

2011 | 14

Working Paper

Research Department

Investment shocks and macroeconomic co-movement

Francesco Furlanetto, Gisle J. Natvik and Martin Seneca

Working papers fra Norges Bank, fra 1992/1 til 2009/2 kan bestilles over e-post:

servicesenter@norges-bank.no

Fra 1999 og fremover er publikasjonene tilgjengelig på www.norges-bank.no

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 forfatterens regning.

Working papers from Norges Bank, from 1992/1 to 2009/2 can be ordered by e-mail:

servicesenter@norges-bank.no

Working papers from 1999 onwards are available on www.norges-bank.no

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 1502-8143 (online)

ISBN 978-82-7553-846-2 (online)

Investment Shocks and Macroeconomic Co-movement

Francesco Furlanetto* Gisle J. Natvik[†] Martin Seneca[‡]

August 2011 (First Draft: October 2010)

Abstract

Recent studies find that shocks to the marginal efficiency of investment are a main driver of business cycles. Yet, they struggle to explain why consumption co-moves with real variables such as investment and output, which is a typical feature of an empirically recognizable business cycle. In this paper we show that within a conventional business cycle model, rule-of-thumb consumption provides a straightforward explanation of macroeconomic co-movement after a shock to the marginal efficiency of investment.

JEL classification: E32. *Keywords:* Investment shocks, consumption, rule-of-thumb consumers, nominal rigidities, co-movement.

*Norges Bank, PO Box 1179, Sentrum, 0107 Oslo, Norway. Email: francesco.furlanetto@norges-bank.no.

[†]Norges Bank. Email: gisle.natvik@norges-bank.no.

[‡]Norges Bank. Email: martin.seneca@norges-bank.no.

1 Introduction

Recent research indicates that shocks to the rate at which current investment is transformed into future capital are important drivers of business cycles. For instance, Justiniano, Primiceri and Tambalotti (2010, 2011) argue that such shocks to the marginal efficiency of investment (MEI) are the most important driving force behind aggregate fluctuations accounting for 50% of the variance in US output since 1954. However, attributing a central role to MEI-shocks is problematic because the shocks affect the cost of consumption in terms of capital forgone. Hence, while consumption co-moves positively with other macroeconomic variables such as investment and output in the data, conventional macro models tend to imply that MEI-shocks move consumption in the opposite direction of output and investment. This co-movement problem is present even in studies which argue that MEI-shocks are the main driver of business cycles, such as Justiniano, Primiceri and Tambalotti (2010 and 2011) and Gertler, Sala and Trigari (2008).¹ In addition, the response of consumption contradicts the VAR evidence, which suggests a significant increase in consumption on impact of a positive MEI shock, cf. Peersman and Straub (2007).

In this paper, we propose an explanation why consumption may co-move with other real variables in response to MEI-shocks. The explanation we pursue is that part of the population are rule-of-thumb consumers who do

¹The impulse response of consumption to MEI-shocks is negative and significant for the first five to eight quarters in these models. Moreover, the model by Justiniano, Primiceri and Tambalotti (2010) underestimates the unconditional correlation between consumption and investment considerably, as it is positive in the data and negative in the model. The disconnect between consumption and investment is reflected in the variance decomposition, according to which MEI shocks explain six per cent of consumption only.

not use financial markets to smooth consumption, but spend their entire disposable income each period instead. We build our analysis on the model used by Galí, López-Salido and Valles (2007) (GLV, hereafter) to explain how government spending can stimulate private consumption, extended with sticky wages, as in Furlanetto (2011). As in standard models, when the economy is hit by an MEI-shock, agents who use financial markets cut consumption in order to finance investment. Rule-of-thumb agents, by contrast, increase their consumption since the MEI shock stimulates labor income. Hence, if the share of rule-of-thumb agents is large enough, aggregate consumption may increase.

