchen wir, wie sich eine Veränderung der Staatsverschuldung in einem nichtrcardianischen Umfeld ohne Kapital, mit einem endogenen Arbeitskräfteangebot und endogenen, zeitvariablen Preisaufschlägen auswirkt. Wir finden, dass eine Reduzierung der Steuern auf Kosten einer höheren Verschuldung in der kurzen und in der langen Frist zu sinkendem Konsum und fallender Beschäftigung führt, sofern die Preise flexibel sind. Es ist bemerkenswert, dass der negative Effekt in der langen Frist besteht, obwohl wir auf die Einführung von Kapital verzichtet haben. Dagegen finden wir nicht den positiven kurzfristigen Effekt. Wenn allerdings träge Preise unterstellt werden, dann beobachten wir auch in unserem Modell den positiven kurzfristigen Effekt. Das Papier zeigt also ein mikrofundierte allgemeines Gleichgewichtsmodell, bei dem höhere Staatsschulden kurzfristig positiv und langfristig negativ wirken, ohne dass wir Kapital berücksichtigen müssen. Der neuartige Ansatz dieser Arbeit besteht in der Einführung externer tiefsitzender Gewohnheiten in einem nichtrcardianischen Umfeld. Hieraus ergibt sich ein neuer Transmissionsmechanismus der Staatsverschuldung, da antizyklische Änderungen der Aufschläge durch externe tiefsitzende Gewohnheiten verursacht werden.



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# Deep Habits and the Macroeconomic Effects of Government Debt<sup>1</sup>

## 1 Introduction

The latest economic crises in Europe and the United States have pushed many governments to intervene to fight the recession. The active use of fiscal policy has raised concern about debt and revived the old debate on the impact of government debt on economic activity. This is equivalent to asking the following question: how does debt-financed lump-sum fiscal policy affect macroeconomic aggregates? This paper contributes to answering that question by studying the effects of debt-financed tax cuts in a micro-founded, general equilibrium, non-Ricardian model.

As summarized by Bernheim (1989) and Elmendorf and Mankiw (1999), the economic effects of lump-sum fiscal policy are expansionary in the short run (the traditional Keynesian view) and contractionary in the long run (the Neoclassical view). Indeed, a raise in public debt to finance tax cuts (or raise transfers) stimulates aggregate demand, causing output to increase when prices (and/or wages) are sticky. This is the short-run effect. However, the real interest rate must rise to bring securities market into balance. Consequently, investment is crowded out. Accordingly, capital and output eventually decrease. This is the long-run effect. However, this old (traditional) literature was not based on micro-founded behavior. For instance, in the Keynesian view, illustrated by the undergraduate IS-LM, there is no role for expected future income.

Furthermore, the vast majority of micro-founded literature on fiscal policy has focused on the economic effects of distortionary fiscal policy. By contrast, the economic effects of lump-sum fiscal policy have not received much attention because the assumption of infinitely-lived representative households is usually adopted. In other words, Ricardian equivalence holds in those models, implying the neutrality of lump-sum fiscal policy.

Nevertheless, given the recent macroeconomic events, i.e. the global re-

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The author would like to thank Michel Guillard and Ferhat Mihoubi for very helpful comments and suggestions. This paper was partly written during my stay as a visiting researcher at the Deutsche Bundesbank. The author is grateful to Heinz Herrmann and Stéphane Moyon for their helpful comments. The paper presents the personal opinion of the author and does not necessarily reflect the views of the Deutsche Bundesbank.

cession of 2008-2010, it is of great interest to focus on lump-sum fiscal policy, which directly affects aggregate demand. For this, the departure from the Ricardian equivalence is necessary. There are two alternatives: Overlapping generation structure or rule of thumb (liquidity-constrained consumers) structure, developed by Gali et al (2007). We discard the last alternative from our analysis because the rule of thumb is an ad-hoc assumption. Hence, in our paper we adopt the overlapping generation structure. Specifically, we develop a micro-founded general equilibrium model with overlapping generation structure, monopolistic competition and external deep habit formation. In addition, our model abstracts from capital accumulation. We show that an increase in government debt to finance tax cuts has a long-run contractionary effect despite the lack of capital. On the other hand, the short-run effect of debt-financed tax cuts is contractionary in a flexible-price framework, while it is expansionary in a sticky-price framework.

At this stage, it is of interest to notice that, in the non-Ricardian framework, the short-run and the long-run effects on output depend on the assumptions made about price adjustment, labor supply, and capital.

First, if labor is supplied inelastically, there is no short-run effect on output even when prices are sticky. In the long run, output decreases because of capital adjustment. Indeed, Annicchiarico (2007) shows that the increase in aggregate demand caused by the rise in government debt entails higher consumption and higher real interest rates in the short run. The real interest rate rise crowds out investment and output falls in the long run.

Second, if labor supply is endogenous and physical capital is absent, when prices are flexible, the higher government debt will have no short-run or long-run effects on output. So, government debt is neutral despite the non-Ricardian framework. However, if prices are sticky, the short-run expansionary effect on output is evident but there is no long-run effect. This result is found in Devereux (2010). He analyzes the effect of government debt increase in a non-Ricardian framework without capital and with sticky prices and shows that higher government debt leads to the consumption and output rise in the short run.

In this paper, in the flexible-price model, we find that the government-debt neutrality expected to occur, because of the lack of capital, does not hold. Actually, the crowding out effect of government debt on output is based on the countercyclical markup movements induced by the assumption of external deep habits. Indeed, the novelty in this paper is the introduction of external deep habits into a non-Ricardian framework. In other words, we bring together wealth effects, which imply a non-neutral fiscal policy, and time-varying markups which are countercyclical to output. This offers a new transmission mechanism of government debt through the countercyclical

cal markup movements. The transmission mechanism can be summarized as follows. Debt-financed tax cuts raise the interest rate, entailing higher markups, which in turn induce a fall in employment and consumption.

As shown by Ravn, Schmitt-Grohe and Uribe (2006), the assumption of external deep habits profoundly alters the supply side of the economy. Under external deep habits, households do not simply form habits from a benchmark consumption level, but rather feel the need to catch up with the Joneses on a good-by-good basis<sup>2</sup>. Households that consume a lot of a particular good today are more likely to buy this kind of good in the future by force of habit. Such behavior influences firms' pricing strategy. Indeed, under deep habits, the demand for goods faced by firms becomes dynamic, implying time-varying markups. So a higher real interest rate implies higher markups because firms discount future profits more. As a consequence, labor demand declines, and output and consumption decrease. In addition, the decline in aggregate demand entails lower elasticity of demand, inducing higher markups. This is a price elasticity of demand effect which strengthens the decline in output.

In the sticky-price model, an increase in government debt to finance tax reduction induces an increase in consumption and aggregate demand. As prices cannot fully adjust to balance the goods market, output increases. Thus the short-run expansionary effect is obtained.

Our paper offers an alternative channel for debt-financed lump-sum fiscal policy through countercyclical movements of markups that give rise to long-run contractionary effects.

The remainder of the paper is organized as follows. The next section develops the flexible-price model. Sections 3 and 4 study the steady state equilibrium and the implications of an increase in government debt in the long run. Section 5 investigates the impact of temporary and permanent public debt shocks. Section 6 develops the sticky-price model and describes the effects of a temporary public debt shock. Section 7 concludes.

## 2 The Model

The economy consists of three types of agents: infinitely-lived dynasties (or families), monopolistically competitive firms, and the fiscal authority. Each period, new and identical infinitely-lived families (component of a generation) appear in the economy without financial wealth and owing a monopolistically competitive firm producing a specific good using labor. It is assumed that

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<sup>2</sup>In this paper deep habits refer to external deep habits. It is the catching up with the Joneses described by Abel (1990) but on a good-by-good basis.

the firm's ownership is not transferable. Therefore, the profit of the family firms is transferred in full to the owner-manager (the infinitely-lived family). On the other hand, labor moves freely in this economy.

Moreover, there is uncertainty in the economy caused by fiscal shocks. However, we assume that agents have access to complete markets. In addition, as in most of the recent New Keynesian literature, we assume a cashless economy à la Woodford (2003). Here, money is only a unit of account.

## 2.1 Consumers

A generation  $j$  consists of many identical infinitely-lived families (or agents) of type  $j$ , where  $j$  belongs to the interval  $[1, N_t]$ . Accordingly, we can consider a representative agent framework into a generation. In this economy agents care about their own consumption of a specific good compared to the benchmark level of the consumption of that specific good. We start by given the aggregation rule which will be used to aggregate individual variables:

$$z_t = \sum_{j \leq t-1} \frac{(N_j - N_{j-1})}{N_{t-1}} z_{j,t-1}, \quad (1)$$

where  $z$  is a generic variable. Notice that  $N_j - N_{j-1}$  is the number of agents compound of the representative generation  $j \leq t$ , where  $N_j$  is the number of agents born in period  $j \leq t$ .

We adopt an extended version of the CES habit-adjusted consumption index,  $x_{j,t}$ , used by Ravn et al (2006):

$$x_{j,t} = M_t^{\frac{1}{1-\varepsilon}} \left( \sum_{m=1}^{M_t} (c_{j,t}(m) - \phi \tilde{c}_{t-1}(m))^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad (2)$$

where

$$\tilde{c}_{t-1}(m) = \begin{cases} c_{t-1}(m) & \forall m \leq M_{t-1} \\ c_{t-1} & \forall m \in ]M_{t-1}, M_t] \end{cases}.$$

Here  $x_{j,t}$  denotes the CES habit-adjusted consumption index with elasticity of substitution,  $\varepsilon > 1$ . The parameter  $\phi$  measures the degree of external habit formation in consumption of each variety. When  $\phi = 0$ , consumption externalities disappear.  $c_{j,t}(m)$  is the consumption of good  $m \in [1, M_t]$  by agent  $j$  born in period  $j \leq t$  and  $c_{t-1}(m)$  denotes the *per capita* aggregate consumption of good  $m$  in period  $t-1$ .  $c_{j,t-1}$  and  $c_{t-1}$  denote the individual consumption of a basket of goods in period  $t-1$  and *per capita* aggregate consumption of the basket of goods in period  $t-1$ , respectively<sup>3</sup>.

<sup>3</sup>We might use Dixit-Stiglitz aggregator to obtain the consumption basket of goods, that is (2) when  $\phi$  equals zero.

