ANO 2008/10

Oslo

June 2008

Working Paper

Research Department

Fiscal shocks and real rigidities

by

Francesco Furlanetto and Martin Seneca

NORGES BANK

Working papers fra Norges Bank kan bestilles over e-post:
tjenestetorget@norges-bank.no
eller ved henvendelse til:
Norges Bank, Abonnementsservice
Postboks 1179 Sentrum
0107 Oslo
Telefon 22 31 63 83, Telefaks 22 41 31 05

Fra 1999 og senere er publikasjonene tilgjengelige som pdf-filer
på www.norges-bank.no, under "Publikasjoner".

Working papers inneholder forskningsarbeider
og utredninger som vanligvis
ikke har fått sin endelige form.
Hensikten er blant annet at forfatteren
kan motta kommentarer fra kolleger
og andre interesserte.

Synspunkter og konklusjoner i arbeidene
står for forfatternes regning.

Working papers from Norges Bank can be ordered by e-mail:
tjenestetorget@norges-bank.no
or from Norges Bank, Subscription service,
P.O.Box. 1179 Sentrum
N-0107Oslo, Norway.
Tel. +47 22 31 63 83, Fax. +47 22 41 31 05

Working papers from 1999 onwards are available as pdf-files on the bank's
web site: www.norges-bank.no, under "Publications".

Norges Bank's working papers present
research projects and reports
(not usually in their final form)
and are intended inter alia to enable
the author to benefit from the comments
of colleagues and other interested parties.

Views and conclusions expressed in working papers are
the responsibility of the authors alone.

ISSN 0801-2504 (trykt) 1502-8143 (online)

ISBN 978-82-7553-443-7 (printed), 978-82-7553-444-4 (online)

Fiscal shocks and real rigidities*

Francesco Furlanetto† Martin Seneca‡

Norges Bank University of Aarhus

June 2008

Abstract

In this paper we show that empirically plausible results on the effects of fiscal shocks in Galí, López-Salido and Vallés (2007) rely on a high degree of price stickiness and a large percentage of financially constrained agents. Real rigidities in the form of habit persistence, fixed firm-specific capital and Kimball demand curves interact in interesting ways with nominal and financial rigidities and allow us to reproduce the same consumption multiplier as Galí et al. (2007) under only two and a half quarters of price stickiness, instead of four, and only 30 per cent of constrained agents instead of 50 per cent. Therefore, real rigidities are useful in the study of fiscal shocks in addition to monetary and productivity shocks as has been shown in the previous literature.

JEL Classification: E32, E62.

Keywords: rule-of-thumb consumers, fiscal shocks, nominal rigidities, real rigidities, firm-specific capital, habit persistence, Kimball demand curves.

*We thank (without implicating) Maarten Dossche, Jordi Galí, Gisle Natvik, Bo Sandemann Rasmussen and Tommy Sveen for useful comments and discussion. Martin Seneca thanks Danmarks Nationalbank for financial support.

†Norges Bank, PO Box 1179, Sentrum, 0107 Oslo, Norway. Email: francesco.furlanetto@norges-bank.no. Telephone: +47-22316128. Telefax: +47-22424062. Website: www.norges-bank.no/research/furlanetto/

‡Corresponding author: School of Economics and Management, University of Aarhus, 8000 Aarhus C, Denmark. Telephone: +45-89422140. Email: mseneca@econ.au.dk. Website: seneca.dk

1 Introduction

One of the most important developments in modern macroeconomics has been the replacement of traditional ad hoc models with dynamic stochastic general equilibrium (DSGE) models in economic policy analysis. In the New Keynesian DSGE literature, the bulk of the contributions have focused on monetary policy issues. But recently, a number of authors have begun to investigate the responses of key macroeconomic variables to fiscal shocks in the class of DSGE models with imperfect competition and nominal rigidities.

In a noteworthy example, Galí et al. (2007) show that nominal rigidities in combination with deviations from Ricardian equivalence can explain empirically observed responses to government spending shocks, while responses in the baseline real business cycle (RBC) model are in contrast with the empirical evidence. In particular, a number of recent empirical papers suggest that private consumption increases following a positive shock to government consumption.[1] While the RBC model predicts a decline in private consumption following such a shock, cf. Baxter and King (1993), private consumption may rise after a positive shock to government spending in the sticky-price model of Galí et al. (2007) if so-called rule-of-thumb consumers, who simply consume their current disposable income each period, are allowed to co-exist with intertemporally optimising consumers.[2] In the model, intertemporally optimising consumers decrease their consumption following a government spending shock because they correctly anticipate a decline in future income as a consequence of taxation. But rule-of-thumb consumers increase their consumption because their current income increases. Under the necessary auxiliary assumptions of sticky prices, monopolistic competition in the labour market and deficit financing, if a sufficiently

[1] See, for example, Blanchard and Perotti (2002), Caldara and Kamps (2007), Fatas and Mihov (2002), Galí et al. (2007) and Perotti (2005).

[2] Alternative approaches with similar objectives can be found in Bouakez and Rebei (2007), Linnemann and Shabert (2005), Linnemann (2006), López-Salido and Rabanal (2006) and Ravn, Schmitt-Grohé and Uribe (2007).

large fraction of households behave according to a rule of thumb, aggregate consumption rises.

A potential weakness of the rule-of-thumb theory of consumption is that both the degree of nominal rigidity and the fraction of rule-of-thumb consumers needed to generate a positive response of consumption is uncomfortably high given the recent empirical literature. In the baseline calibration in Galí et al. (2007), the expected duration of prices is set at one year, and half the consumers in the economy choose how much to consume by following a simple rule of thumb. Recent microeconomic evidence, however, points to two or three quarters of expected price duration, e.g. Bils and Klenow (2004) and Nakamura and Steinsson (2007), and several studies arrive at estimates of the percentage of rule-of-thumb consumers that are much lower than the 50 per cent originally suggested by Mankiw (2000). For instance, Campbell and Mankiw (1991) obtain 35 per cent for the US and 20 per cent for the UK, while Banerjee and Batini (2003) find 26 per cent for the US and 15 per cent for the UK.

The values of these parameters are crucial in the Galí et al. (2007) model. Once they are lowered to more realistic values (say, 2.5 quarters of price stickiness and 30 per cent of constrained agents as in our benchmark), the main result in Galí et al. (2007), i.e. that a model with rule-of-thumb consumers can generate a positive response of consumption following a government spending shock, is lost.

The main objective of this paper is to reconcile the evidence on these structural characteristics of the economy with the empirical responses of private consumption to a government spending shock. We show that this can be done by adding a number of what we consider to be realistic features to the model developed by Galí et al. (2007) to lower its dependence on price stickiness and households that do not take part in financial markets so as to smooth consumption.[3] The features we consider

[3]The idea that a fraction of households follow the simple rule of thumb that they consume their current disposable income each period, while the remaining fraction solve an intertemporal optimisation problem, was first put forward in the empirical consumption literature as an alternative to the permanent income hypothesis, see in particular Hall (1978) and Campbell and Mankiw (1989). We emphasise the interpretation that some households follow a rule of thumb because a financial

are real rigidities in the form of habit persistence in consumption, non-constant elasticities of demand, and fixed firm-specific capital.[4] Each of these rigidities has proven to be very useful in DSGE analyses in explaining empirical regularities of the transmission of other shocks, especially monetary shocks, see e.g. Christiano et al. (2005), Smets and Wouters (2003) and Woodford (2003), and productivity shocks, e.g. Francis and Ramey (2005) and Furlanetto and Seneca (2007). But their implications for the propagation of fiscal shocks have not been thoroughly analysed so far. This, in itself, provides a second motivation for this paper. Before giving a preview of the results, we briefly discuss each of these rigidities in turn.

The idea that habits may influence households' consumption behaviour grew out of the attempts in the mid-20th century empirical demand theory to explain the importance of lagged dependent variables in estimated demand functions, see e.g. Brown (1952), or the discussions of this literature in Deaton and Muellbauer (1980) and Deaton (1992). More recently, habit formation has been introduced into policy-oriented general equilibrium models following the specification in the asset pricing model by Abel (1990), in which utility today depends on consumption today relative to consumption in previous periods. For an example, see Christiano et al. (2005). In our model, habit persistence is important because it smooths the negative response of optimising households to a government spending shock. Hence, a smaller fraction of rule-of-thumb consumers is needed to generate a plausible response of aggregate consumption.

The second source of real rigidity that we introduce into the model is demand functions with non-constant elasticity of demand of the sort suggested by Kimball (1995). This represents a modification of the formalisation of monopolistic com-

friction bars them from participating in financial and capital markets. Alternatively, rule-of-thumb consumers may choose not to do so because of myopia or extreme impatience.

[4] We refer to all these three features as real rigidies to separate them conceptionally from the nominal rigidities that act as direct impediments to the adjustment of nominal variables, and from the financial constraint represented by rule-of-thumb consumers. Hence, our definition includes both the rigidities that work as direct impediments to the adjustment of real variables, and the 'real rigidities' of Ball and Romer (1990), the presence of which characterises an economy with strategic complementarity in price setting, cf. the discussion in Woodford (2003, ch. 3).

petition by Dixit and Stiglitz (1977) that has become standard in macroeconomics following the seminal paper by Blanchard and Kiyotaki (1987). The relative demand for an individual good is still decreasing in the relative price, but the elasticity – and hence the desired mark-up over marginal costs of the price-setting firm that produces it – now depend on its relative output. This induces a potential source of strategic complementarity in price setting in the model as discussed by Kimball (1995) and Woodford (2003, ch. 3). If the elasticity of demand falls with relative output, for instance, a firm that reduces its price will moderate its price reduction because the increase in demand it induces increases the desired mark-up. In this case, the firm is more reluctant to change prices away from the level charged by other firms in the economy that may not be changing their prices in any given period. In this way, the Kimball demand specification amplifies the effect of any nominal price rigidity that prevents some firms from adjusting prices. This makes it possible to obtain realistic dynamics of key macroeconomic variables with lower degrees of nominal price stickiness as emphasised by Eichenbaum and Fisher (2007) and Levin et al. (2007).