A central feature of our model is nominal wage rigidity. Besides its empirical justification, wage stickiness has been shown to be an important feature in models with rule-of-thumb consumers as equilibrium dynamics are highly sensitive to specific assumption without it, cf. Colciago (2011) and Natvik (2011). In addition, we show that wage stickiness implies that the aggregate consumption Euler equation in a model with rule-of-thumb behavior is observationally different from the Euler equation in a model where preferences are non-separable in consumption and leisure. This is interesting because non-separability has previously been proposed as an explanation of macroeconomic co-movement.²

²In the literature, alternative explanations of co-movement in response to MEI shocks have been given. Greenwood, Hercowitz and Huffman (1988) and Jaimovich and Rebelo (2009) propose preferences with low or no wealth effect on labor supply together with variable capacity utilization. Guerrieri, Henderson and Kim (2010) obtain co-movement in a two-sector model. Furlanetto and Seneca (2010) show that a combination of non-separable preferences and nominal rigidities deliver co-movement under very general parameterizations. Eusepi and Preston (2009) emphasize heterogeneity in consumption between employed and unemployed workers. Khan and Tsoukalas (2011) combine some of these ingredients and show how is it possible to obtain co-movement in an estimated model.

Beyond providing a simple explanation why consumption responds positively to MEI-shocks, our results contribute to the literature on rule-of-thumb consumers in macro models. Previous studies in this strand have primarily focused on explaining the effects of fiscal shocks (GLV, 2007, and Mankiw, 2000) and neutral technology shocks (Furlanetto and Seneca, 2011), and on the monetary policy stance required to prevent equilibrium indeterminacy (GLV, 2004, Bilbie, 2008, and Natvik, 2009). As recent evidence from estimated models points toward MEI shocks as the main driver of business cycles, our finding is the potentially most important reason why macroeconomic models should account for rule-of-thumb behavior.

The paper is organized as follows. Section 2 briefly presents the model and its calibration. Results are presented in section 3. Section 4 discusses the role of wage rigidity. Section 5 concludes.

2 The Model

We consider a New Keynesian DSGE model with sticky wages, sticky prices, endogenous capital accumulation, capital adjustment costs and rule-of-thumb consumers. Essentially, our model is the one proposed by GLV (2007) augmented with wage stickiness. We therefore go straight to presenting the log-linear version of the model. We use lower-case letters to denote variables in log-deviations from steady state, and upper-case letters without time subscripts to express steady state values.

We focus our interest on the MEI shock, m_t , which affects the transformation of current investment, i_t , into future capital, k_{t+1} , as can be seen in the capital accumulation equation

$$k_{t+1} = (1 - \delta) k_t + \delta (i_t + m_t)$$

where δ is the depreciation rate. The shock follows the exogenous process

$$m_t = \rho_m m_{t-1} + e_{m,t},$$

where ρ_m measures the persistence of the shock and $e_{m,t}$ is an i.i.d. shock.

The economy consists of a continuum of firms, a continuum of households, a continuum of labor unions, a central bank responsible for monetary policy, and a government, which collects lump-sum taxes to finance a fixed amount of government spending. There is monopolistic competition in goods and labor markets with a continuum of differentiated intermediate goods and a continuum of differentiated labor services. This leads to downward-sloping demand curves for each intermediate good and for each labor type.

A fraction λ of households are rule-of-thumb consumers. These consumers simply consume their respective disposable incomes each period:

$$c_t^r = \frac{WN}{PC} (w_t - p_t + n_t^r). \quad (1)$$

Here w_t is the nominal wage, p_t is the price level and n_t^r is the number of hours worked by each rule-of-thumb agent.

The remaining fraction $(1 - \lambda)$ of households are optimizers, who have access to both financial and capital markets. Hence, they choose plans for consumption, c_t^o , according to a standard Euler equation obtained from the maximization of a log-separable utility function:

$$c_t^o = E_t c_{t+1}^o - (r_t - E_t \pi_{t+1}), \quad (2)$$

where r_t represents the nominal interest rate and π_t is the price inflation rate.

The presence of capital adjustment costs implies the following dynamics for Tobin's q :

$$q_t = -(r_t - E_t[\pi_{t+1}]) + [1 - \beta(1 - \delta)] E_t[r_{t+1}^k - p_{t+1}] + \beta E_t[q_{t+1}] + \beta \delta E_t[m_{t+1}].$$

Here β is the discount rate, r_t^k denotes the rental rate of capital.

Optimizing households choose investment, i_t , to maximize life-time utility according to the following equation

$$i_t - k_t = \eta(q_t + m_t),$$

where η is the elasticity of investment with respect to q .