Notice that the consumption reference used in (2) differs from the one used in Ravn et al (2006). The reason is the following. Remember that each agent is owner of a monopolistically-competitive firm so the number of specific goods grows at the same rate as the population. The appearance of new specific goods in each period raises a new difficulty to develop a deep-habits non-Ricardian model. Indeed, new goods appearing in period  $t$  were not consumed in period  $t - 1$ . Consequently, the benchmark level cannot be the average level of past consumption of those goods. Therefore, we assume that agents observe *per capita* aggregate consumption of the basket of goods in period  $t - 1$ , which will be considered as the benchmark level of the consumption of goods appearing between periods  $t - 1$  and  $t$ . This assumption is important to develop a deep-habits non-Ricardian model precluding the life cycle of goods and eliminating any discontinuity between the first period and the next periods. This is also helpful to restore symmetry in the firm's decisions.

Letting  $\beta$  denote the constant subjective discount factor and  $E_t$  the mathematical expectations operator conditional on information available in period  $t$ , the life-time utility of a representative agent  $j$  is:

$$E_t \sum_{s=t}^{\infty} \beta^{s-t} \ln(x_{j,s} - d(l_{j,s})), \quad (3)$$

where  $d(l_{j,t})$  is an increasing and convex function giving the disutility of the labor supply of agent  $j$ ,  $l_{j,t}$ , more specifically

$$d(l_{j,t}) \equiv \alpha \frac{l_{j,t}^{1+\frac{1}{\sigma}}}{1 + \frac{1}{\sigma}} \quad (4)$$

with  $\sigma > 0$  representing the Frisch elasticity of labor supply.

(3) features preferences à la Greenwood, Hercowitz and Huffman (1988) (henceforth "GHH"). The reason is twofold. First, it is helpful to make the aggregation feasible. We will show later that the GHH specification makes labor age-independent, which is necessary to aggregate individual human wealth. Second, the labor supply is endogenous, which raises a potential problem of negative labor supply, since we have an overlapping generations structure. Actually, if leisure is a normal good, wealthier agents will supply less labor. Indeed, if labor is not constrained by a lower positive bound, then labor supply may be negative. As shown by Ascari and Rankin (2007), the GHH specification makes labor supply independent of wealth<sup>4</sup>.

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<sup>4</sup>This issue is discussed in more detail in Ascari and Rankin (2007).

In each period, agents supply labor,  $l_{j,t}$ , in a competitive market and receive real wages,  $w_t$ , which are independent of the agents' age.

Agent  $j$  maximizes its expected utility subject to its intertemporal budget constraint:

$$\sum_{m=1}^{M_t} p_t(m) c_{j,t}(m) + E_t q_{t,t+1} v_{j,t+1} \leq v_{j,t} + w_t l_{j,t} - \tau_{j,t} + \psi_{j,t}. \quad (5)$$

where  $p_t(m)$  is the relative price of the differentiated good  $m$ . Agent  $j$  receives an average profit  $\psi_{j,t}$  from the family's ownership of a monopolistic firm and pays lump-sum taxes  $\tau_{j,t}$ .  $v_{j,t}$  is agent  $j$ 's initial financial wealth.  $q_{t,t+1}$  is the stochastic discount factor, and more generally:

$$q_{t,s} = q_{t,t+1} \times q_{t+1,t+2} \times \dots \times q_{s-1,s} \quad \text{with } q_{t,t} \equiv 1. \quad (6)$$

In addition, as markets are complete, there is a risk-free one-period interest rate defined by:

$$R_t = [E_t q_{t,t+1}]^{-1}. \quad (7)$$

The problem above can be solved in two stages. In a first stage, for any given level of  $x_{j,t}$ , agent  $j$ 's demand for individual goods varieties must solve the cost minimization problem:

$$\min \sum_{m=1}^{M_t} p_t(m) c_{j,t}(m)$$

subject to the aggregate constraint (2). Solving this problem yields the demand functions:

$$c_{j,t}(m) = \frac{1}{M_t} (p_t(m))^{-\varepsilon} x_{j,t} + \phi \tilde{c}_{t-1}(m), \quad \text{for all } m \in [1, M_t]. \quad (8)$$

The price index is defined by:

$$P_t \equiv \left( \frac{1}{M_t} \sum_{m=1}^{M_t} P_t(m)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}, \quad (9)$$

where  $P_t(m)$  denotes nominal price of good  $m$ . For simplicity, we assume that each period's nominal price index is normalized to unity, so all remaining prices are expressed in terms of a basket of goods (the numéraire).

Using equation (8) and the definition of the price index (9), we define the total expenditure on habit-adjusted consumption as<sup>5</sup>:

$$x_{j,t} = \sum_{m=1}^{M_t} p_t(m) c_{j,t}(m) - \phi \sum_{m=1}^{M_t} p_t(m) \tilde{c}_{t-1}(m). \quad (10)$$

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<sup>5</sup>See Appendix 1 for further details.

Notice that demand for good  $m$  by agent  $j$ , equation (8), features a dynamic component, as it depends not only on current period habit-adjusted consumption,  $x_{j,t}$ , but also on the lagged value of consumption of good  $m$ . This, in turn, makes the pricing decision of firm  $m \in [1, M_t]$  intertemporal. Indeed, as pointed out by Ravn et al (2006), the deep habits assumption makes the price elasticity of demand procyclical. From equation (8), we can easily see that an increase in the level of  $x_{j,t}$  raises the relative importance of the price-elastic term  $\frac{1}{M_t} (p_t(m))^{-\varepsilon} x_{j,t}$ , and reduces the relative importance of the price-inelastic demand component,  $\phi \tilde{c}_{t-1}(m)$ . As a result, the price elasticity of demand for good  $m$  increases with aggregate demand.

The second stage of household  $j$ 's problem consists in choosing its demand for  $x_{j,t}$  and its financial asset holdings  $v_{j,t+1}$ , resulting from the maximization of life-time utility (3) subject to the dynamic budget identity (5). The first-order conditions for this maximizing problem yield the following optimality conditions:

$$x_{j,t} - d(l_{j,t}) = \beta^{-1} q_{t,t+1} (x_{j,t+1} - d(l_{j,t+1})), \quad \forall j \text{ and } \forall s^t \quad (11)$$

$$d_l(l_{j,t}) = w_t, \quad (12)$$

$$x_{j,t} + \phi \sum_{m=1}^{M_t} p_t(m) \tilde{c}_{t-1}(m) + E_t q_{t,t+1} v_{j,t+1} = v_{j,t} + w_t l_{j,t} - \tau_{j,t} + \psi_{j,t}, \quad (13)$$

$$\lim_{T \rightarrow +\infty} E_t q_{t,T} v_{j,T} = 0. \quad (14)$$

We note from equation (12) that labor is independent of the agent's age and also independent of the agent's consumption. This is a consequence of the GHH preferences, which feature no wealth effect on hours. Equation (13) is the intertemporal budget constraint of agent  $j$ , which is obtained by introducing (10) into (5). Equation (14) represents the transversality condition.

Moreover, we notice, from (11), that the standard Euler equation is modified in two ways. First it is expressed in terms of individual habit-adjusted consumption  $x_{j,t}$  rather than individual consumption  $c_{j,t}$ . Second, the term  $d(l_{j,t})$  is subtracted from the individual habit-adjusted consumption  $x_{j,t}$ . As we have already mentioned, the term  $d(l_{j,t})$  is independent of agents' age, i.e. it is identical for all agents. Consequently, we can drop the subscript  $j$ . In addition, Ascari and Rankin (2007) consider that  $d(l_t)$  acts as a "subsistence" level of consumption. For this reason, they define "adjusted" consumption as individual habit-adjusted consumption minus its subsistence level ( $d(l_t)$ ).

We follow Ascari and Rankin (2007) and define adjusted consumption as<sup>6</sup>:

$$a_{j,t} \equiv x_{j,t} - d(l_t). \quad (15)$$

In addition, we define human wealth (discounted present value of labor income and profits minus taxes) as:

$$h_{j,t} = E_t \sum_{s=t}^{\infty} q_{t,s} [w_s l_{j,s} + \psi_{j,s} - \tau_{j,s}]. \quad (16)$$

Iterating the budget constraint (13) forward (from  $t$  to infinity), taking into account the no-Ponzi game restriction, using (11) iterated forward (from  $t$  to infinity), applying the definition of adjusted consumption (15), and the definition of human wealth (16) yields<sup>7</sup>:

$$a_{j,t} = (1 - \beta)(v_{j,t} + h_{j,t} - \chi_t) \quad (17)$$

where

$$\chi_t = \phi E_t \sum_{s=t}^{\infty} q_{t,s} \sum_{m=1}^{N_t} p_s(m) \tilde{c}_{s-1}(m)$$

denotes the future time path of reference consumption.

We note from equation (17) that in the absence of a consumption externality ( $\phi = 0$  and thus  $\chi_t = 0$ ), individuals condition their consumption solely on their consolidated wealth ( $v_{j,t} + h_{j,t}$ ), with a ratio of  $(1 - \beta)$  of total wealth. With a non-zero consumption externality, however, individual adjusted consumption is also directly affected by the future time path of economy-wide, *per capita* consumption of good  $m$ .

So far, we have focused on individual variables. Now we consider aggregate variables. Variables without the subscript "j" represent a *per capita* aggregate value. We apply the aggregation rule used in (1) to  $x_{j,t}$  and  $v_{j,t}$ . Agents are assumed to pay the same amount of taxes independently of their age, so  $\tau_{j,t} = \tau_t$ . Moreover, we will show later that, as firms display the same behavior, the average profits received from firms are independent of the agents' age, i.e.  $\psi_{j,t} = \psi_t$ . Accordingly, since  $l_{j,t}$  is the same for all age cohorts, human wealth is also the same for all, namely  $h_{j,t} = h_t$ .

Finally, notice that applying the aggregation rule used in (1) in period  $t$  to the variable  $v_{j,t+1}$  yields:

$$\sum_{j \leq t} \frac{(N_j - N_{j-1})}{N_t} v_{j,t+1} = (1 + n) v_t,$$

<sup>6</sup>From (3), we note that individuals' preferences are undefined for habit-adjusted consumption values below the subsistence level.  $a_{j,t}$  needs to be positive for all  $j, t$ .

<sup>7</sup>See Appendix 1 for further details.



as generation  $j = t + 1$  has no financial wealth in period  $t + 1$ , i.e.  $v_{t,t} = 0$ . Here,  $n$  denotes the population growth rate, i.e.  $N_t = (1 + n) N_{t-1}$ .