Firm-specific capital is a relatively recent addition to the DSGE literature pioneered by Christiano (2005), Sveen and Weinke (2005) and Woodford (2005). The standard assumption in the literature is that firms rent perfectly mobile capital from households in a rental market. With firm-specific capital, in contrast, the economy's capital stock is owned by firms, and capital cannot be instantaneously reallocated across firms to equalise marginal costs. As argued, for instance, by Danthine and Donaldson (2002), the firm-specific capital assumption is probably the more appealing one in terms of realism.

For our purposes, the important implication of firm-specific capital is that it increases the strategic complementarity in price setting as described by Sveen and Weinke (2005) and Woodford (2005). For simplicity, we follow Coenen et al. (2007) by abstracting from the endogenous accumulation of firm-specific capital.[5] Instead,

[5]Similarly, some authors abstract from the endogenous capital accumulation process under the

we assume that each firm is endowed with a fixed level of the capital good as in Sbordone (2002), resulting in a production process with decreasing returns to labour. With this specification, we retain the important implication of firm-specific capital that firms cannot reallocate capital instantaneously across firms to equalise marginal costs.

As already mentioned, non-constant elasticities of demand and fixed firm-specific capital help us to reduce the degree of price stickiness in the model, according to the mechanism explained in Sveen and Weinke (2005), Eichenbaum and Fisher (2007) and Woodford (2005). However, these frictions are also useful to lower the percentage of rule-of-thumb consumers in the model and this effect is new in the literature. In fact, they imply a lower inflation response to a given change in the marginal cost which translates in a lower response by the monetary policy authority. A lower increase in the interest rate pushes-up optimising consumption, making the model less dependent on rule-of-thumb consumers.

Introducing the rigidities just described in the model developed by Galí et al. (2007) gives us this paper's main result: Real rigidities are useful not only in accounting for the economy's responses to monetary policy and productivity developments as has been emphasised in the existing literature, but also in accounting for responses to fiscal policy shocks. In particular, we arrive at an empirically plausible increase in private consumption following a government spending shock for a much lower degree of price rigidity and a much lower fraction of rule-of-thumb consumers than in Galí et al. (2007). With habit formation in consumption, fixed firm-specific capital and Kimball demand, we obtain the same consumption multiplier as in Galí et al. (2007) with two and a half quarters of expected price duration (as opposed to four) and 30 per cent of rule-of-thumb consumers (as opposed to 50). Thus, as in Furlanetto and Seneca (2007), we find an important role for the *interaction* of nominal, real and financial rigidities in realistically accounting for the empirical evidence on the response of a key macroeconomic variable to empirically important

rental market assumption, e.g. Erceg, Henderson and Levin (2000).

disturbances to the economy. Importantly, rule-of-thumb consumers remain essential to generate this result. An alternative perspective, then, is that the rule-of-thumb theory becomes more appealing in a setting that is probably more realistic than the one in which it was originally introduced.

The paper is organised as follows. In section 2, we present the model, and in section 3 the results. Section 5 gives a few concluding remarks.

2 The model

The model is a standard New Keynesian dynamic stochastic general equilibrium model augmented with habit persistence in consumption, Kimball (1995) demand curves and rule-of-thumb consumers. Except for the presence of real rigidities, the model is identical to Galí et al. (2007). The economy consists of a continuum of firms, a continuum of households, a continuum of labour unions, a central bank responsible for monetary policy, and a government collecting lump-sum taxes and issuing bonds to finance its expenditures. There is monopolistic competition in both goods and labour markets. In particular, there is a continuum of differentiated intermediate goods and a continuum of differentiated labour services. In the goods market, this leads to a downward-sloping demand curve for each intermediate good, and in the labour market it leads to a downward-sloping demand curve for each labour type.

A fraction λ of households are rule-of-thumb consumers - or 'spenders' in the terminology of Mankiw (2000). These consumers simply consume their respective disposable income each period. The remaining fraction $1 - \lambda$ of households are optimisers - or 'savers' - that have access to financial markets. Hence, they choose plans for consumption and bond holdings to maximise lifetime utility. Consumers are assumed to form habits in consumption. That is, the utility a household obtains from a given level of consumption in a given period depends on the level of consumption in that period relative to the level of consumption in the previous period. Wages

are set by unions each representing a differentiated type of labour service supplied by households. Wages are assumed to be flexible. That is, each union sets a new wage for its members each period to maximise an average of their utilities taking the effect of this wage on the members' budget constraints into account.

Each firm produces one of the differentiated intermediate goods. It does so by combining capital with a homogenous labour input constructed as a Dixit-Stiglitz aggregate of the differentiated labour services supplied by households. The firm sets its price according to a Calvo (1983) price-setting mechanism and stands ready to satisfy demand at the chosen price. The elasticity of the demand it faces depends on the level of output produced as in Kimball (1995). In particular, the elasticity of demand falls with the level of output. This is known to increase the degree of strategic complementarity in price-setting, cf. Woodford (2003, ch 3).

We consider two alternative assumptions concerning the structure of the capital market. Under the first assumption, the economy's capital stock is owned by the optimising households. In this case, firms rent the capital they employ in production in a common rental market, and capital can be reallocated across firms instantaneously. We allow for endogenous accumulation of capital under this assumption by letting households choose how much to invest in new capital each period. But we also assume that it is costly to adjust the capital stock. Consequently, the aggregate stock of capital is fixed in the limiting case where the capital adjustment cost goes to infinity. Rule-of-thumb consumers do not take part in the capital market. Under the second assumption, the capital stock is owned by firms, and capital cannot be reallocated across them. That is, capital is specific to individual firms. For simplicity, we abstract from endogenous capital accumulation and assume that the capital stock is fixed under this assumption. To encompass these two alternative assumptions on the structure of the capital market in the model, we define a dummy variable ι taking the value 1 under the rental market assumption and 0 when capital

is firm-specific[6], i.e.

$$\iota = \begin{cases} 1 & \text{if capital is owned by households} \\ 0 & \text{if capital is owned by firms} \end{cases}$$

Each period begins by the realisation of shocks to the economy. We concentrate on fiscal spending shocks and abstract from other shocks that may affect the economy.

2.1 Households

The instantaneous utility function of a household is given by

$$U_t^i = \frac{\left(C_t^i - h_i \bar{C}_{t-1}^i\right)^{1-\sigma} - 1}{1-\sigma} - \frac{\left(N_t^i\right)^{1+\varphi}}{1+\varphi} \tag{1}$$

where $i \in \{o, r\}$ denotes the type of household – optimising or rule-of-thumb – and $\bar{C}_{t-1}^i$ denotes aggregate consumption by households of type i at time t. The degree of habit in consumption is governed by the parameter h_i. With this specification, habit formation is external with respect to the household itself in the sense that the household ignores the effect of its current consumption choice on the lagged consumption term that enters the utility function in the next period. But habit formation is internal with respect to the type of household since the lagged consumption term is aggregate consumption by the class of households to which the household belongs as opposed to aggregate consumption by all households in the economy. In the limiting case where $h_i = 0$, there is no habit formation for a household of type i.

[6]Nothing, in principle, prevents this variable from taking intermediate values. This would correspond to an economy in which a share of the capital stock is owned by households and rented to firms, while the remaining share is firm-specific. We do not pursue this possibility here, though few things would change in the specification of the model.

An optimising household maximises expected lifetime utility given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U_t^o \tag{2}$$

where E_o is an operator representing expectations over all states of the economy conditional on period-0 information, and $\beta \in (0,1)$ is the subjective discount factor. Maximisation is subject to a sequence of flow budget constraints (and implicitly a no-Ponzi game condition):

$$P_t C_t^o + E_t \left(\Lambda_{t,t+1} B_{t+1}\right) = W_t N_t^o + B_t - P_t T_t^o + \iota \left(R_t^k K_t^o - P_t I_t^o\right) \tag{3}$$

where W_t is the nominal wage, P_t is the aggregate price index and T_t^o is the real lump-sum tax paid by optimising consumers. The left-hand side gives the allocation of resourses to consumption and a portfolio of bonds, $E_t \left(\Lambda_{t,t+1} B_{t+1}\right)$, where $\Lambda_{t,t+1}$ is the stochastic discount factor so that the risk-free interest rate is given by the relation $1 + R_t = \left(E_t \Lambda_{t,t+1}\right)^{-1}$. The right-hand side gives available resources as the sum of labour income, $W_t N_t^o$, initial financial wealth, B_t, less nominal lump-sum taxes paid to the government, $P_t T_t^o$. Finally, under the assumption that the economy's capital stock is owned by households, the household receives rent for its capital, $R_t^k K_t^o$, where R_t^k is the rental rate of the capital it owns, K_t^o, and allocates resources to investment, $P_t I_t^o$. Under this assumption, the household's capital evolves according to

$$K_{t+1}^o = (1-\delta) K_t^o + \phi \left(\frac{I_t^o}{K_t^o}\right) K_t^o \tag{4}$$

where δ is the rate of depreciation, and $\phi(.)$ is an adjustment cost function satisfying $\phi(\delta) = \delta$, $\phi' > 0$, $\phi'(\delta) = 1$ and $\phi'' \leq 0$.