Using this result and aggregating equation (11), where we replace  $a_{j,t+1}$  by its expression given by equation (17) expressed in  $t + 1$ , one obtains<sup>8</sup>:

$$a_t = \beta^{-1} q_{t,t+1} a_{t+1} + n (\beta^{-1} - 1) q_{t,t+1} v_{t+1}. \quad (18)$$

This equation is the aggregate Euler equation, which differs from the individual Euler condition (11) as long as the population growth rate is different from zero. The last term on the right hand side reflects a real wealth effect, which is characteristic of a non-Ricardian economy. Indeed, the growth rate of aggregate adjusted consumption is negatively correlated with the aggregate financial wealth. An increase in beginning-of-period financial wealth in period  $t + 1$  cannot be proportionally allocated to present and future aggregate adjusted consumption because only those consumers alive during this period benefit.

## 2.2 Firms

This section focuses on the supply side. Here we describe the problem of a firm  $m$  appeared before  $t - 1$ . Later on, we will show that new firms behave in the same way as old firms.

The differentiated good  $m \in [1, M_{t-1}]$  is produced by a monopolist,  $m$ , who uses labor input  $l_t(m)$  and specific human capital—normalized to one—to produce a quantity  $y_t(m)$  using linear production technology:

$$y_t(m) = l_t(m). \quad (19)$$

Firms are assumed to be price setters. Letting

$$\psi_t(m) = p_t(m) y_t(m) - w_t l_t(m) \quad (20)$$

defines firm  $m$ 's profits in period  $t$ , using (6), the owner-manager  $m$ 's problem is to maximize the discounted value of the sum of its present and future cash flows,

$$E_t \sum_{s=t}^T q_{t,s} \psi_s(m),$$

subject to (19), and

$$y_t(m) = (p_t(m))^{-\varepsilon} \frac{N_t x_t}{M_t} + \phi (1 + n) y_{t-1}(m), \quad \forall m \leq M_{t-1}, \quad (21)$$

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<sup>8</sup>See Appendix 2 for further details.

where equation (21) is given by the aggregation of (8) expressed in level terms.  $x_t$  is *per capita* habit-adjusted consumption.

Note that the marginal costs of firm  $m$  are equal to real wages,  $w_t$ . The first-order conditions corresponding to firm  $m$ 's optimization problem give the following equilibrium equations: (21),

$$\lambda_t(m) = p_t(m) - w_t + \phi(1+n) E_t q_{t,t+1} \lambda_{t+1}(m), \quad (22)$$

and

$$\lambda_t(m) = \frac{M_t y_t(m)}{N_t \varepsilon x_t} (p_t(m))^{\varepsilon+1}. \quad (23)$$

$\lambda_t(m)$  is the Lagrangian multiplier associated with (21) and represents the shadow value of selling an extra unit of good  $m$  in period  $t$ . Equation (22) states that the value of selling an extra unit of good  $m$  in period  $t$ ,  $\lambda_t(m)$ , has two components. The first term on the right hand side represents the short-run profit margin of firm  $m$  in period  $t$ . The second term on the right hand side corresponds to the future expected profits associated with selling an extra unit of good  $m$  in period  $t$ .

Furthermore, remember that demand for new goods—appearing in  $t$ , i.e.  $m \in ]M_{t-1}, M_t]$ —features a dynamic component, the same as the old goods, which is the average of goods supplied in period  $t-1$ . Consequently, firms appearing in period  $t$  are also subject to (21) and have the same optimality conditions as firms appearing in periods before  $t-1$ .

Let  $\eta_t(m)$  denote the relative markup, in other words the ratio between profit margin (prices minus marginal cost) and prices charged by firm  $m$ :

$$\eta_t(m) \equiv \frac{p_t(m) - w_t}{p_t(m)} \quad (24)$$

and define the elasticity of demand as

$$\epsilon_t(m) \equiv \varepsilon \left[ 1 - \phi(1+n) \frac{y_{t-1}(m)}{y_t(m)} \right]. \quad (25)$$

Rearranging equation (23) below using (21) and the definition (25) yields:

$$\lambda_t(m) = \epsilon_t^{-1}(m). \quad (26)$$

Equation (26) states that the value of selling an extra unit of good  $m$  in period  $t$  equals the inverse of the price elasticity of demand. Now, combining (22) and (26) leads to:

$$\eta_t(m) = \epsilon_t(m)^{-1} - \phi(1+n) E_t q_{t,t+1} \frac{p_{t+1}(m)}{p_t(m)} \epsilon_{t+1}(m)^{-1}. \quad (27)$$

Notice that in the absence of deep habits, i.e.  $\phi = 0$ , the price elasticity of demand and the relative markup lose their dynamic component. Equation (27) becomes:

$$\eta_t(m) = \frac{1}{\varepsilon}.$$

Equation (27) shows that the short-run profit margin of the firm  $m$  in period  $t$  is negatively related to the price elasticity of demand for good  $m$ ,  $\epsilon_t(m)$ , and it is negatively related to the future expected profits associated with selling an extra unit of good  $m$  in period  $t$ ,  $\lambda_{t+1}(m)$ . Also, it is negatively related to the discount factor  $q_{t,t+1}$ . Moreover, the deep habit assumption gives rise to two effects, a price elasticity effect and an intertemporal effect. Ravn et al (2006) explain these effects clearly .

First, when aggregate demand for good  $m$ ,  $y_t(m)$ , increases, the price elasticity of demand,  $\epsilon_t(m)$ , increases too, inducing a decline in the short-run profit margin of firm  $m$  in period  $t$ , and thus a decline in markups: this is what Ravn et al (2006) call the price-elasticity effect of deep habits on markup. Second, today's price decisions will affect future demand, and so when the present value of future per unit profit is expected to be high—or future price elasticity of demand,  $\epsilon_{t+1}(m)$ , is expected to be low—, firms have an incentive to invest in the customer base today. Therefore, they induce higher current sales by lowering the current markups. Ravn et al (2006) call this effect: the intertemporal effect of deep habits on markup. The intertemporal effect is also driven by the change in the real interest rate. Indeed if the real interest rate goes up, then the firm discounts future profits more, and thus has less incentive to invest in market share today.

## 2.3 Government

In period  $t$ , the government collects lump-sum taxes from households, and issues one-period risk-free government bonds. Government expenditures are assumed to be zero. Therefore, government revenues are obtained from net tax receipts and debt issue. The flow budget constraint of the government, expressed in *per capita* terms, reads as

$$(1+n) \frac{b_{t+1}}{R_t} = b_t - \tau_t, \quad (28)$$

where  $b_t$ ,  $R_t$ , and  $\tau_t$  are the number of *per capita* government bonds issued at the start of period  $t - 1$ , the risk-free return and the *per capita* lump-sum taxes, respectively<sup>9</sup>. For the government to remain solvent, the No Ponzi condition must be satisfied.

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<sup>9</sup>The public debt is a predetermined value.

In this paper, we focus on the effects of a change public debt. Actually, the fiscal shock used in the analysis is a public debt shock. For this reason, we specify a fiscal rule such that a law of motion of public debt follows a first-order autoregressive process:

$$b_{t+1} = \rho b_t + (1 - \rho) \bar{b} + \xi_t, \quad (29)$$

where  $\xi_t$  reflects a public debt shock,  $\bar{b}$  is the target level of long-run debt, and  $0 < \rho < 1$  denotes the speed of debt adjustment.

Specifically, our debt-stabilizing fiscal rule is given by:

$$\tau_t = \left(1 - \rho \frac{(1+n)}{R_t}\right) b_t - \frac{(1+n)}{R_t} ((1-\rho) \bar{b} + \xi_t). \quad (30)$$

### 3 Symmetric Equilibrium

Firms are different because of the date of appearance. Recall that, in our model, even firms appearing in  $t$  face a dynamic (backward) demand of goods. Thus, assuming that all firms make the same decisions, in  $t-1$ , implies that firms display the same behavior and make the same decisions also in period  $t$ . As we have already mentioned, agents are owner-managers of monopolistically competitive firms, i.e.  $M_t = N_t$ . Accordingly,  $p_t(m) = 1$ ,  $c_t(m) = c_t$ ,  $y_t(m) = y_t$ ,  $l_t(m) = l_t$ ,  $\eta_t(m) = \eta_t$ , and  $\epsilon_t(m) = \epsilon_t$ . In addition, the equilibrium in the financial market, in the goods market and the labor market is given by :

$$v_t = b_t,$$

$$y_t = c_t,$$

$$l_t = y_t.$$

It follows that we can describe the symmetric equilibrium using the following set of equations:

$$a_t = \beta^{-1} q_{t,t+1} a_{t+1} + \gamma q_{t,t+1} b_{t+1}, \quad (31)$$

$$\eta(y_t) = \epsilon_t(y_t, y_{t-1}) - \tilde{\phi} E_t q_{t,t+1} \epsilon_{t+1}(y_{t+1}, y_t), \quad (32)$$

$$a_t = y_t - \tilde{\phi} y_{t-1} - d(y_t), \quad (33)$$

$$b_{t+1} = \rho b_t + (1 - \rho) \bar{b} + \xi_t, \quad (34)$$

where

$$\epsilon_t(y_t, y_{t-1}) \equiv \varepsilon^{-1} \left( \frac{y_t}{y_t - \tilde{\phi} y_{t-1}} \right), \quad (35)$$

$$\eta(y_t) \equiv 1 - d_l(y_t), \quad (36)$$

$\tilde{\phi} = \phi(1+n)$  and  $\gamma = n(\beta^{-1} - 1)$ . (33) gives the definition of adjusted consumption. (33) is obtained by replacing *per capita* habit-adjusted consumption by its expression given by (21) in the definition of aggregate adjusted consumption given by the aggregation of (15). (31) is the modified aggregate Euler equation. (34) states that government debt is stabilized, in each period, with an adjustment speed  $\rho$ . (35) is obtained from (25), and states that the elasticity of demand is positively related to aggregate demand,  $y_t$ . In the symmetric equilibrium (27) becomes (32), which states that the relative markup is dynamic.

In the absence of deep habits, i.e.  $\phi = 0$ , the relative markup is invariant and equals  $\varepsilon^{-1}$ . We note that using the definition (36) with equation (32) gives the equilibrium level of labor. As a consequence, the level of output is determined, as is consumption. In this case, fiscal policy is neutral despite the non-Ricardian structure. Accordingly, wealth effects are insignificant. In fact, a change in government debt affects only the real interest rate.

In the deep habit case, i.e.  $\phi \neq 0$ , equation (32) does not solely determine the equilibrium level of employment. We notice, from equation (32), that the markup depends on the present value of future marginal profits induced by a unit increase in current sales,  $\tilde{\phi} E_t q_{t,t+1} \epsilon_{t+1}(y_{t+1}, y_t)$ , and the short-run price elasticity of demand,  $\epsilon_t$ . In this case, wealth effects are significant. For instance, an increase in debt to finance tax cuts in period  $t$  implies a rise in the real interest rate, which has an impact on the markup. The description of this new mechanism is illustrated in Section 4.5, which gives the response of the economy to fiscal shock.

## 4 Steady State Equilibrium

In this section we analyze the long-run effects of fiscal policy on the steady state levels of consumption, output and real interest rates. If we drop out the indication of time and use (7), the system of equations (31)-(34) becomes:

$$R = \beta^{-1} + \gamma \frac{\bar{b}}{a}, \quad (37)$$

$$d_l(y) = 1 - \left( \frac{1 - \frac{\tilde{\phi}}{R}}{1 - \tilde{\phi}} \right) \varepsilon^{-1}, \quad (38)$$

$$a = \left( 1 - \tilde{\phi} \right) y - d(y), \quad (39)$$

$$b = \bar{b}, \quad (40)$$

with

$$d(y) = \alpha \frac{y^{1+\frac{1}{\sigma}}}{1+\frac{1}{\sigma}}, \quad (41)$$

and

$$d_l(y) = \alpha y^{\frac{1}{\sigma}}$$

First of all, we notice that  $\eta \geq \varepsilon^{-1}$ . The steady state markup in the presence of deep habits, i.e. when  $\phi \neq 0$ , is greater than the steady state markup in the absence of deep habits, i.e. when  $\phi = 0$ . Firms have more market power in the presence of deep habits. Indeed, charging a low markup in the short run implies high market power in the long run because of the habit effect.

The above steady state system, (37)-(38), can be rewritten as:

$$R \equiv \mathfrak{R}(y) = \beta^{-1} + \gamma \frac{\bar{b}}{a}, \quad (42)$$

$$y \equiv \Upsilon(R) = \left[ \left( 1 - \frac{1 - \frac{\tilde{\phi}}{R}}{\varepsilon(1 - \tilde{\phi})} \right) \alpha^{-1} \right]^\sigma, \quad (43)$$

with

$$a = \left( 1 - \tilde{\phi} \right) y - \frac{y^{1+\frac{1}{\sigma}}}{1+\frac{1}{\sigma}},$$

where (43) is obtained by substituting the derivative of  $d(l)$  in (41) into (38).

We show in Appendix 4 that the necessary and sufficient condition for the existence and the uniqueness of the steady state equilibrium is

$$0 < \underline{y} < \bar{y}, \quad (44)$$

where

$$\underline{y} \equiv \left[ \frac{1 - \frac{1}{\varepsilon(1-\tilde{\phi})}}{\alpha} \right]^\sigma,$$

and

$$\bar{y} \equiv \left[ \frac{(1 - \tilde{\phi}) \left( 1 + \frac{1}{\sigma} \right)}{\alpha} \right]^\sigma.$$

Equivalently to (44), we have

$$\begin{cases} \tilde{\phi} < \tilde{\phi}_{\max} \equiv (1 - \varepsilon^{-1}), & \text{for } \sigma < 4(\varepsilon - 4)^{-1}, \\ \tilde{\phi} \in [0, \tilde{\phi}_1) \cup (\tilde{\phi}_2, \tilde{\phi}_{\max}), & \text{for } \sigma < 4(\varepsilon - 4)^{-1}, \end{cases}$$

where

$$\tilde{\phi}_1, \tilde{\phi}_2 = \frac{2d-1}{2d} \mp \sqrt{\frac{\varepsilon-4d}{4\varepsilon d^2}}, \quad \text{with } d = 1 + \frac{1}{\sigma}.$$

Equations (42) and (43) are graphed in Figure 1. Functions  $\Upsilon$  and  $\Re$  are represented by the dashed-line curve and the solid-line curve in  $yR$ plane, respectively. We easily see that in the interval  $(\underline{y}, \bar{y})$ , the two curves intersect once. The steady state equilibrium is given by  $E$ .

Figure 1 also displays the qualitative effects of a change in the long-run level of public debt,  $\bar{b}$ . If  $\bar{b}$  increases ( $\Delta\bar{b} > 0$ ), the  $\Re$  curve moves upward, entailing an increase in long-run gross interest rates,  $R$ , and a decrease in long-run output,  $y$ . The new steady state equilibrium is given by  $E'$ .

Remember that, in a non-Ricardian framework, the crowding out effect on output obtained is due to the presence of physical capital. So, if we make abstraction from capital accumulation, the crowding out effect is expected to disappear. We need to point out that in the long run, the crowding out effect of a debt-financed tax cut is preserved even without capital. At this stage, we emphasize a new transmission mechanism of fiscal policy. This new channel is based on a lack of Ricardian equivalence and the countercyclical movement of the markup. In the next section, we analyze the effects of temporary and permanent debt-financed tax cuts.

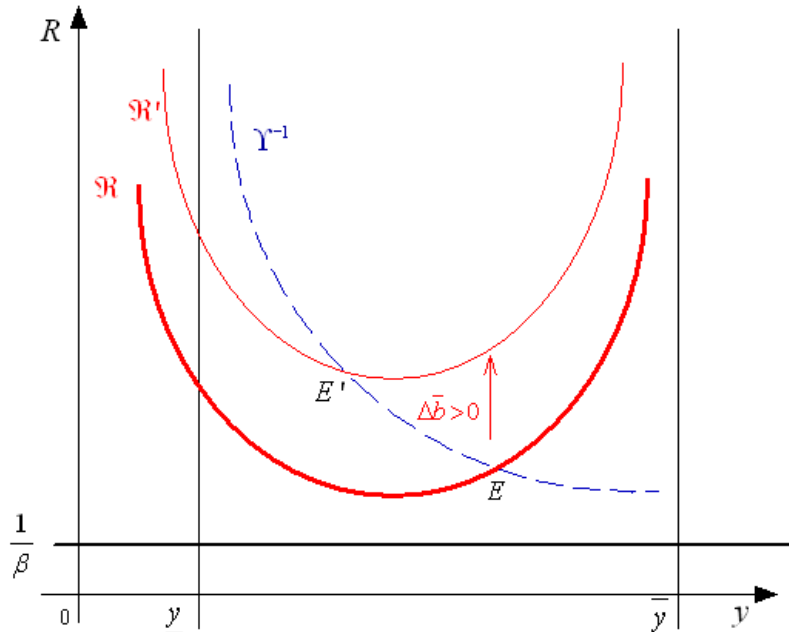


Figure 1: Steady state equilibrium.

*Numerical illustration:*

We also give a numerical illustration of the long-run effects of deep habits. We therefore give values to the parameters. We adopt the calibration used in Ravn et al (2006)<sup>10</sup>. Notice that accordingly  $\sigma < 4(\varepsilon - 4)^{-1}$ , so the necessary and sufficient condition for the steady state equilibrium is  $\tilde{\phi} < \tilde{\phi}_{\max}$ . Figure 2 displays the effects of the variation of  $\phi$  from 0 to

$$\phi_{\max} = \frac{(1 - \varepsilon^{-1})}{(1 + n)}.$$

Figure 2 shows that a higher degree of habit formation implies lower long-run levels of consumption and output, and higher long-run levels of markup and real interest rates and lower elasticity of demand. We observe that the variation is non-linear. In fact, the variation is sharp for values of  $\phi$  between approximately 0.2 and 0.4.

The intuition behind the effects of the change in the degree of deep habits is the following. The higher the degree of habit formation, the more agents care about the difference between their consumption of a specific brand and the average consumption of that brand in the last period. This is a catching up with the Joneses mechanism on a specific brand basis. Agents who have low consumption (the young) are willing to sacrifice future consumption to increase their consumption today. They do so by lowering their savings today in order to catch up with the benchmark level of consumption. The decrease in savings entails higher real interest rates, implying a higher markup. As a result employment decreases, entailing lower consumption and output. This result is in line with Fisher and Heijdra (2009) who show that in a Blanchard-Yaari framework with exogenous labor supply, consumption externalities cause the long-run level of consumption and capital to drop. In our framework this result is preserved even without capital because of the effects of the endogenous markup.

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<sup>10</sup>We assume that  $\bar{b} = 0.6$ ,  $\varepsilon = 5.3$ ,  $\sigma = 1.3$ ,  $n = 0.02$  and  $\beta = 0.96$ . We will give more details about the calibration exercise in the next section.



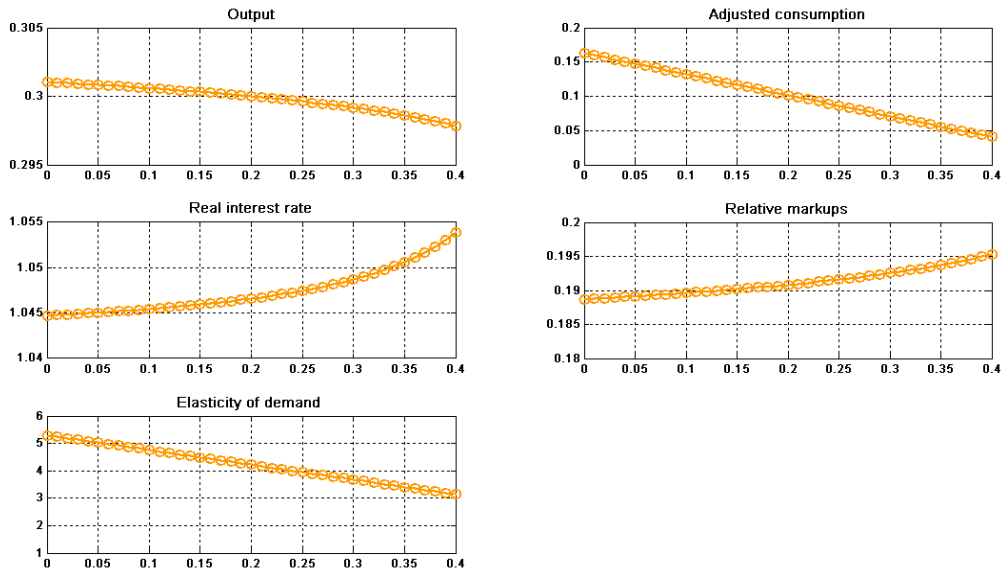


Figure 2: Increase in  $\phi$  from 0 to 0.4.

## 5 Public Debt Shocks

In this section we calibrate our model and investigate the implications of temporary and permanent debt-financed tax cuts. This exercise is just an illustration of the effects of fiscal shocks. We specify that this paper does not aim to show that the model fits the data. We want to shed lights on the response of the economy to public debt shock in a deep-habits non-Ricardian model.