The optimisation problem, according to which the household chooses plans for consumption and bond holdings, gives rise to a modified version of the well-known Euler equation which we state in log-linear form[7]:

[7] In general, lower case variables denote log-deviations from corresponding uppercase variables.

$$c_t^o = \frac{1}{1+h_o} c_{t-1}^o + \frac{1}{1+h_o} E_t c_{t+1}^o - \frac{1-h_o}{1+h_o} \frac{1}{\sigma} \left(r_t - E_t \pi_{t+1} \right) \tag{5}$$

Because of habit formation in consumption, the Euler equation now contains a term in lagged consumption. Note that this equation reduces to the standard Euler equation for $h_o = 0$. For $\iota = 0$, i.e. under the assumption that firms own the capital stock, this is the only first-order condition for optimising consumers. For $\iota = 1$, i.e. with a rental market for capital, the optimising household also chooses investment. As shown by Galí et al. (2007), the first-order conditions to this problem represent the dynamics of Tobin's q and its relation to investment, and their log-linear forms are given by

$$q_t = -\left(r_t - E_t \left[\pi_{t+1} \right] \right) + \left[1 - \beta \left(1 - \delta \right) \right] E_t \left[r_{t+1}^k - p_t \right] + \beta E_t \left[q_{t+1} \right] \tag{6}$$

$$i_t - k_t = \eta q_t \tag{7}$$

where $\eta = -1/\left(\phi'' \left(\delta \right) \delta \right)$.[8]

A rule-of-thumb household does not take part in financial or capital markets, and thus faces the following simple budget constraint regardless of the assumption on the ownership of capital:

$$P_t C_t^r = W_t N_t^r - P_t T_t^r \tag{8}$$

Here, C_t^r is the household's real consumption at time t, and N_t^r is the hours worked by the household in period t. As a rule-of-thumb household simply consumes its current income, consumption follows directly from the budget constraint. A first-order log-linear approximation around the steady state with constant consumption

Omission of time subscripts indicates steady-state variables.

[8] Note that i_t and k_t are the log-deviations from corresponding steady-state values of aggregate investment and capital, respectively, defined as $K_t = \left(1 - \lambda \right) K_t^o$ and $I_t = \left(1 - \lambda \right) I_t^o$.

equalised across households gives

$$c_t^r = \frac{WN}{PC}\left(w_t + n_t\right) - \frac{Y}{C}t_t^r \tag{9}$$

where omission of time subscripts indicates steady-state variables.[9]

Aggregate variables are given as simple weighted averages:

$$c_t = \lambda c_t^r + (1-\lambda)\, c_t^o \tag{10}$$

$$n_t = \lambda n_t^r + (1-\lambda)\, n_t^o \tag{11}$$

and

$$t_t = \lambda t_t^r + (1-\lambda)\, t_t^o \tag{12}$$

2.2 Labour unions

The economy has a continuum of unions $z \in [0,1]$ each representing a continuum of workers, a fraction $(1-\lambda)$ are optimising, and a fraction λ are rule-of-thumb consumers. Each union sets the wage rate for its members, who stand ready to satisfy firms' demand for their labour services at the chosen wage. The workers in a union provide the same type of labour (irrespective of their consumption behaviour) differentiated from the type of labour services provided by members of other unions. The labour service supplied by each union, $N(z)$, is a simple aggregate of its members' labour services. In turn, the labour entering the production function of any firm is a Dixit-Stiglitz aggregate of the labour services provided by the unions in the economy. Hence, the labour demand for a union's labour services is given by

$$N_t(z) = \left(\frac{W_t(z)}{W_t}\right)^{-\varepsilon_w} N_t \tag{13}$$

[9] We maintain the assumption that consumption is equalised across agents in the steady state to facilitate comparability with Galí et al. (2007). For an alternative approach, see Natvik (2008).

where $W_t(z)$ is the wage set by the union, and ε_w is the elasticity of labour demand.

Each period, a representative union chooses $W_t(z)$ to maximise the present value of an average of its members' current and future period utility functions, that is,

$$\max_{W_t(z)} E_t \sum_{k=0}^{\infty} \beta^{t+k} \left[\lambda U^r_{t+k} + (1-\lambda) U^o_{t+k} \right] \tag{14}$$

subject to the labour demand functions and the budget constraints of its members, thus taking the effect of the wage decision on the income of its members into account.

The first-order condition can be expressed in the form of Galí et al. (2007):

$$\left[\frac{\lambda}{MRS^r_t} + \frac{1-\lambda}{MRS^o_t} \right] = \frac{\varepsilon_w}{\varepsilon_{w-1}} \frac{W_t}{P_t} \tag{15}$$

where, now, the marginal rate of substitution is given by $MRS^i_t = \left(C^i_t - h_i C^i_t\right)^{\sigma} N^{\varphi}_t$ for $i \in \{o, r\}$ because of habit formation in consumption. As shown by Furlanetto and Seneca (2007), log-linearising this expression gives

$$w_t - p_t = \chi_r \left(c^r_t - h_r c^r_{t-1} \right) + \chi_o \left(c^o_t - h_o c^o_{t-1} \right) + \varphi n_t \tag{16}$$

where

$$\chi_r = \sigma \frac{\lambda}{1-h_r} \frac{(1-h_o)^{\sigma}}{\lambda (1-h_o)^{\sigma} + (1-\lambda)(1-h_r)^{\sigma}}$$

and

$$\chi_o = \sigma \frac{(1-\lambda)}{1-h_o} \frac{(1-h_r)^{\sigma}}{\lambda (1-h_o)^{\sigma} + (1-\lambda)(1-h_r)^{\sigma}}$$

2.3 Goods demand

The economy has a continuum of firms $j \in [0,1]$, each of which produces a differentiated product, $Y_t(j)$. The final good used in private and public consumption is an index of this continuum of intermediate goods. Following Kimball (1995) it is

defined implicitly by the relationship

$$\int_0^1 \mathcal{G}\left(X_t\left(j\right)\right) dj = 1 \tag{17}$$

where $X_t\left(j\right) = Y_t\left(j\right)/Y_t$ is relative demand, and $\mathcal{G}\left(.\right)$ is a function satisfying $\mathcal{G}\left(1\right) = 1$, $\mathcal{G}' > 0$ and $\mathcal{G}'' < 0$.

For a given level of consumption and investment, and for given prices, $P_t\left(j\right)$, expenditure minimisation leads to the following demand for firm j's product

$$X_t\left(j\right) = \tilde{\mathcal{G}}\left(\frac{P_t\left(j\right)Y_t}{\upsilon_t}\right) \tag{18}$$

where $\tilde{\mathcal{G}}\left(.\right)$ is the inverse function of $\mathcal{G}'\left(.\right)$ and υ_t is the Lagrange multiplier from the minimisation problem. If we define the price deflator P_t implicitly by

$$P_t Y_t = \int_0^1 P_t\left(j\right) Y_t\left(j\right) dj \tag{19}$$

we have

$$\upsilon_t = P_t Y_t \left(\int_0^1 \mathcal{G}'\left(X_t\left(j\right)\right) X_t\left(j\right) dj\right)^{-1} \tag{20}$$

Note that the assumption that $\mathcal{G}'' < 0$ implies that this demand function is downward-sloping. It follows that the price elasticity of demand is given by

$$\xi\left(X_t\left(j\right)\right) = -\frac{\mathcal{G}'\left(X_t\left(j\right)\right)}{\mathcal{G}''\left(X_t\left(j\right)\right) X_t\left(j\right)} \tag{21}$$

In log-linear terms, the demand function becomes

$$y_t\left(j\right) = -\bar{\xi}\left(p_t\left(j\right) - p_t\right) + y_t \tag{22}$$

where $\bar{\xi} = \xi\left(1\right)$.

In the special case where

$$\mathcal{G}\left(X_t\left(j\right)\right) = \left(X_t\left(j\right)\right)^{\frac{\epsilon-1}{\epsilon}} \tag{23}$$

(17) reduces to the more common Dixit-Stiglitz aggregator, which leads to a constant elasticity of substitution since, in this case, $\xi\left(X_t\left(j\right)\right) = \bar{\xi}$ for all $X_t\left(j\right)$. As is well-known, this leads to a constant desired mark-up of price-setting firms given by $\mu_p = \bar{\xi}/\left(\bar{\xi}-1\right)$. In the general Kimball specification, we allow the demand elasticity and hence the desired mark-up to vary with the level of output. For future reference define

$$\epsilon\left(X_t\left(j\right)\right) = \frac{\partial\xi\left(X_t\left(j\right)\right)}{\partial P_t\left(j\right)}\frac{P_t\left(j\right)}{\xi\left(X_t\left(j\right)\right)} \tag{24}$$

This is the own price elasticity of the elasticity of demand. In the steady state we have $\epsilon\left(1\right) = \bar{\epsilon}$. In the analysis, we employ the case where $\bar{\epsilon} > 0$, i.e., the case where the elasticity of demand is increasing in the price set by the firm, or equivalently decreasing in its relative output. This is known to increase the strategic complementarity in price setting as discussed in section 1.

2.4 Firms

Firm j produces according to the technology

$$Y_t\left(j\right) = \tilde{K}_t\left(j\right)^{\alpha} N_t\left(j\right)^{1-\alpha} \tag{25}$$

where $\tilde{K}\left(j\right)$ the capital used as input by firm j, $N_t\left(j\right)$ is the labour employed by the firm, and $0 < \alpha < 1$. When the capital is owned by the firms, we assume that all firms have identical endowments of capital and we normalise this level to 1. Denoting the household-owned capital employed in production by firm j by $K_t\left(j\right)$, we have in general that $\tilde{K}_t\left(j\right) = \left(K_t\left(j\right)\right)^{\iota}$. Note that real marginal costs are given

by

$$MC_t(j) = \frac{W_t/P_t}{(1-\alpha)\left(\tilde{K}_t(j)/N_t(j)\right)^{\alpha}} \tag{26}$$

When firms rent capital from households, i.e. when $\iota = 1$, cost minimisation implies that firm j will choose factor inputs such that

$$\frac{W_t}{R_t^k} = \frac{1-\alpha}{\alpha}\frac{K_t(j)}{N_t(j)} \tag{27}$$

Since all firms have to pay the same wage for the labour they employ, and the same rental rate for the capital they rent, it follows that marginal costs are equalised across firms under this assumption. In contrast, when $\iota = 0$ and capital is firm-specific, marginal costs will generally be different across firms.