In Table I we summarize the information on our calibrated parameters. We assume that each period corresponds to a year. We set the discount factor  $\beta$  to 0.96, implying an annual discount rate of approximately 4%. We follow Ravn et al (2006) and set the elasticity of substitution,  $\varepsilon$ , equal to 5.3, and the Frisch labor supply elasticity,  $\sigma$ , equal to 1.3. In addition, the parameter  $\alpha$  is calibrated such that the long-run level of labor equals 0.3. The population growth rate,  $n$ , is set equal to 0.02, which larger than the values observed in the data. The reason is that, this value is supposed to take into account all the wealth effects which would affect the real economy. The degree of habit formation  $\phi$  is set to 0.2. This value is definitely very lower than the value estimated by Ravn et al (2006), which is 0.86. The reason is that  $\phi = 0.86$  induces a value of the gross real interest,  $R$ , of 3. This value is unrealistic. Moreover, the eigenvalues depend on the parameter  $\phi$ . As a consequence the determinacy of the equilibrium depends on  $\phi$ . As shown in Blanchard and Kahn (1980), a necessary condition for the uniqueness of a stable solution in the neighborhood of the steady state is that there are as many eigenvalues larger than one in modulus as there are non-predetermined variables in the model. Therefore, we choose the value of 0.2 which allows to verify the Blanchard and Kahn's conditions. In addition,  $\phi = 0.2$  gives a plausible value for  $R$ , namely 1.046.

We solve the model and simulate the model using DYNARE<sup>11</sup>.

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<sup>11</sup>See Juillard (2004).

<i>Definition</i>	<i>Parameter</i>	<i>Value</i>
Discount factor	$\beta$	0.96
Elasticity of substitution across varieties	$\varepsilon$	5.3
Population growth rate	$n$	0.02
Frisch elasticity of labor supply	$\sigma$	1.3
Degree of habit formation	$\phi$	0.2
Public debt adjustment speed	$\rho$	0.9
Long-run level of labor	$\bar{l}$	0.3
Public debt long-run target level	$\bar{b}$	0.6

Table I: Parameter values.

## 5.1 Temporary Public Debt Increase

Here we simulate a temporary tax cut financed by an increase in public debt. We assume that the public debt rises from 60% to 90%. In other words,  $\xi$  is set equal to 0.3. Notice that all variables are expressed in deviation (percentage) from the steady state. Figure 3 represents the time paths in response to a one-period debt-financed tax cut. We also contrast the effect of shock with and without deep habits.

First, in the absence of deep habits, the public debt increase only affects the real interest rate, which rises. In this case, fiscal policy is neutral despite the non-Ricardian framework. This is a consequence of the using the GHH preference. In fact, the usual wealth effect on labour supply has been eliminated. Thus an increase in government debt does not affect labor supply or output.

Second, in the presence of deep habits, higher public debt entails lower consumption and consequently output. Consumption, employment and output fall on impact. Relative markups and the real interest rate jump on impact. In addition, the elasticity of demand decreases, then increases and then falls to reach its steady state value.

These results can be explained as follows. First, the increasing government debt makes current agents feel wealthier and want to consume more today, all other things being equal. Second, in the securities market, the supply of public bonds outstrips demand for government bonds. As the economy is non-Ricardian, agents do not fear future taxes increases. Consequently, they do not lift the demand for government bonds by the same amount as the government bond supply rises. So, an interest rate increase is necessary to balance the securities market. Third, a higher real interest rate reduces the present value of future per unit profits. As a result, firms

have less incentive to invest in the customer base today and hence they are willing to increase markups today. In addition, higher markups entail lower employment and consequently lower consumption. Besides, lower consumption today implies lower price elasticity of demand and thus higher markups today, all other things being equal. At the same time, lower consumption today implies higher elasticity of demand in  $t + 1$ . As a result firms have less incentive to invest in the customer base and will increase their markups today. As we can easily notice, there is no ambiguity, an increase in government debt,  $\xi_t > 0$ , to finance tax reductions in  $t$ , implies an increase in the markup, a decrease in employment, and a drop in consumption. In the next period, firms facing lower demand for their products will set a lower markup in order to increase their demand for goods. Consequently, employment increases and consumption goes up. Finally, the economy converges towards the steady state equilibrium. However, the convergence takes time because of the persistence of the government debt process (29).

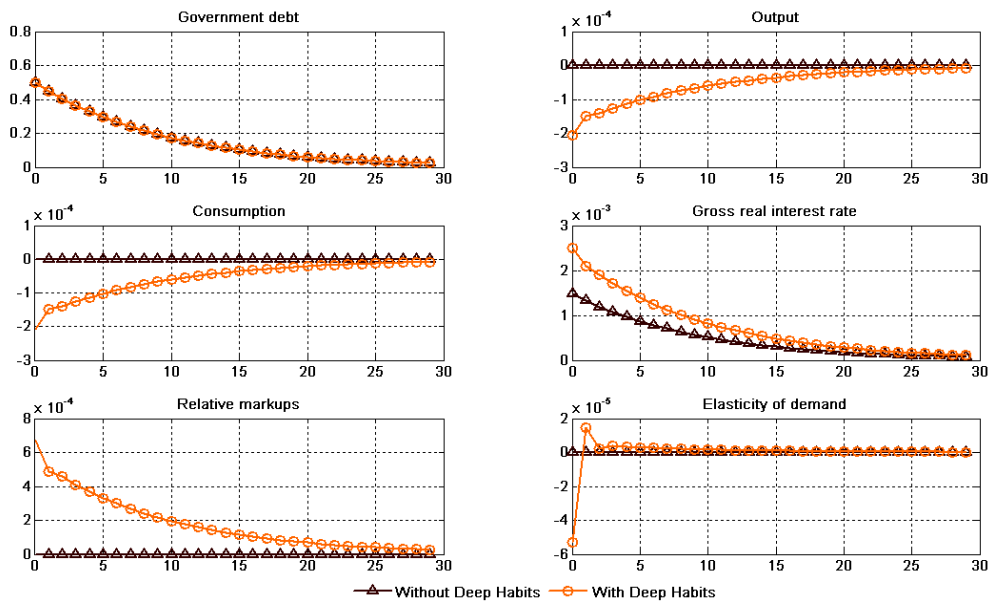


Figure 3: Temporary shock.

## 5.2 Permanent Public Debt Increase

Here we simulate a permanent debt-financed tax cut. This exercise is slightly different from the previous one. In fact, we assume that the long-run target level of public debt rises from 60% to 120%. Figure 4 shows that a permanent public debt shock entails a decline in consumption and output. On the other hand, the real interest rate and markups increase, while the elasticity of demand decreases.

As we have already mentioned in Section 4, an increase in the supply of government bonds entails a higher real interest rate as the economy is non-Ricardian. The higher the real interest rate, the higher the markup. As the rise in the real interest rate is permanent, the increase in the markup is also permanent. In this economy, the markup is dynamic and depends on future sales. When the real interest rate goes up, future profits are discounted less so firms have less incentive to invest in the customer base today. Consequently, they raise their markup, implying a decline in employment and consumption. It emerges from our result that the long-run crowding out effect of public debt is not only related to the presence of capital. We show that in a framework without capital, the lack of Ricardian equivalence coupled with a dynamic markup restores the long-run crowding out effect of a debt-financed tax cut.

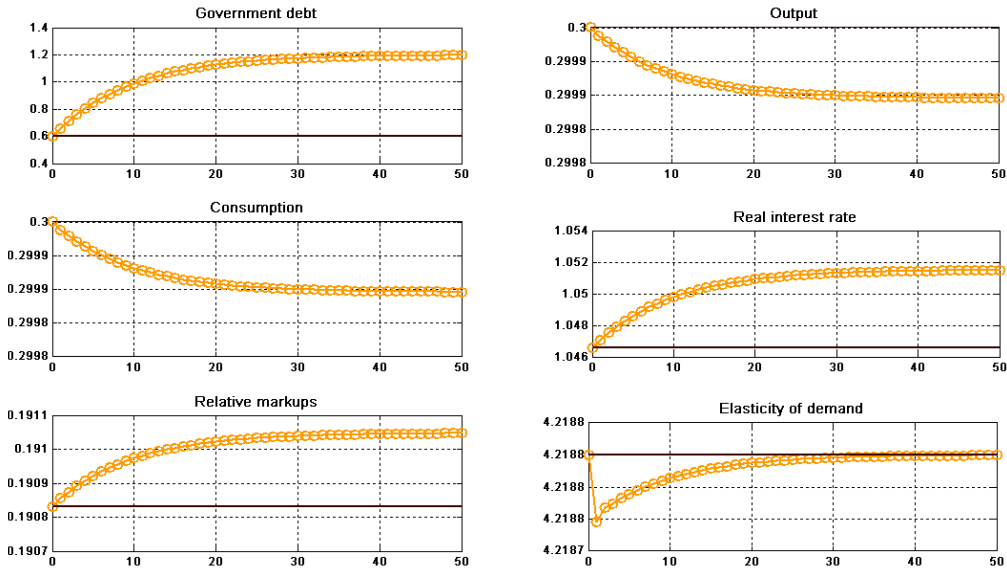


Figure 4: Permanent shock.

## 6 The Sticky Prices Model

In this section, we extend the simple version developed in Section 1 by incorporating sticky prices. The goal is to render the model capable of reproducing the short-run expansionary effect of lump-sum fiscal policy. In this extended version, the economy consists of four types of agents: infinitely-lived dynasties (or families), monopolistically competitive firms, the monetary authority and the fiscal authority. Consumption and labor supply decisions are the same as in Section 2. For this reason we will skip the description of households' problem. On the other hand, firms' program is altered by the assumption of price rigidities. Thus we will start this section by studying the behavior of firms. Then we will describe the program of the government and the central bank. Next, we will briefly describe the symmetric equilibrium. As the price stickiness assumption does not alter the steady state, the long-run analysis is identical to the one in Section 4. Finally, we will study the effects of a public debt shock.

### 6.1 Production and Price-Setting Decisions

As in Section 2, we assume that firm  $m$  transforms homogenous labor into a differentiated good according to a linear production technology:

$$y_t(m) = l_t(m). \quad (45)$$

Notice that  $l_t(m)$  is the quantity of labor used by firm  $m$  to produce good  $m$ , in period  $t$ . Also,  $y_t(m)$  is the production by firm  $m$  of good  $m \in [1, M_t]$ , in period  $t$ .

We assume that monopolistic firms are subject to Rotemberg's (1982) convex adjustment costs associated with changing nominal prices:

$$\frac{\phi_\pi}{2} \left( \frac{P_t(m)}{P_{t-1}(m)} - \bar{\Pi} \right)^2, \quad (46)$$

where  $\bar{\Pi}$  denotes the steady state inflation rate, and  $\phi_\pi \geq 0$  measures the degree of nominal rigidities. When  $\phi_\pi = 0$  prices are flexible, while positive values of  $\phi_\pi$  imply that firms find it costless to adjust their prices in line with the central bank inflation target.

Letting

$$\psi_t(m) = \frac{P_t(m)}{P_t} y_t(m) - w_t y_t(m) - \frac{\phi_\pi}{2} \left( \frac{P_t(m)}{P_{t-1}(m)} - \bar{\Pi} \right)^2, \quad (47)$$

defines firm  $m$ 's profits in period  $t$ . Using (6), the owner-manager  $m$ 's problem is to maximize the discounted value of the sum of its present and future cash flows,

$$E_t \sum_{s=t}^T q_{t,s} \psi_s(m),$$

subject to (45),

$$y_t(m) = \left( \frac{P_t(m)}{P_t} \right)^{-\varepsilon} \frac{N_t x_t}{M_t} + \phi_c (1+n) y_{t-1}(m), \quad \forall m \leq M_{t-1} \quad (48)$$

where  $\phi_c$  denotes the degree of external habit formation parameter.  $x_t$  is *per capita* habit-adjusted consumption. Equation (48) is given from the aggregation of (8) expressed in level terms.

Note that the marginal costs of firm  $m$  are equal to real wages,  $w_t$ . The first-order conditions corresponding to firm  $m$ 's optimization problem give the following equilibrium equations: (48),

$$\lambda_t(m) = \frac{P_t(m)}{P_t} - w_t + \phi_c (1+n) E_t q_{t,t+1} \lambda_{t+1}(m), \quad (49)$$

and

$$\begin{aligned} y_t(m) - \phi_\pi \frac{P_t}{P_{t-1}(m)} \left( \frac{P_t(m)}{P_{t-1}(m)} - \bar{\Pi} \right) + \phi_\pi E_t q_{t,t+1} \frac{P_{t+1}(m)}{P_t(m)} \left( \frac{P_{t+1}(m)}{P_t(m)} - \bar{\Pi} \right) \\ = \varepsilon \lambda_t(m) \frac{N_t}{M_t} x_t \left( \frac{P_t(m)}{P_t} \right)^{-\varepsilon-1}. \end{aligned} \quad (50)$$

Recall that  $\lambda_t(m)$  is the Lagrangian multiplier associated with (48) and represents the shadow value of selling an extra unit of good  $m$  in period  $t$ . Equation (49) is identical to equation (22) in Section 2. On the other hand, (23) is altered to include the cost of price adjustment.

## 6.2 Government

The flow budget constraint of the government reads as

$$\frac{B_{t+1}}{(1+i_t)} = B_t - T_t, \quad (51)$$

where  $B_t$ , and  $T_t$  are nominal government bonds issued at the start of period  $t-1$  and total lump-sum taxes, respectively.  $i_t$  is the one-period risk-free

nominal interest rate. For the government to remain solvent, the No Ponzi condition must be satisfied.

Letting  $b_t = \frac{B_t}{N_t P_{t-1}}$ ,  $\tau_t = \frac{T_t}{N_t P_t}$ , the government budget constraint is rewritten in real terms, as follows:

$$b_{t+1} = \frac{1 + i_t}{(1 + n)} \left[ \frac{b_t}{\Pi_t} - \tau_t \right]. \quad (52)$$

As in Section 2, we specify a fiscal rule such that a law of motion of public debt follows a first-order autoregressive process:

$$b_{t+1} = \rho_b b_t + (1 - \rho_b) \bar{b} + \xi_t, \quad (53)$$

where  $\xi_t$  reflects a public debt shock,  $\bar{b}$  is the target level of long-run debt, and  $0 < \rho_b < 1$  denotes the speed of debt adjustment.

Using (52) and (53), our debt-stabilizing fiscal rule is as follows:

$$\tau_t = \left( \Pi_t^{-1} - \rho_b \frac{1 + n}{1 + i_t} \right) b_t - \frac{1 + n}{1 + i_t} [(1 - \rho_b) \bar{b} + \xi_t]. \quad (54)$$

### 6.3 Monetary Authority

The monetary authority controls the nominal interest rate. Specifically, monetary policy is assumed to be described by a simple Taylor rule, given by:

$$1 + i_t = \rho_i (1 + i_{t-1}) + (1 - \rho_i) \left( \bar{R} \bar{\Pi} \left( \frac{\Pi_t}{\bar{\Pi}} \right)^\varphi \right), \quad (55)$$

$\bar{\Pi}$  represents the long-run target level for the inflation rate.  $\bar{R}$  is the steady state equilibrium gross real interest rate. Note that the Taylor formulation (55) is modified to allow for interest rate smoothing, as proposed by Clarida et al. (1998). In particular, the parameter  $\rho_i \in [0, 1]$  captures the degree of interest rate smoothing.  $\varphi > 1$  is the Taylor rule coefficient, describing the degree of responsiveness of interest rates to inflation.

It is noteworthy to point out that, as it was shown by Aloui and Guillard (2009), taking into account the Zero Lower Bound (ZLB, henceforth) on nominal interest rates in a non-Ricardian model leads to multiple steady-state solutions. Precisely, the authors find four steady state equilibria. However, this is not the issue in this paper. We want to focus on the transmission mechanism of government debt through the time-varying markups. Therefore, the ZLB is not incorporated into the specification of (55).



## 6.4 Symmetric Equilibrium and Steady State

The equilibrium in the financial market is rewritten:

$$v_t = \frac{b_t}{\Pi_t}.$$

The symmetric equilibrium described by (31)-(36) becomes:

$$a_t = \beta^{-1} q_{t,t+1} a_{t+1} + \zeta q_{t,t+1} \frac{b_{t+1}}{\Pi_{t+1}}, \quad (56)$$

$$\eta(y_t) = \lambda_t - \tilde{\phi}_c E_t q_{t,t+1} \lambda_{t+1}, \quad (57)$$

$$y_t - \phi_\pi \Pi_t (\Pi_t - \bar{\Pi}) + \phi_\pi E_t q_{t,t+1} \Pi_{t+1} (\Pi_{t+1} - \bar{\Pi}) = \varepsilon \lambda_t (y_t - \tilde{\phi}_c y_{t-1}), \quad (58)$$

$$a_t = y_t - \tilde{\phi}_c y_{t-1} - d(y_t), \quad (59)$$

$$b_{t+1} = \rho_b b_t + (1 - \rho_b) \bar{b} + \xi_t, \quad (60)$$

$$1 + i_t = \rho_i (1 + i_{t-1}) + (1 - \rho_i) \bar{R} \bar{\Pi} \left( \frac{\Pi_t}{\bar{\Pi}} \right)^\varphi, \quad (61)$$

$$1 + i_t = \left[ E_t \frac{q_{t,t+1}}{\Pi_{t+1}} \right]^{-1}. \quad (62)$$

Recall that

$$\eta(y_t) \equiv 1 - d_t(y_t),$$

and

$$d(y_t) = \alpha \frac{y_t^{1+\frac{1}{\sigma}}}{1 + \frac{1}{\sigma}}.$$

$\tilde{\phi}_c = \phi_c (1 + n)$ , and  $\zeta = n(\beta^{-1} - 1)$ . Equation (62) is the Fisher equation. The steady state system is identical to the system of equation (37)-(38), which is analyzed in detail in Section 4.

## 6.5 Public Debt Shocks

As in Section 5, the numerical simulation is conducted using DYNARE. Recall that the equilibrium is locally determined so we can investigate the effects of a temporary public debt shock around the steady state equilibrium. In Table II we summarize the information on our calibrated parameters, which is the same as in Section 5.

We assume that the monetary authority reacts to the fluctuations in inflation. Thus we set the Taylor rule coefficient at 1.5. We follow Clarida

et al (1998) and set the degree of interest rate inertia at 0.9. The degree of price stickiness is set equal to the value estimated by Ravn et al (2010), i.e. 14.5/4.

<i>Definition</i>	<i>Parameter</i>	<i>Value</i>
Discount factor	$\beta$	0.96
Elasticity of substitution across varieties	$\varepsilon$	5.3
Population growth rate	$n$	0.02
Frisch elasticity of labor supply	$\sigma$	1.3
Degree of habit formation	$\phi_c$	0.2
Public debt adjustment speed	$\rho_b$	0.9
Degree of interest rate inertia	$\rho_i$	0 or 0.9
Degree of price stickiness	$\phi_\pi$	0 or 14.5/4
Taylor rule coefficient	$\varphi$	1.5
Labor long-run level	$\bar{l}$	0.3
Inflation long-run target level	$\bar{\Pi}$	1.02
Public debt long-run target level	$\bar{b}$	0.6

Table II: Parameter values.

Figures 5a and 5b depict the effects of the temporary public debt shock. We assume that the public debt rises from 60% to 90%. In other words,  $\xi$  is set equal to 0.3. Figure 5a contrasts the effect of a temporary public debt shock when prices are fully flexible with its effect when prices are sticky<sup>12</sup>. Figure 5b contrasts the effect of a temporary public debt shock with and without nominal interest rate smoothing.

First, when prices are fully flexible, tax cuts entail lower consumption, and employment and output fall. Inflation increases in line with the nominal interest rate. Relative markups and the real interest rate rise. The intuition is the following. Higher public debt makes current agents feel wealthier, increasing the desire to consume more today. Accordingly, the real interest rate increases, implying higher inflation. This is a consequence of our Taylor rule specification. Indeed, during the adjustment, the real interest rate targeted by the monetary authority is below the natural real interest rate, implying inflationary bias. Furthermore, a higher real interest rate reduces the present value of future per unit profit margins. As a result, firms have less incentive to invest in the customer base today and hence they are willing to increase markups today. In addition, higher markups entail lower employment and consequently lower output and consumption. Furthermore, the decline in consumption today implies lower demand for goods in the subsequent peri-

<sup>12</sup>Notice that here we set  $\rho_i = 0$ .

ods. Thus the elasticity of demand increases, implying that markups decline. Consequently, employment increases and output goes up.