We now turn to the firms' price-setting decisions. Each firm is allowed to set a new price, P_t^*, with a fixed probability $(1-\theta)$ as in Calvo (1983). This implies that the expected duration of prices is given by $(1-\theta)^{-1}$.The firm's decision is made to maximise the value of the firm to its owners, the optimising households, given by

$$\sum_{k=0}^{\infty} E_t\left\{\Lambda_{t,t+k}\left[P_t^* Y_{t+k}(j) - \Psi\left(Y_{t+k}(j)\right)\right]\right\} \tag{28}$$

where $\Psi(.)$ is the cost function, subject to its production function (25) and to the demand for its product given by (18).[10]

The following first-order condition represents the price-setting equation:

$$\begin{aligned}&\sum_{k=0}^{\infty}\theta_p^k E_t\left\{\Lambda_{t,t+k}Y_{t+k}(j)\left[P_t^*\left(1-\xi\left(X_{t+k}(j)\right)\right)\right]\right\}\\ &=\sum_{k=0}^{\infty}\theta_p^k E_t\left\{\Lambda_{t,t+k}Y_{t+k}(j)\left[\xi\left(X_{t+k}(j)\right)P_{t+k}MC_{t+k}(j)\right]\right\}\end{aligned} \tag{29}$$

[10] With rental capital, the cost function is the value function from the cost minimisation problem. With fixed firm-specific capital, the cost function is simply $W_{t+k}N_{t+k}(j)$ where the production function is used to substitute for $N_{t+k}(j)$.

where $MC_t(j)$ is firm j's real marginal cost given by (26).

From the log-linearisation of (29) we may derive the following New Keynesian Phillips curve for price inflation

$$\pi_t = \beta E_t \pi_{t+1} + \kappa m c_t \tag{30}$$

where the slope parameter κ is given by

$$\kappa = \frac{(1-\beta\theta)(1-\theta)}{\theta}\left(1 + \frac{\bar{\epsilon}}{\bar{\xi}-1} + (1-\iota)\frac{\alpha}{1-\alpha}\bar{\xi}\right)^{-1} \tag{31}$$

The derivation is sketched in appendix A. Note that κ is declining in both θ (the degree of nominal rigidity) and $\bar{\epsilon}$ (the curvature of the demand parameter). Also $\kappa|_{\iota=0} < \kappa|_{\iota=1}$. That is, the New Keynesian Phillips curve is flatter with fixed firm-specific capital than with rental capital.

2.5 Economic policy

The specification of economic policy follows Galí et al. (2007). The central bank controls the risk-free interest rate, which it sets according to a simple Taylor rule

$$r_t = r + \phi_\pi \pi_t \tag{32}$$

The government budget constraint is

$$P_t T_t + R_t^{-1} B_{t+1} = B_t + P_t G_t \tag{33}$$

the linearisation of which becomes

$$b_{t+1} = \beta(b_t + g_t - t_t) \tag{34}$$

where $b_t = (B_t/P_{t-1} - B/P)\,Y$, $g_t = (G_t - G)/Y$ and $t_t = (T_t - T)/Y$. Fiscal policy is given by the rule

$$t_t = \phi_b b_t + \phi_g g_t \tag{35}$$

Government spending (normalised by steady-state output and expressed in deviations from steady state) evolves exogenously according to the following first-order autoregressive process

$$g_t = \rho_g g_{t-1} + \varepsilon_t \tag{36}$$

where $0 < \rho_g < 1$ and ε_t is white noise with variance σ_ε^2. With this specification, the government finances the exogenous disturbances to its spending in any given period partly through taxes, partly through the issuance of bonds.

2.6 Equilibrium

Market clearing requires that

$$Y_t = C_t + I_t + G_t \tag{37}$$

In log-linear form, this becomes

$$y_t = \frac{C}{Y} c_t + \frac{I}{Y} i_t + g_t \tag{38}$$

3 The consumption multiplier

As in Galí et al. (2007), we analyse the effects of government spending shocks emphasising the response of private consumption. Specifically, we focus on the impact response of aggregate private consumption following a shock to government spending normalised to one per cent of the level of output in the steady state. We

refer to this impact response as the consumption multiplier. As shown by Galí et al. (2007), this impact multiplier is significantly above zero in the data.

3.1 The model without real rigidities

To set the scene, figure 1 shows the consumption multiplier as a function of the fraction of rule-of-thumb consumers, λ, and as a function of the degree of price rigidity, θ, in the model analysed by Galí et al. (2007). This is equivalent to the model in section 2 when $h_o = h_r = \bar{\varepsilon} = 0$ and $\iota = 1$. That is, it is a version of the model with a rental market for capital, without habit formation in consumption, and with a constant elasticity of demand. The calibration of the remaining parameters follows the baseline calibration in Galí et al. (2007). Hence, we consider a time period to be one quarter, and we set $\delta = 0.025$, $\alpha = 0.33$, $\sigma = \eta = 1$, $\beta = 0.99$, $\lambda = 0.5$, $\gamma_g = 0.2$, $\phi_\pi = 1.5$, $\phi_b = 0.33$, $\phi_g = 0.1$, $\bar{\xi} = 6$, $\rho_g = 0.9$ and $\varphi = 0.2$. Finally, in the baseline calibration $\lambda = 0.5$ and $\theta = 0.75$. Note for future reference that this baseline calibration gives a value of the consumption multiplier of approximately 1.2.

Consider the solid lines first. These lines show the consumption multiplier in the Galí et al. (2007) model as a function of λ (left panel) and θ (right panel) with the other parameters remaining as under the baseline calibration. We see that, keeping θ fixed at 0.75, the consumption multiplier is positive only for values of λ larger than 0.3. Similarly, keeping λ fixed at 0.5, the multiplier is positive only for values of θ above a critical value between 0.5 and 0.6 corresponding to between two and three quarters of expected price stickiness. Hence, if we lower one of these two key parameters from the value chosen under the baseline calibration to one that is more realistic given the empirical evidence described in section 1, the consumption multiplier is no longer positive.

Considering the dashed lines, we see that by lowering one of the two parameters to a more plausible value – $\theta = 0.6$ and $\lambda = 0.3$ respectively – we make it harder

to obtain a positive consumption multiplier for all values of the other parameter. For $\theta = 0.6$, the fraction of rule-of-thumb consumers needs to be close to 0.5 to drive the consumption multiplier above zero, and for $\lambda = 0.3$, the expected duration of prices must be longer than a year. Moreover, under our preferred calibration in which $\theta = 0.6$ and $\lambda = 0.3$ at the same time, the consumption multiplier is seen to be negative.

In sum, these pictures show that the positive response of consumption is a fragile result in two crucial dimensions. It relies on implausibly high values for the degree of nominal rigidity and the percentage of constrained agents. Our contribution is to provide a solution to this problem by reconciling a sizeable increase in consumption as in Gali et al. (2007) with reasonable values for the degree of nominal rigidity and the financial friction. We do this by adding real rigidities to the model.

3.2 Adding real rigidities

Motivated by the previous sensitivity analysis of the model in Galí et al. (2007), we now present responses from the model augmented with habit persistence, Kimball demand and fixed firm-specific capital. We set the fraction of rule-of-thumb consumers, λ, to 0.3 inspired by the empirical evidence discussed in section 1, and we set the degree of habit persistence of optimising households, h_o, equal to 0.85, a value which is within the range of values considered in the literature.[11] However, we let the degree of habit persistence of rule-of-thumb households be zero, that is, $h_r = 0$. This is to facilitate the interpretation that rule-of-thumb households are inherently different from optimising households by having an entirely static horizon.

The calibration of the curvature of the Kimball demand function, represented by $\bar{\varepsilon}$, is more difficult. As noted by Dossche et al. (2006), there is no agreement on what a plausible value might be for this parameter in the literature; estimates range from 1.3 (Bergin and Feenstra, 2000) to 471 (Kimball, 1995). In this section

[11] It falls between the value estimated by Christiano et al. (2005) and the one considered by Woodford (2003, ch. 5).

we therefore calibrate $\bar{\varepsilon}$ by fixing values for the slope of the New Keynesian Phillips curve, κ, and the degree of nominal rigidity, θ. This allows us to recover a value of $\bar{\varepsilon}$ implied by the expression for κ given in (31). We set θ at 0.6, cf. section 1, while we fix κ at 0.03 based on the reduced-form evidence on the slope of the New Keynesian Phillips curve in Galí et al. (2005) and Levin et al. (2007). The implied value of $\bar{\varepsilon}$ is 25.

It is possible that 25 is still too high a value for $\bar{\epsilon}$, at least according to the evidence provided by Dossche et al. (2006). They suggest that a value around 4 is more reasonable, though they find evidence of considerable variation across sectors. We note that we would need a higher value of $\bar{\epsilon}$ (around 40) if we had kept the rental capital assumption. This illustrates that different real rigidities may interact in the economy in a way that allows us to consider reasonable values for other parameters representing real and financial rigidities.[12] Similarly, if we are slightly less ambitious in bringing down the expected duration of prices, we may obtain a value of $\kappa = 0.03$ with $\bar{\epsilon} = 4$ in the version of our model with firm-specific capital. This requires us to accept an expected duration of prices of slightly more than 3 quarters instead of our benchmark $2\frac{1}{2}$, but still in the range of the plausible values according to Nakamura and Steinsson (2007).

Note that our calibration of κ implies a much flatter New Keynesian Phillips curve than in Galí et al. (2007), where $\kappa = 0.0858$. In the model without real rigidities, we would need a Calvo parameter of 0.85 to generate a slope of 0.03, clearly an unrealistic value given the empirical evidence available.

Figure 2 presents impulse responses to key macroeconomic variables under this calibration along with responses from the model by Galí et al. (2007).[13] The main result of our paper is that the responses of consumption are nearly identical in the two models. In both cases, we obtain a consumption multiplier of approximately

[12] The model's equilibrium dynamics for variables other than investment is not affected by the choice of assumption concerning the structure of the capital market. We therefore omit reporting of the impulse responses for the rental capital case with Kimball demand and habit formation.

[13] The responses reported here are in percentage deviations from steady state and so they differ slightly from the ones reported in Galí et al. (2007), which are normalised by steady-state output.

1.2. Hence, the introduction of real rigidities in the form of habit persistence in consumption, Kimball demand and fixed firm-specific capital allows us to generate the same consumption multiplier as in Galí et al. (2007) with an expected price duration of two and a half quarters (instead of four) and with only 30 per cent of financially constrained agents (instead of 50). The crucial difference between the two models is that, in the model with real rigidities, both the fraction of rule-of-thumb consumers and the degree of price rigidity are more in line with the empirical evidence.