Second, when prices are sticky, tax cuts lead to an increase in output on impact, while relative markups negatively deviate from their steady state level. After the initial jump, the output decreases. Notice that output is then below its steady state level during the adjustment process, reflecting the crowding out effect of government debt. The real interest rate rises gradually and then starts to fall again. Inflation increases on impact, but then drops below its steady state value. Thus during the adjustment period, inflation is below its steady state level. Nominal interest rates go up on impact. These results can be explained as follows. As the economy is non-Ricardian, a tax reduction stimulates aggregate demand. For this reason total consumption jumps upwards on impact and then starts to decline. As prices are sticky, output also jumps on impact and then starts to decrease. At the same time, the real interest rate increases gradually in order to balance the securities market. After the shock, the nominal interest rate increases, then slips below its steady state level along the adjustment path. This is consistent with the behavior of the inflation rate. Consider now the effects on markups. Here the elasticity effect dominates the intertemporal effect. Indeed, markups decrease on impact, despite the increase in the real interest rate. In fact, higher aggregate demand entails higher elasticity of demand, implying lower markups. But, as long as real interest rates rise and output decreases, the intertemporal effect on markups starts to dominate the elasticity effect, implying an increase in markup below its steady state level. It is clear that the introduction of the sticky prices assumption restores the short-run expansionary effect of fiscal policy.

Moreover, we notice from Figure 5b that nominal interest rate smoothing strengthens the short-run expansionary effect. In fact, the real interest rate declines, strengthening the intertemporal effect on the markup and so the output increases more. The reason is the following. The increase in the nominal interest rate in response to the first period increase in inflation is smoothed over time. As the first period increase in the nominal interest rate is not sufficient to balance the Fisher equation, the real interest rate decreases. Consequently, markup declines more, entailing higher employment, output

and consumption.

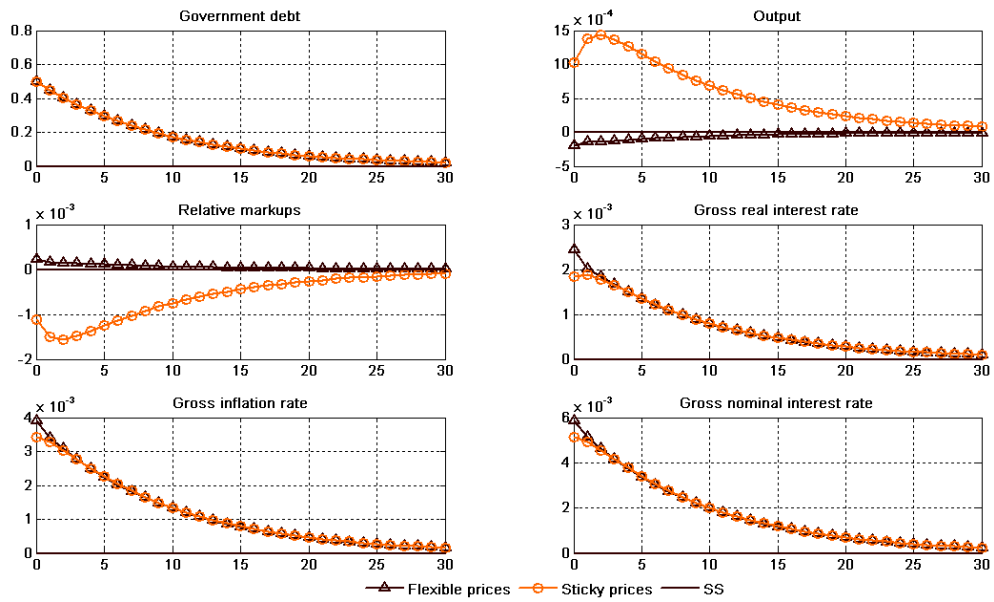


Figure 5a: Temporary shock.

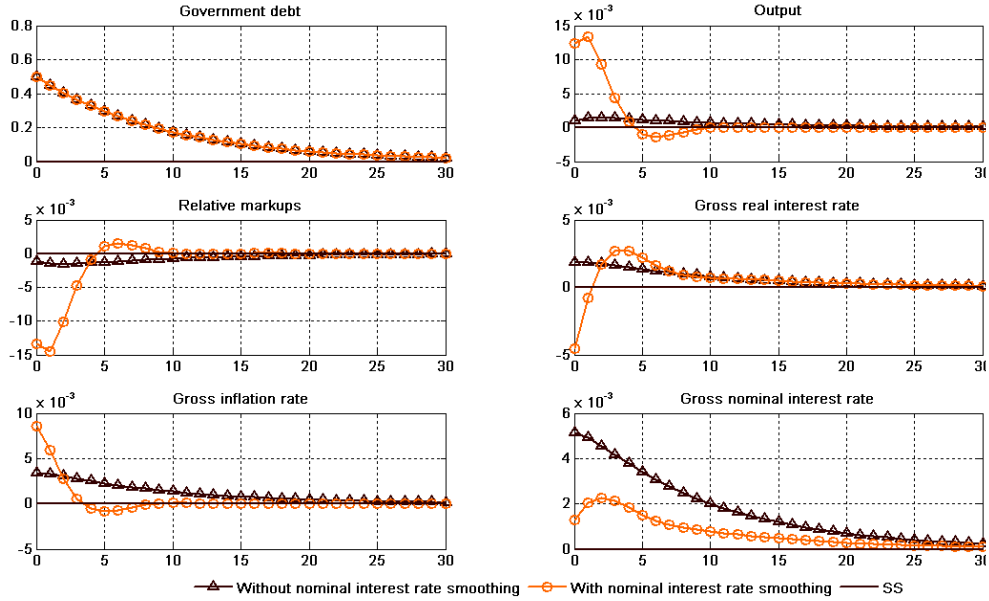


Figure 5b: Temporary shock.

## 7 Conclusion

The goal of this paper is to merge two recent strands in the macroeconomic literature: the OLG framework and time-varying markups. Our principal motivation in adopting the OLG approach is to break down Ricardian equivalence in order to study the impact of government debt on macroeconomic aggregates. We develop an extended stochastic version of overlapping generations based on Weil (1987) with a monopolistically competitive structure, endogenous labor supply, and where agents' preferences feature external habit formation.

The main contribution of this paper is to provide a new transmission mechanism of public debt through the countercyclical markup movements induced by external deep habits. We show that, when prices are sticky, debt-financed lump-sum fiscal policy is expansionary in the short run and contractionary in the long run.

Rather than reiterating the rest of our findings, let us briefly indicate some possible extensions of this model. One is to introduce monetary policy. It is worthwhile analyzing the interaction between monetary and fiscal policy

in such a framework. In addition, given the recent economic crisis, such a model may be a useful tool to explore the role of government debt and deficits in an economy constrained by the zero lower bound on nominal interest rates.

# Appendix 1

## Optimality conditions for the consumer

Here we present the optimality conditions for the agents  $j$ .

### 1 The demand function of good $m$

The household  $j$  minimizes total expenditure  $\sum_{m=1}^{M_t} p_t(m) c_{j,t}(m)$  subject to the aggregate constraint

$$x_{j,t} = M_t^{\frac{1}{1-\varepsilon}} \left( \sum_{m=1}^M (c_{j,t}(m) - \phi \tilde{c}_{t-1}(m))^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad (\text{A1.1})$$

where  $p_t(m)$  denotes the relative price of good  $m$  at time  $t$ .

The Lagrangian for this problem is:

$$\min \sum_{m=1}^{M_t} p_t(m) c_{j,t}(m) + \zeta_t \left( x_{j,t} - M_t^{\frac{1}{1-\varepsilon}} \left( \sum_{m=1}^{M_t} (c_{j,t}(m) - \phi \tilde{c}_{t-1}(m))^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}} \right)$$

where  $\zeta_t$  is the Lagrange multiplier.

The first order conditions of this problem for  $c_{j,t}(m)$  and  $\zeta_t$  are:

$$\frac{p_t(m)}{\zeta_t} = M_t^{\frac{1}{1-\varepsilon}} (c_{j,t}(m) - \phi \tilde{c}_{t-1}(m))^{-\frac{1}{\varepsilon}} \left( \sum_{m=1}^{M_t} (c_{j,t}(m) - \phi \tilde{c}_{t-1}(m))^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{1}{\varepsilon-1}}, \quad (\text{A1.2})$$

$$x_{j,t} = M_t^{\frac{1}{1-\varepsilon}} \left( \sum_{m=1}^{M_t} (c_{j,t}(m) - \phi \tilde{c}_{t-1}(m))^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}}. \quad (\text{A1.3})$$

Rearranging (A1.2) using (A1.3) yields:

$$c_{j,t}(m) = \frac{1}{M_t} \left( \frac{p_t(m)}{\zeta_t} \right)^{-\varepsilon} x_{j,t} + \phi \tilde{c}_{t-1}(m). \quad (\text{A1.4})$$

From the definition of the composite level of consumption (A1.1), this implies

$$\zeta_t = \left( \frac{1}{M_t} \sum_{m=1}^M (p_t(m))^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}.$$

We define  $P_t$  as a price index which verifies:

$$P_t c_t = \sum_{m=1}^M P_t(m) \sum_{j \leq t} (N_j - N_{j-1}) c_{j,t}(m),$$

where  $P_t(m)$  is the nominal price of good  $m$ . The accounting definition of  $c_t$  is given by

$$c_t = M_t^{\frac{1}{1-\varepsilon}} \left( \sum_{m=1}^M c_t(m)^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}},$$

which combined with (A1.2) and (A1.4) allows us to write:

$$P_t = \left( \frac{1}{M_t} \sum_{m=1}^M (P_t(m))^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}.$$

Assuming that the price index equals one, the optimal level of  $c_{j,t}(m)$  for  $m \in [1, M_t]$  is given by

$$c_{j,t}(m) = \frac{1}{M_t} (p_t(m))^{-\varepsilon} x_{j,t} + \phi \tilde{c}_{t-1}(m). \quad (\text{A1.5})$$

Moreover we multiply (8) by  $p_t(m)$

$$p_t(m) c_{j,t}(m) = \frac{1}{M_t} p_t(m)^{1-\varepsilon} x_{j,t} + \phi p_t(m) \tilde{c}_{t-1}(m),$$

then we sum the resulting equation over the variety goods  $m$ , which yields

$$\sum_{m=1}^M p_t(m) c_{j,t}(m) = \frac{1}{M_t} \sum_{m=1}^M p_t(m)^{1-\varepsilon} x_{j,t} + \phi \sum_{m=1}^M p_t(m) \tilde{c}_{t-1}(m).$$

Finally, using the definition of the price index, we obtain

$$x_{j,t} = \sum_{m=1}^M p_t(m) c_{j,t}(m) - \phi \sum_{m=1}^M p_t(m) \tilde{c}_{t-1}(m). \quad (\text{A1.6})$$

## 2 The individual Euler equation

We build the following Lagrangian function corresponding to the consumer's program:

$$E_t \sum_{s=t}^{\infty} \beta^{s-t} \ln(x_{j,s} - d(l_{j,s})) - \rho_s \left( x_{j,s} + \phi \sum_{m=1}^M p_s(m) \tilde{c}_{s-1}(m) - v_{j,s} - w_s l_{j,s} + \tau_{j,s} - \psi_{j,s} + q_{t,s+1} v_{j,s+1} \right)$$



where  $\lambda_t$  is a Lagrange multiplier.

The first order conditions of this problem for  $x_{j,t}$ ,  $l_{j,t}$ ,  $v_{j,t+1}$  and  $\rho_t$  are:

$$\frac{1}{x_{j,t} - d(l_{j,t})} = \rho_t, \quad (\text{A1.7})$$

$$-\frac{d_l(l_{j,t})}{x_{j,t} - d(l_{j,t})} = -\rho_t w_t, \quad (\text{A1.8})$$

$$E_t q_{t,t+1} \rho_t = \beta \rho_{t+1}, \quad (\text{A1.9})$$

$$x_{j,t} + \phi \sum_{m=1}^M p_t(m) \tilde{c}_{t-1}(m) + E_t q_{t,t+1} v_{j,t+1} = v_{j,t} + l_{j,t} - \tau_{j,t} + \psi_{j,t}. \quad (\text{A1.10})$$

Eliminating  $\rho_t$  by combining (A1.7) and (A1.9), we obtain the individual Euler equation:

$$\beta \frac{(x_{j,t} - d(l_{j,t}))}{x_{j,t+1} - d(l_{j,t+1})} = q_{t,t+1}. \quad (\text{A1.11})$$

Then we combine (A1.7) and (A1.8) to get the labor supply function:

$$d_l(l_{j,t}) = w_t. \quad (\text{A1.12})$$

Let us call  $a_{j,t} (\equiv x_{j,t} - d(l_{j,t}))$  the "adjusted consumption" of agent  $j$ , (A1.11) is rewritten:

$$a_{j,t} = \beta^{-1} q_{t,t+1} a_{j,t+1}. \quad (\text{A1.13})$$

## Appendix 2

### Aggregation

We remember that individual "adjusted" consumption is defined by:

$$a_{j,t} = (1 - \beta) (v_{j,t} + h_t - \chi_t). \quad (\text{A2.1})$$

Iterating the equation (A2.1) once:

$$a_{j,t+1} = (1 - \beta) (v_{j,t+1} + h_{j,t+1} - \chi_{t+1}), \quad (\text{A2.2})$$

then introducing

$$a_{j,t} = \beta^{-1} q_{t,t+1} a_{j,t+1}$$

into (A2.2) leads to:

$$a_{j,t} = (1 - \beta) \beta^{-1} q_{t,t+1} (v_{j,t+1} + h_{j,t+1} - \chi_{t+1}).$$

Now, aggregating this last equation, and using the fact that  $h_{j,t+1}$  is age independent, yields:

$$a_t = (1 - \beta) \beta^{-1} q_{t,t+1} ((1 + n) v_{t+1} + h_{t+1} - \chi_{t+1}). \quad (\text{A2.3})$$

In addition, aggregating (A2.2) yields:

$$a_{t+1} = (1 - \beta) (v_{t+1} + h_{t+1} - \chi_{t+1}). \quad (\text{A2.4})$$

Finally, we obtain the aggregate Euler equation

$$a_t = \beta^{-1} q_{t,t+1} a_{t+1} + n (\beta^{-1} - 1) q_{t,t+1} v_{t+1}$$

by combining (A2.3) and (A2.4).

## Appendix 3

### Optimality conditions for the firm

The Lagrangian function corresponding to the firm's problem is:

$$E_t \sum_{s=t}^T q_{t,s} (p_s(m) y_s(m) - w_s y_s(m)) - \lambda_s(m) \left( y_s(m) - (p_s(m))^{-\varepsilon} \frac{N_s}{M_s} x_s - \phi(1+n) y_{s-1}(m) \right).$$

The first order conditions of this problem for  $y_t$ ,  $p_t$ , and  $\lambda_t$  are:

$$p_t(m) - w_t - \lambda_t(m) + \phi(1+n) E_t q_{t,t+1} \lambda_{t+1}(m) = 0, \quad (\text{A3.1})$$

$$y_t(m) = \varepsilon \lambda_t(m) \frac{N_t}{M_t} x_t (p_t(m))^{-\varepsilon-1}, \quad (\text{A3.2})$$

$$y_t(m) = (p_t(m))^{-\varepsilon} \frac{N_t}{M_t} x_t + \phi(1+n) y_{t-1}(m) \quad (\text{A3.3})$$

Let

$$\eta_t(m) \equiv \frac{p_t(m) - w_t(m)}{p_t(m)} \quad (\text{A3.4})$$

denote the relative markup charged by firm  $m$ . Let us define  $\epsilon_t$  as the elasticity of demand:

$$\epsilon_t \equiv \varepsilon \left( 1 - \phi(1+n) \frac{y_{t-1}(m)}{y_t(m)} \right).$$

Equation (A3.2) becomes:

$$\lambda_t(m) = \frac{p_t(m)}{\epsilon_t(m)}$$

and equation (A3.1) becomes:

$$\epsilon_t(m)^{-1} = \eta_t(m) + \phi(1+n) E_t q_{t,t+1} \epsilon_{t+1}(m)^{-1}. \quad (\text{A3.5})$$

## Appendix 4

### Steady state

The aim of this appendix is to prove the existence and the uniqueness of the steady state equilibrium. The steady state system consists of the following main equations:

$$\mathfrak{R}(y) = \beta^{-1} + \gamma \frac{\bar{b}}{a}, \quad (\text{A4.1})$$

$$\Upsilon(R) = \left[ \left( 1 - \frac{1 - \frac{\tilde{\phi}}{R}}{\varepsilon(1 - \tilde{\phi})} \right) \alpha^{-1} \right]^\sigma, \quad (\text{A4.2})$$

with

$$a = (1 - \tilde{\phi})y - \alpha \frac{y^{1 + \frac{1}{\sigma}}}{1 + \frac{1}{\sigma}},$$

where  $\tilde{\phi} = \phi(1 + n)$  and  $\gamma = n(\beta^{-1} - 1)$ . First,  $a$  must be positive, because otherwise preferences are undefined. This implies the following necessary condition

$$0 < y < \bar{y} \equiv \left[ \frac{(1 - \tilde{\phi})(1 + \frac{1}{\sigma})}{\alpha} \right]^\sigma. \quad (\text{A4.3})$$

Second, we notice from (A4.2) that  $y$  cannot be less than  $\underline{y}$ , defined by:

$$\underline{y} \equiv \left[ \frac{1 - \frac{\varepsilon^{-1}}{(1 - \tilde{\phi})}}{\alpha} \right]^\sigma = \lim_{R \rightarrow +\infty} \Upsilon(R). \quad (\text{A4.4})$$

According to (A4.4), (A4.3) becomes:

$$\underline{y} < \bar{y}, \quad (\text{A4.5})$$

that is

$$\Phi(\tilde{\phi}) \equiv d\tilde{\phi}^2 + (1 - 2d)\tilde{\phi} + d + \varepsilon^{-1} - 1 > 0, \quad (\text{A4.6})$$

with  $d = 1 + \sigma^{-1}$ .

First,  $\Phi(\tilde{\phi})$  is always positive for  $0 < \sigma < 4(\varepsilon - 4)^{-1}$ . In fact, the discriminant of  $\Phi(\tilde{\phi})$  is negative, implying the positivity of  $\Phi(\tilde{\phi})$ , since  $\Phi(0) = \sigma^{-1} + \varepsilon^{-1} > 0$ .

Second, for  $\sigma > 4(\varepsilon - 4)^{-1}$ , the discriminant of  $\Phi(\tilde{\phi})$  is positive.  $\Phi(\tilde{\phi})$  is positive only for  $\tilde{\phi} \in [0, \tilde{\phi}_1] \cup (\tilde{\phi}_2, 1]$ , where  $\tilde{\phi}_1$  and  $\tilde{\phi}_2$  denote the roots of  $\Phi(\tilde{\phi})$ . i.e.

$$\tilde{\phi}_1, \tilde{\phi}_2 = \frac{2d-1}{2d} \mp \sqrt{\frac{\varepsilon-4d}{4\varepsilon d^2}}. \quad (\text{A4.7})$$

Now we have to check under which conditions the curves corresponding to (A4.1) and (A4.2), respectively, intersect in  $yR$ plane. So let us analyze  $\Upsilon(\cdot)$  and  $\Re(\cdot)$ . We observe that the inverse of the function,  $\Upsilon(\cdot)$ , is strictly decreasing as its derivative is strictly negative in  $(\underline{y}, +\infty)$ . On the other hand,  $\Re(y)$  is decreasing in  $(\underline{y}, y_{\min}]$  and increasing in  $[y_{\min}, \bar{y})$ . In fact, its derivative, i.e.

$$\Re_y(y) = \gamma \bar{b} \frac{y^{\frac{1}{\sigma}} - (1 - \tilde{\phi})}{\left( (1 - \tilde{\phi})y - \frac{y^{1+\frac{1}{\sigma}}}{1+\frac{1}{\sigma}} \right)^2}, \quad (\text{A4.8})$$

vanishes for

$$y_{\min} = (1 - \tilde{\phi})^\sigma$$

and is negative when  $y < y_{\min}$ , and positive when  $y > y_{\min}$ . Moreover, when  $y$  goes to zero,  $\Re(y)$  goes to infinity. In other words,  $\Re(y)$  admits a vertical asymptote for  $y = 0$ . We deduce that, if condition (A4.5) is satisfied, it is sufficient that  $\underline{y}$  is positive so that the two curves intersect once. In other words, the necessary and sufficient condition for the existence and the uniqueness of the steady state equilibrium is

$$0 < \underline{y} < \bar{y},$$

which can be rewritten as

$$\tilde{\phi} < \tilde{\phi}_{\max} \equiv (1 - \varepsilon^{-1}) \quad (\text{A4.9})$$

for  $\sigma < 4(\varepsilon - 4)^{-1}$  and

$$\tilde{\phi} \in [0, \tilde{\phi}_1] \cup (\tilde{\phi}_2, \tilde{\phi}_{\max}) \quad (\text{A4.10})$$

for  $\sigma > 4(\varepsilon - 4)^{-1}$ .

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