Part of the explanation for our result is that, in the model with real rigidities, habit persistence works to mitigate the contractionary effect from Ricardian households by smoothing their response to the shock. Rule-of-thumb households still respond by increasing their consumption since the partial bond financing of the government spending shock makes current income go up. But with habit formation in consumption, optimising households need time to adjust to the lower level of consumption called for by the reduction in lifetime income that results from current *and* future taxation. This makes them reduce consumption less on impact of the shock. Though rule-of-thumb consumers now weigh less in the aggregate, the net effect on aggregate consumption is therefore unchanged.

This is not the only effect in play, however. With a relatively flat New Keynesian Phillips curve, a positive shock to government spending that increases firms' marginal costs by increasing aggregate demand in the economy has a smaller effect on inflation through the price-setting process. This makes the central bank respond by increasing interest rates less than in an economy with a steeper Phillips curve. This further moderates the negative consumption response of optimising consumers. It is the combination of habit formation in consumption and a less responsive demand effect through monetary policy that allows us to generate the same consumption multiplier as in Galí et al. (2007) for a lower percentage of rule-of-thumb consumers.

Importantly, the introduction of real rigidities that are known to increase the strategic complementarities in price setting, cf. Woodford (2003), allows us to reduce

the slope of the Phillips curve without increasing the degree of nominal rigidity. In contrast, our analysis is consistent with fixing θ at 0.6 in keeping with microeconomic evidence on the frequency of price changes. Note also from figure 2 that the responses of the other aggregate variables are also nearly identical in the models. The only exception, of course, is investment, which is constant by assumption in the model with firm-specific capital.[14]

The importance of habit formation for the consumption response can be seen from figure 3, in which we report the consumption multiplier as a function of h_o keeping $\kappa = 0.03$ (left panel), and κ keeping $h_o = 0.85$ (right panel) when $\lambda = 0.3$ (in contrast to the baseline $\lambda = 0.5$). Remaining parameters are at their baseline values. On the left panel it is seen that reducing the degree of habit persistence lowers the impact response of private consumption following a shock to government spending. In the extreme case without habit persistence, even if we allow for curvature in the demand curves by setting $\bar{\epsilon} = 25$ so that $\kappa = 0.03$ when $\theta = 0.6$, the consumption multiplier is small (albeit positive).

The right panel in figure 3 shows the consumption multiplier as a function of κ, the slope of the New Keynesian Phillips curve. As noted in section 2, this slope is inversely related to $\bar{\epsilon}$, meaning that κ goes from 0 to 0.1 as $\bar{\epsilon}$ goes from infinity to 0.1. That is, $\bar{\epsilon}$ declines as we move from left to right on the graph. When $\lambda = 0.3$ in the model with habit formation, we see that κ has to be close to 0.03 to generate a consumption multiplier close to 1.2. In particular, increasing the slope of the New Keynesian Phillips curve reduces the multiplier. For $\kappa = 0.0858$ as in the baseline calibration of Galí et al. (2007), we see that the multiplier falls to approximately 0.8 even when habit persistence curbs the contractionary effect from the 70 per cent of households that optimise intertemporally.

To summarise, we have shown that the empirically realistic consumption multi-

[14] As argued by Furlanetto (2007), the model in Galí et al. (2007) exhibits a counterfactually large response of the real wage. However, once he introduces a nominal wage rigidity that smoothes the wage response, the increase in consumption is confirmed. We have also considered a version of the model with real rigidities augmented with nominal wage rigidities. Results are qualitatively similar to the ones reported here. For sake of completeness, they are reported in appendix B.

plier obtained by Galí et al. (2007) with 50 per cent of rule-of-thumb consumers and 4 quarters of expected price stickiness, can be obtained for considerably lower values of these parameters once real rigidities are added to the model. Habit formation, which directly smoothes the adjustment of private consumption of intertemporally optimising households, reduces the negative response of optimising consumers for a given monetary policy response. When combined with real rigidities that amplify the implications of nominal rigidities, the contractionary response of monetary policy to the fiscal expansion is reduced even for considerably lower degrees of nominal rigidities. This further reduces the negative consumption response of optimising households. The combination of these effects allows us to generate the same positive consumption multiplier as in Galí et al. (2007) with a percentage of rule-of-thumb consumers given by 30 and an expected duration of price rigidities given by two and a half periods.

4 Concluding remarks

This paper shows that the rule-of-thumb theory of consumption does not rely on a high degree of nominal rigidity or a large financial friction when accounting for the conditional responses to government spending shocks. When empirically plausible real rigidities are added to the model, they interact with nominal and financial rigidities in ways that allow us to specify more reasonable parameter values for all the rigidities at work in the model. Hence, we believe that this paper complements the analysis in Galí et al. (2007) by showing how the rule-of-thumb consumption theory becomes more appealing once realistic features are added to the model.

Interestingly, the same combination of real rigidities that we apply has been used in the previous literature to replicate conditional responses to other shocks, especially monetary shocks and technology shocks. Habit persistence has been used to reproduce the hump-shaped response of output and consumption on the impact of a monetary shock, while Kimball demand curves and firm-specific capital have

been used to reconcile the microeconomic evidence on the degree of price rigidity with the macroeconomic evidence on the slope of the New Keynesian Phillips curve, cf. references in section 1. In a companion paper to this one, Furlanetto and Seneca (2007) show that the interaction of nominal, real and financial rigidities is also very helpful in accounting for the responses of hours worked following a productivity shock.

Thus, at a more general level, this paper contributes to this literature by showing how nominal and real rigidities may interact with a financial friction in ways that generate plausible dynamics following empirically important disturbances to the economy. We believe this is a further indication that, while the simple basic real business cycle framework is an important benchmark both conceptually and methodologically, a realistic model of the economy is likely to be one in which many frictions and rigidities interact. Providing further evidence on how this may occur – and not least further empirical evidence on the relative importance of these rigidities and frictions along the lines of Coenen and Straub (2005) and Forni, Monteforte and Sessa (2007) – is, we believe, an important topic for further research in macroeconomics.

A Appendix

The first-order condition to the price-setting problem is:

$$\sum_{k=0}^{\infty} \theta_p^k E_t \left\{ \Lambda_{t,t+k} Y_{t+k}(j) \left[P_t^* \left(1 - \xi\left(X_{t+k}(j)\right)\right) - \xi\left(X_{t+k}(j)\right) P_{t+k} MC_{t+k}(j) \right] \right\} = 0$$

We log-linearise this first-order condition to get

$$0 = E_t \sum_{k=0}^{\infty} \left(\theta_p \beta\right)^k \left[\left(1 - \bar{\xi}\right) p_t^* - \left(1 - \bar{\xi}\right) mc_{t+k}(j) - \left(1 - \bar{\xi}\right) p_{t+k} - \bar{\epsilon}\left(p_t^* - p_{t+k}\right) \right]$$

where we have substituted in log-linearisations of (21) and (18). Since

$$mc_{t+k}(j) = mc_{t+k} - (1 - \iota) \frac{\alpha}{1 - \alpha} \bar{\xi}\left(p_t^* - p_{t+k}\right)$$

where mc_{t+k} is the average marginal cost in log-linear terms, we get

$$\begin{aligned}
&\frac{1}{1 - \theta_p \beta} \left(1 + \frac{\bar{\epsilon}}{\bar{\xi} - 1} + (1 - \iota) \frac{\alpha \bar{\xi}}{1 - \alpha}\right) \left(p_t^* - p_{t-1}\right) \\
&= E_t \sum_{k=0}^{\infty} \left(\theta_p \beta\right)^k \left[\left(1 + \frac{\bar{\epsilon}}{\bar{\xi} - 1}\right) \left(p_{t+k} - p_{t-1}\right) + mc_{t+k} - (1 - \iota) \frac{\alpha \bar{\xi}}{1 - \alpha} \left(p_{t-1} - p_{t+k}\right) \right] \\
&= \left(1 + \frac{\bar{\epsilon}}{\bar{\xi} - 1} + (1 - \iota) \frac{\alpha \bar{\xi}}{1 - \alpha}\right) \pi_t + mc_t \\
&+ \frac{1}{1 - \theta \beta} \left(1 + \frac{\bar{\epsilon}}{\bar{\xi} - 1} + (1 - \iota) \frac{\alpha \bar{\xi}}{1 - \alpha}\right) E_t \left(p_{t+1}^* - p_t\right) \\
&+ \frac{\theta \beta}{1 - \theta \beta} \left(1 + \frac{\bar{\epsilon}}{\bar{\theta} - 1} + (1 - \iota) \frac{\alpha \bar{\theta}}{1 - \alpha}\right) \pi_t
\end{aligned}$$

As shown by Eichenbaum and Fisher (2007), the price index implies that

$$p_t^* - p_{t-1} = \frac{\pi_t}{1 - \theta}$$

Using this gives

$$\frac{\pi_t}{1-\theta} = (1-\theta\beta)\,\pi_t + (1-\theta\beta)\left(1+\frac{\bar{\epsilon}}{\bar{\xi}-1}+(1-\iota)\,\frac{\alpha\bar{\xi}}{1-\alpha}\right)^{-1} mc_t + \frac{\theta\beta}{1-\theta}E_t\pi_{t+1} + \theta\beta\pi_t$$

Rearranging gives the New Keynesian Phillips curve in the text:

$$\pi_t = \frac{(1-\theta\beta)\,(1-\theta)}{\theta_p}\left(1+\frac{\bar{\epsilon}}{\bar{\xi}-1}+(1-\iota)\,\frac{\alpha\bar{\xi}}{1-\alpha}\right)^{-1} mc_t + \beta E_t\pi_{t+1}$$

B Appendix

An unpleasant feature of the model presented in the previous section is that, independently of the presence of real rigidities, it implies a large increase in the real wage which is counterfactual. Many empirical studies – Blanchard and Perotti (2002), Perotti (2005), Fatas and Mihov (2002) among many others – find a zero response or at most a tiny positive response, in general not statistically significant. Furlanetto (2007) shows that by introducing sticky wages in the model, it is possible to reconcile a plausible conditional response of real wages and a positive and sizeable response of private consumption on the impact of a government spending shock. In other words, the Galí et al. (2007) result does not rely on the large counterfactual response of real wages, as one might intuitively think, but is confirmed in a more general setting with wage rigidities. For sake of completeness, we want to show that real rigidities can substitute for nominal and financial rigidities, also in a framework with sticky wages. As shown in Furlanetto and Seneca (2007), with sticky wages and habit formation in consumption, equation (15) is substituted by the following equation for wages

$$\pi_t^w = \beta E_t\left(\pi_{t+1}^w\right) + \kappa_w\left(mrs_t - (w_t - p_t)\right) \tag{39}$$

where mrs_t is the average marginal rate of substitution given by

$$mrs_t = \chi_r \left(c_t^r - h_r c_{t-1}^r \right) + \chi_o \left(c_t^o - h_o c_{t-1}^o \right) + \varphi n_t \tag{40}$$

and the slope coefficient κ_w is

$$\kappa_w = \frac{\varepsilon_w - 1}{\phi_w}$$

Here, ϕ_w governs the size of wage adjustment costs à la Rotemberg (1982).[15] We calibrate ε_w equal to 4 and ϕ_w equal to 454.5. This choice yields the same New Keynesian Phillips curve for wages as in a Calvo setting à la Erceg, Henderson and Levin (2000) with four quarters of wage stickiness.

A second criticism that can be raised to the Galí et al. (2007) model concerns the calibration of the inverse of the labor supply elasticity φ. Galí et al. (2007) are forced to set it at 0.2 to make the model determinate. However, the determinacy region is larger under sticky wages and therefore we can raise φ to more plausible values. We set φ equal to 3, consistent with a labor supply elasticity of 1/3, as in Galí and Monacelli (2005) and consistent with a considerable microeconomic evidence. In figure 4 we plot the impulse responses for the model in Galí et al. (2007) augmented with sticky wages along with a model further extended with real rigidities as in section 2 (Kimball demand and habit consumption, while keeping the rental capital assumption).

We see that the model with real rigidities can reproduce approximately the same multiplier as the model without real rigidities under only 30 percent of constrained agents. Thus, once again, real rigidities can substitute for nominal rigidities and financial frictions. Note also that real wages respond very little in both cases due to wage adjustment costs.

[15] Instead of wage adjustment costs, we may assume that a union is allowed to reset its wage rate each period with a fixed probability $1 - \theta_w$ as in Calvo (1983). But to undo the implications of the implied heterogeneity across unions, a risk-sharing arrangement between unions must be in place. This follows since rule-of-thumb consumers are barred from sharing risk through financial markets. Results, however, are very similar. In particular we would get a Phillips curve with $\kappa_w = (1 - \beta\theta_w)(1 - \theta_w)\theta_w^{-1}(1 + \varphi\varepsilon_w)^{-1}$ where θ_w is the Calvo parameter for wage setting.

References

[1] Abel, A.B., 1990. Asset prices under habit formation and catching up with the Joneses. American Economic Review 80, 38-42.

[2] Banerjee, R., Batini, N., 2003. UK Consumers' habits. Bank of England External MPC Unit Discussion Paper 13.

[3] Ball, L., Romer, D., 1990. Real rigidities and the non-neutrality of money. Review of Economic Studies 57, 183-230.

[4] Baxter, M., King, R., 1993. Fiscal policy in general equilibrium. American Economic Review 83, 315-334.

[5] Bergin, P., Feenstra, R., 2000. Staggered price setting, translog preferences and endogenous persistence. Journal of Monetary Economics 45, 657-680.

[6] Bils, M., Klenow, P., 2004. Some evidence on the importance of sticky prices. Journal of Political Economy 112, 947-985.

[7] Blanchard, O.J., Kiyotaki, N., 1987. Monopolistic competition and the effects of aggregate demand. American Economic Review, 77, 647-666.

[8] Blanchard, O., Perotti, R., 2002. An empirical characterization of the dynamic effects of changes in government spending and taxes on output. Quarterly Journal of Economics 117, 1329-68.

[9] Bouakez, H., Rebei, N., 2007. Why does private consumption rise after a government spending shock? Canadian Journal of Economics 40, 954-979.

[10] Brown, T.M., 1952. Habit persistence and lags in consumer behaviour. Econometrica 20, 355-371.

[11] Caldara, D., Kamps, C., 2007. What do we know about the effects of fiscal policy shocks? A Comparative Analysis. Stockholm University, mimeo.

[12] Calvo, G., 1983. Staggered prices in a utility maximizing framework. Journal of Monetary Economics 12, 383-398.

[13] Campbell, J., Mankiw, N.G., 1989. Consumption, income and interest rates: Reinterpreting the time series evidence. NBER Macroeconomics Annual 1989.

[14] Campbell, J., Mankiw, N.G., 1991. The response of consumption to income: A cross-country investigation. European Economic Review 35, 723-767.

[15] Christiano, Lawrence, 2005. Firm-specific capital and aggregate inflation dynamics in the Woodford model. Mimeo

[16] Christiano L.J., Eichenbaum, M., Evans, C., 2005. Nominal rigidities and the dynamic effects of a shock to monetary policy. Journal of Political Economy 113(1), 1-45.

[17] Coenen, G., Levin, A.T., Christoffel, K., 2007. Identifying the influences of nominal and real rigidities in aggregate price-setting behavior. Journal of Monetary Economics 54(8), 2439-2466.

[18] Coenen, G., Straub, R., 2005. Does government spending crowd in private consumption? Theory and empirical evidence for the euro area. International Finance 8, 436-470.

[19] Danthine, J.P., Donaldson, J., 2002. A note on NNS models: Introducing physical capital; avoiding rationing. Economic Letters 77, 433-437

[20] Deaton, A., 1992. Understanding consumption. Oxford: Oxford University Press.

[21] Deaton, A., Muellbauer, J., 1980. Economics and consumer behavior. Cambridge: Cambridge University Press.

[22] Dixit, A.K., Stiglitz, J.E., 1977. Monopolistic competition and optimum product diversity. American Economic Review 67, 297-308.

[23] Dossche, M., Heylen, F., Van den Poel, D., 2006. The kinked demand curve and price rigidity: Evidence from Scanner Data. Gent Universiteit Working Paper 2006/429.

[24] Eichenbaum, M., Fisher, J., 2007. Estimating the frequency of price re-optimization in Calvo-style models. Journal of Monetary Economics, 54(7), 2032-2047.

[25] Erceg, C.J., Henderson, D.W., Levin, A.T., 2000. Optimal monetary policy with staggered wage and price contracts. Journal of Monetary Economics 46(2), 381-413.

[26] Fatas, A., Mihov, I., 2002. Fiscal Policy and business cycles: An empirical investigation. INSEAD, mimeo.

[27] Forni, L., Monteforte, L., Sessa, L., 2007. The general equilibrium effects of fiscal policy: Estimates for the euro area. Banca d'Italia, Tema di discussione 652.

[28] Francis, N., Ramey, V.A., 2005. Is the technology-driven real business cycle hypothesis dead? Shocks and aggregate fluctuations revisited. Journal of Monetary Economics, 52, 1379-1399.

[29] Furlanetto, F., 2007. Fiscal shocks and the consumption response when wages are sticky. University of Lausanne, DEEP Working Paper 07.11.

[30] Furlanetto, F., Seneca, M., 2007. Rule-of-thumb consumers, productivity and hours. Danmarks Nationalbank Working Paper 48.

[31] Galí, J., Gertler, M., López-Salido, J.D., 2005. Robustness of the estimates of the hybrid New Keynesian Phillips curve. Journal of Monetary Economics 52, 1107-1118.

[32] Galí, J., López-Salido, J.D., Vallés, J., 2007. Understanding the effects of government spending on consumption. Journal of the European Economic Association, 5(1), 227-270.

[33] Hall, R.E., 1978. Stochastic implications of the life cycle-permanent income hypothesis: Theory and evidence. Journal of Political Economy 86, 971-987.

[34] Kimball, M., 1995. The quantitative analytics of the vasic neomonetarist model. Journal of Money, Credit and Banking 27, 1241-1277.

[35] Levin, A.T., López-Salido, J.D., Yun, T., 2007. Strategic complementarities and optimal monetary policy. Kiel Working Paper 1355.

[36] Linnemann, L., 2006. The effect of government spending on private consumption: a puzzle? Journal of Money, Credit and Banking 38, 1715-1736

[37] Linnemann, L., Schabert, A., 2006. Productive government expenditure in monetary business cycle models. Scottish Journal of Political Economy 53, 28-46.

[38] López-Salido, J.D., Rabanal, P., 2006. Government spending and consumption hours preferences. "La Caixa" Working Paper 02/2006.

[39] Mankiw, N.G., 2000. The savers-spenders theory of fiscal policy. American Economic Review 90, 120-125.

[40] Nakamura, E., Steinsson, J., 2007. Five facts about prices: A reevaluation of menu cost models. Harvard University, mimeo.

[41] Natvik, G., 2008. Government spending with rule-of-thumb consumers and steady state inequality. University of Oslo, mimeo.

[42] Perotti, R., 2005. Estimating the effects of fiscal policy in OECD countries. CEPR Working Paper 4842.

[43] Ravn, M., S. Schmitt-Grohé and M. Uribe, 2006. Deep habits. Review of Economic Studies 73, 195-218.

[44] Sbordone, A.M., 2002. Prices and unit labor costs: a new test of price stickiness. Journal of Monetary Economics, 49(2), 265-292.

[45] Smets, F., Wouters, R., 2003. An estimated dynamic stochastic general equilibrium model of the euro area. Journal of the European Economic Association 1(5), 1123-1175.

[46] Sveen, T., Weinke, L., 2005. New perspectives on capital, sticky prices, and the Taylor principle. Journal of Economic Theory 123, 21-39.

[47] Woodford, M., 2003. Interest and prices: Foundations of a theory of monetary policy. Princeton: Princeton University Press.

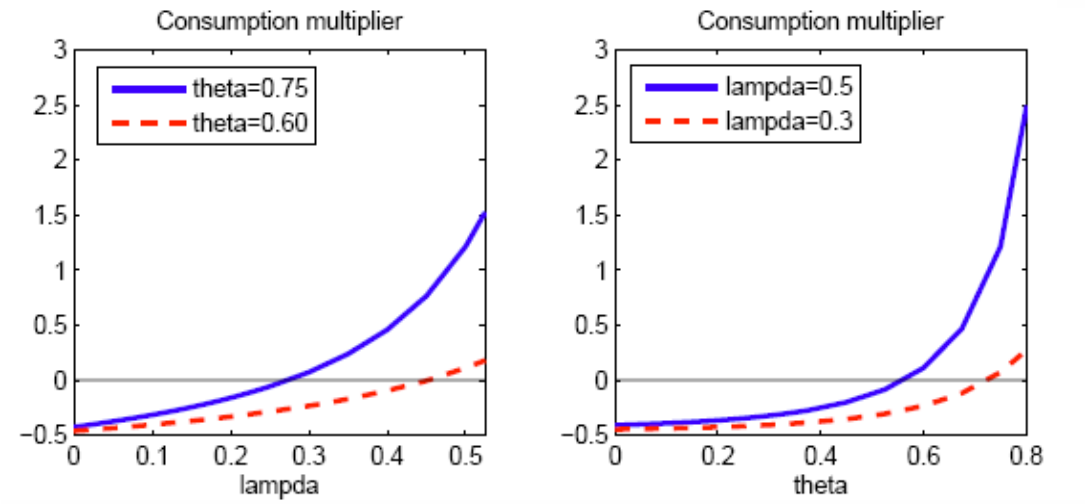

Figure 1: Impact consumption multiplier in the model by Galí et al. (2007) as function of λ, the fraction of rule-of-thumb consumers (left panel), and θ, the degree of price rigidity (right panel). Remaining parameters at baseline values.

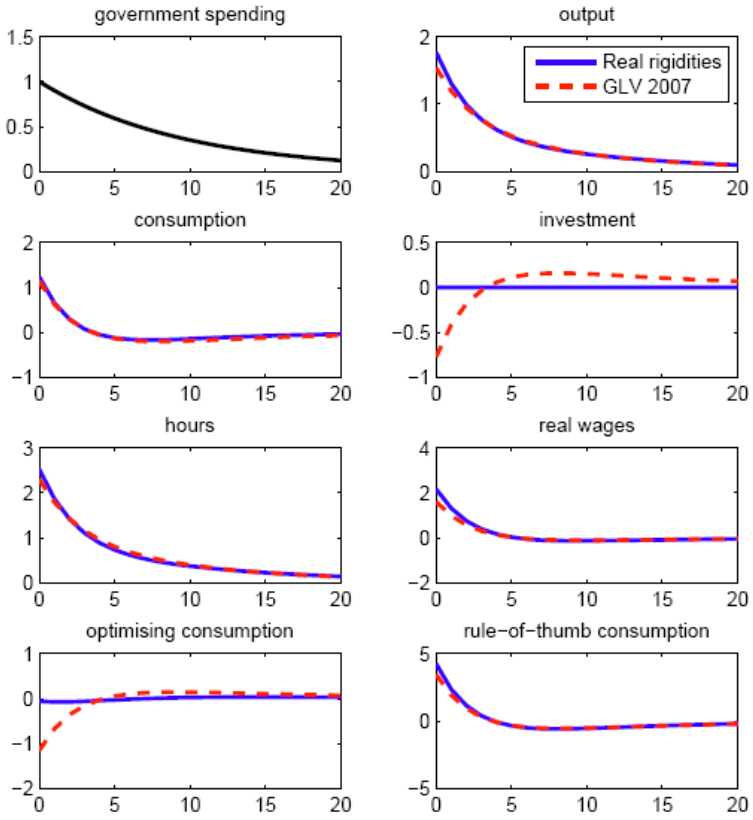

Figure 2: Impulse responses to a government spending shock normalised to one per cent of steady-state output for $\lambda = 0.5$ and $\theta = 0.75$ in the Galí et al. (2007) model (dashed lines), and for $\lambda = 0.3$ and $\theta = 0.6$ in an extended version of the model with real rigidities (solid lines).

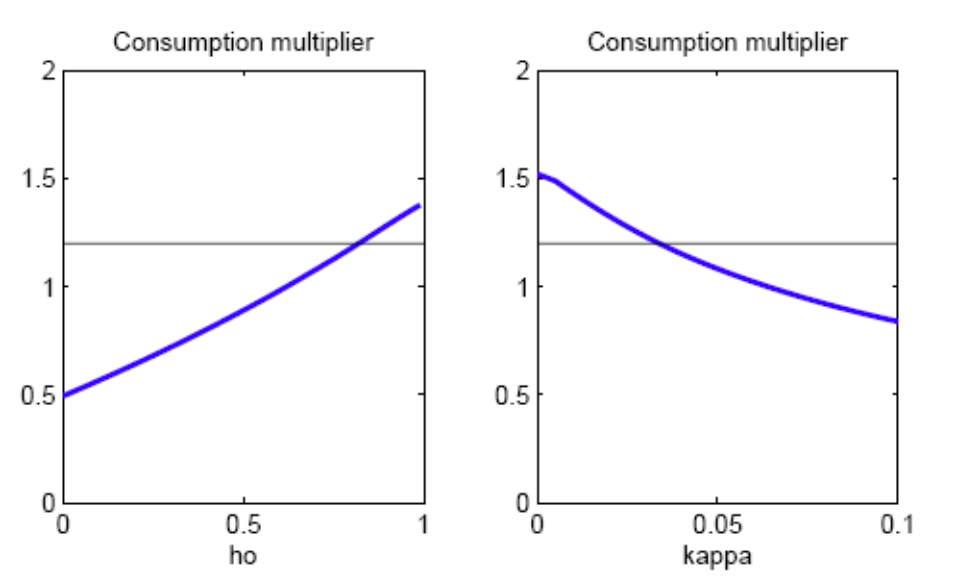

Figure 3: Impact consumption multiplier as a function of h_o, the degree of habit persistence of optimising households (left panel), and κ, the slope of the New Keynesian Phillips curve, for $\lambda = 0.3$ in the Galí et al. (2007) model augmented with real rigidities.

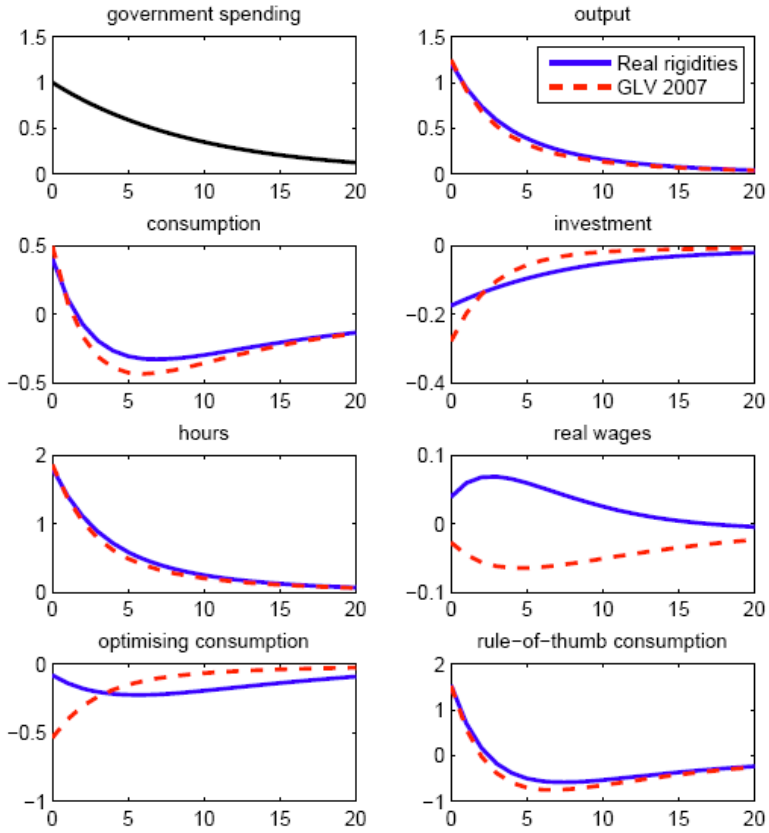

Figure 4: Impulse responses to a government spending shock normalised to one per cent of steady-state output for $\lambda = 0.5$ and $\theta = 0.75$ as in the Galí et al. (2007) model augmented with sticky wages (dashed lines), and for $\lambda = 0.3$ and $\theta = 0.6$ in an extended version with real rigidities in addition to sticky wages (solid lines).

WORKING PAPERS (ANO) FROM NORGES BANK 2004-2008

Working Papers were previously issued as Arbeidsnotater from Norges Bank, see Norges Bank's website http://www.norges-bank.no

2004/1 Tommy Sveen and Lutz Weinke
Pitfalls in the Modelling of Forward-Looking Price Setting and Investment Decisions
Research Department, 27 p

2004/2 Olga Andreeva
Aggregate bankruptcy probabilities and their role in explaining banks' loan losses
Research Department, 44 p

2004/3 Tommy Sveen and Lutz Weinke
New Perspectives on Capital and Sticky Prices Research Department, 23 p

2004/4 Gunnar Bårdsen, Jurgen Doornik and Jan Tore Klovland
A European-type wage equation from an American-style labor market: Evidence from a panel of Norwegian manufacturing industries in the 1930s Research Department, 22 p

2004/5 Steinar Holden and Fredrik Wulfsberg
Downward Nominal Wage Rigidity in Europe Research Department, 33 p

2004/6 Randi Næs
Ownership Structure and Stock Market Liquidity Research Department, 50 p

2004/7 Johannes A. Skjeltorp and Bernt-Arne Ødegaard
The ownership structure of repurchasing firms Research Department, 54 p

2004/8 Johannes A. Skjeltorp
The market impact and timing of open market share repurchases in Norway
Research Department, 51 p

2004/9 Christopher Bowdler and Eilev S. Jansen
Testing for a time-varying price-cost markup in the Euro area inflation process
Research Department, 19 p

2004/10 Eilev S. Jansen
Modelling inflation in the Euro Area Research Department, 49 p

2004/11 Claudia M. Buch, John C. Driscoll, and Charlotte Østergaard
Cross-Border Diversification in Bank Asset Portfolios Research Department, 39 p

2004/12 Tommy Sveen and Lutz Weinke
Firm-Specific Investment, Sticky Prices, and the Taylor Principle Research Department, 23 p

2004/13 Geir Høidal Bjønnes, Dagfinn Rime and Haakon O.Aa. Solheim
Liquidity provision in the overnight foreign exchange market Research Department, 33 p

2004/14 Steinar Holden
Wage formation under low inflation Research Department, 25 p

2004/15 Roger Hammersland
Large T and small N: A three-step approach to the identification of cointegrating relationships in time series models with a small cross-sectional dimension Research Department, 66 p

2004/16 Q. Farooq Akram
Oil wealth and real exchange rates: The FEER for Norway Research Department, 31 p

2004/17 Q. Farooq Akram
En effisient handlingsregel for bruk av petroleumsinntekter Forskningsavdelingen, 40 s

2004/18 Egil Matsen,Tommy Sveen and Ragnar Torvik
Savers, Spenders and Fiscal Policy in a Small Open Economy Research Department, 31 p

2004/19 Roger Hammersland
The degree of independence in European goods markets: An I(2) analysis of German and Norwegian trade data Research Department, 45 p

2004/20 Roger Hammersland
Who was in the driving seat in Europe during the nineties, International financial markets or the BUBA? Research Department, 35 p

2004/21 Øyvind Eitrheim and Solveig K. Erlandsen
House prices in Norway 1819–1989 Research Department, 35 p

2004/22 Solveig Erlandsen and Ragnar Nymoen
Consumption and population age structure Research Department, 22 p

2005/1 Q. Farooq Akram
Efficient consumption of revenues from natural resources –
An application to Norwegian petroleum revenues Research Department, 33 p

2005/2 Q. Farooq Akram, Øyvind Eitrheim and Lucio Sarno
Non-linear dynamics in output, real exchange rates and real money balances: Norway, 1830-2003 Research Department, 53 p

2005/3 Carl Andreas Claussen and Øistein Røisland
Collective economic decisions and the discursive dilemma Monetary Policy Department, 21 p

2005/4 Øistein Røisland
Inflation inertia and the optimal hybrid inflation/price level target
Monetary Policy Department, 8 p

2005/5 Ragna Alstadheim
Is the price level in Norway determined by fiscal policy? Research Department, 21 p

2005/6 Tommy Sveen and Lutz Weinke
Is lumpy investment really irrelevant for the business cycle? Research Department, 26 p

2005/7 Bjørn-Roger Wilhelmsen and Andrea Zaghini
Monetary policy predictability in the euro area: An international comparison
Economics Department, 28 p

2005/8 Moshe Kim, Eirik Gaard Kristiansen and Bent Vale
What determines banks' market power? Akerlof versus Herfindahl Research Department, 38 p

2005/9 Q. Farooq Akram, Gunnar Bårdsen and Øyvind Eitrheim
Monetary policy and asset prices: To respond or not? Research Department, 28 p

2005/10 Eirik Gard Kristiansen
Strategic bank monitoring and firms' debt structure Research Department, 35 p

2005/11 Hilde C. Bjørnland
Monetary policy and the illusionary exchange rate puzzle Research Department, 30 p

2005/12 Q. Farooq Akram, Dagfinn Rime and Lucio Sarno
Arbitrage in the foreign exchange market: Turning on the microscope
Research Department, 43 p

2005/13 Geir H. Bjønnes, Steinar Holden, Dagfinn Rime and Haakon O.Aa. Solheim
"Large" vs. "small" players: A closer look at the dynamics of speculative attacks
Research Department, 31 p

2005/14 Julien Garnier and Bjørn-Roger Wilhelmsen
The natural real interest rate and the output gap in the euro area: A joint estimation
Economics Department, 27 p

2005/15 Egil Matsen
Portfolio choice when managers control returns Research Department, 31 p

2005/16 Hilde C. Bjørnland
Monetary policy and exchange rate interactions in a small open economy
Research Department, 28 p

2006/1 Gunnar Bårdsen, Kjersti-Gro Lindquist and Dimitrios P. Tsomocos
Evaluation of macroeconomic models for financial stability analysis
Financial Markets Department, 45 p

2006/2 Hilde C. Bjørnland, Leif Brubakk and Anne Sofie Jore
Forecasting inflation with an uncertain output gap Economics Department, 37 p

2006/3 Ragna Alstadheim and Dale Henderson
Price-level determinacy, lower bounds on the nominal interest rate, and liquidity traps
Research Department, 34 p

2006/4 Tommy Sveen and Lutz Weinke
Firm-specific capital and welfare Research Department, 34 p

2006/5 Jan F. Qvigstad
When does an interest rate path „look good"? Criteria for an appropriate future interest rate path Norges Bank Monetary Policy, 20 p

2006/6 Tommy Sveen and Lutz Weinke
Firm-specific capital, nominal rigidities, and the Taylor principle Research Department, 23 p

2006/7 Q. Farooq Akram and Øyvind Eitrheim
Flexible inflation targeting and financial stability: Is it enough to stabilise inflation and output? Research Department, 29 p

2006/8 Q. Farooq Akram, Gunnar Bårdsen and Kjersti-Gro Lindquist
Pursuing financial stability under an inflation-targeting regime Research Department, 29 p

2006/9 Yuliya Demyanyk, Charlotte Ostergaard and Bent E. Sørensen
U.S. banking deregulation, small businesses, and interstate insurance of personal income
Research Department, 57 p

2006/10 Q. Farooq Akram, Yakov Ben-Haim and Øyvind Eitrheim
Managing uncertainty through robust-satisficing monetary policy Research Department, 33 p

2006/11 Gisle James Natvik:
Government spending and the Taylor pinciple Research Department, 41 p

2006/12 Kjell Bjørn Nordal:
Banks' optimal implementation strategies for a risk sensitive regulatory capital rule: a real options and signalling approach Research Department, 36 p

2006/13 Q. Farooq Akram and Ragnar Nymoen
Model selection for monetary policy analysis – importance of empirical validity
Research Department, 37 p

2007/1 Steinar Holden and Fredrik Wulfsberg
Are real wages rigid downwards? Research Department, 44 p

2007/2 Dagfinn Rime, Lucio Sarno and Elvira Sojli
Exchange rate forecasting, order flow and macroeconomic information
Research Department, 43 p

2007/3 Lorán Chollete, Randi Næs and Johannes A. Skjeltorp
What captures liquidity risk? A comparison of trade and order based liquidity factors
Research Department, 45 p

2007/4 Moshe Kim, Eirik Gaard Kristiansen and Bent Vale
Life-cycle patterns of interest rate markups in small firm finance Research Department, 42 p

2007/5 Francesco Furlanetto and Martin Seneca
Rule-of-thumb consumers, productivity and hours Research Department, 41 p

2007/6 Yakov Ben-Haim, Q. Farooq Akram and Øyvind Eitrheim
Monetary policy under uncertainty: Min-max vs robust-satisficing strategies
Research Department, 28 p

2007/7 Carl Andreas Claussen and Øistein Røisland

Aggregating judgments on dependent variables: an (im)possibility result
Research Department, 17 p

2007/8 Randi Næs, Johannes Skjeltorp og Bernt Arne Ødegaard
Hvilke faktorer driver kursutviklingen på Oslo Børs? Forskningsavdelingen, 68 s

2007/9 Knut Are Astveit and Tørres G. Trovik
Nowcasting Norwegian GDP: The role of asset prices in a small open economy
Research Department, 29 p

2007/10 Hilde C. Bjørnland, Kai Leitemo and Junior Maih
Estimating the natural rates in a simple new Keynesian framework
Economics Department, 33 p

2007/11 Randi Næs and Bernt Arne Ødegaard
Liquidity and asset pricing: Evidence on the role of investor holding period
Research Department, 31 p

2007/12 Ida Wolden Bache
Assessing estimates of the exchange rate pass-through Research Department, 60 p

2007/13 Q. Farooq Akram
What horizon for targeting inflation? Research Department, 45 p

2007/14 Q. Farooq Akram, Yakov Ben-Haim and Øyvind Eitrheim
Robust-satisficing monetary policy under parameter uncertainty Research Depatrment, 33 p

2007/15 Ida Wolden Bache and Bjørn E. Naug
Estimating New Keynesian import price models Research Department, 40 p

2008/1 Anne Sofie Jore, James Mitchell and Shaun P. Vahey
Combining forecast densities from VARs with uncertain instabilities
Economics Department, 26 p

2008/2 Henrik Andersen
Failure prediction of Norwegian banks: A logit approach Financial Markets Department, 49 p

2008/3 Lorán Chollete, Randi Næs and Johannes A. Skjeltorp
The risk components of liquidity Research Department, 28 p

2008/4 Hilde C. Bjørnland and Kai Leitemo
Identifying the interdependence between US monetary policy and the stock market
Economics Department, 28 p

2008/5 Christian Kascha and Karel Mertens
Business cycle analysis and VARMA models Research Department, 40 p

2008/6 Alan S. Blinder
On the design of Monetary policy committees Norges Bank Monetary Policy, 22 p

2008/7 Francesco Furlanetto
Does monetary policy react to asset prices? Some international evidence
Research Department, 44 p

2008/8 Christian Huurman, Francesco Ravazzolo and Chen Zhou
The power of weather. Some empirical evidence on predicting day-ahead power prices through weather forecasts Research Department, 28 p

2008/9 Randi Næs, Johannes A. Skjeltorp and Bernt Arne Ødegaard
Liquidity at the Oslo Stock Exchange Research Department, 49 p

2008/10 Francesco Furlanetto and Martin Seneca
Fiscal shocks and real rigidities Research Department, 41 p

KEYWORDS:

Rule-of-thumb consumers
Fiscal shocks
Nominal rigidities
Real rigidities
Firm-specific capital
Habit persistence
Kimball demand curves

Lobo Media - 45345