Aggregate variables for consumption (c_t) and hours (n_t) are given as simple weighted averages:

$$c_t = \lambda c_t^r + (1 - \lambda) c_t^o \tag{3}$$

$$n_t = \lambda n_t^r + (1 - \lambda) n_t^o$$

Wages are set by unions, each representing a differentiated type of labor service supplied by households. Wage rigidity is introduced by assuming adjustment costs as in Rotemberg (1982), which implies a New Keynesian Philips curve for wage inflation, π_t^w , given as

$$\pi_t^w = \beta E_t(\pi_{t+1}^w) + \kappa_w (c_t + \phi n_t - (w_t - p_t)).$$

Here ϕ represents the inverse of the Frisch labor supply elasticity, $\kappa_w = (\varepsilon_w - 1) / \phi_w$ with ε_w representing the elasticity of substitution across labor varieties, and ϕ_w is the cost of adjusting wages. Firms do not discriminate between consumer types in their labor demand, and so it follows from the unions' problems that $n_t^r = n_t^o = n_t$.

Each firm produces one of the differentiated goods. It does so by combining rented capital with a homogenous labor input constructed as a Dixit-Stiglitz aggregate of the differentiated labor services supplied by households. Cost minimization implies that relative factor inputs satisfy the condition

$$k_t - n_t = (w_t - p_t) - (r_t^k - p_t)$$

Up to a first-order approximation, production (y_t) is given by

$$y_t = \alpha k_t + (1 - \alpha)(n_t)$$

where α is the capital share in a Cobb-Douglas production function. Firms set their price according to a staggered Calvo-mechanism, and stand ready to satisfy demand at the chosen price. As is well-known, the optimality conditions from this problem imply the New Keynesian Phillips curve

$$\pi_t^p = \beta E_t(\pi_{t+1}^p) + \kappa_p mc_t$$

where $\kappa = (1 - \beta\theta_p)(1 - \theta_p)\theta_p^{-1}$, θ_p is the probability of keeping the price fixed for the period, and mc_t is the real marginal cost given as

$$mc_t = (w_t - p_t) - (y_t - n_t)$$

The central bank controls the risk-free interest rate, which it sets according to the rule

$$r_t = \phi_\pi \pi_t$$

where ϕ_π is a coefficient larger than one that measure the response to inflation.

Market clearing requires that

$$(1 - \gamma_G) y_t = \frac{C}{Y} c_t + \frac{I}{Y} i_t$$

where γ_G measures the ratio of government spending to output.

To facilitate comparison, our calibration follows GLV. Hence, we consider a time period to be a quarter, and we set $\lambda = 0.5$, $\alpha = 0.33$, $\delta = 0.025$, $\phi_\pi = 1.5$ and $\beta = 0.99$. In addition, we set $\gamma_G = 0.20$ with the implication that $I/Y = \alpha\delta(1/\beta + \delta)^{-1}\mu_p^{-1} = 0.18$, $C/Y = 0.62$ and $WN/PC = (1 - \alpha)Y/C\mu_p$, under the assumption that steady-state price mark-ups ($\mu_p - 1$) are 20 per cent.

However, the introduction of wage rigidities increases the range of parameter values for which the equilibrium is determinate, cf. Colciago (2011). This allows us to set more realistic values for some parameters. We therefore set $\phi = 1$ (instead of 0.2) and $\theta_p = 0.5$ (instead of 0.75) in order to reduce the high degrees of labor supply elasticity and nominal rigidity assumed by GLV. Similarly, we set $\eta = 7$ to strike a balance between the value of 1 used by GLV and the value of 13.3 motivated in Woodford (2003).

Finally, we set $\varepsilon_w = 4$ and $\phi_w = 174.7$. This corresponds to a steady-state wage mark-up of approximately 33 per cent and gives the same wage Phillips curve as if wages were reset every 4 quarters under a Calvo-type wage-setting scheme. The persistence of the MEI-shock is calibrated at $\rho_m = 0.73$, in keeping with estimates in Justiniano, Primiceri and Tambalotti (2010) and Smets and Wouters (2007).

3 Results

Figure 1 shows the main result of this paper. Bold lines show impulse responses to an MEI shock in a version of the model presented in the previous section without rule-of-thumb consumers, i.e. with $\lambda = 0$. In this case, the

impact response of consumption is negative ³ The presence of countercyclical mark-ups, induced by sticky prices, is not able to overturn the intertemporal substitution effect that causes a large increase in investment at the expense of current consumption. With rule-of-thumb behavior, however, the consumption response is very different. Dashed lines in figure 1 show impulse responses for a version of the model in which 50 per cent of consumers follow a rule of thumb, i.e. for $\lambda = 0.5$. In this case, the response of consumption is comfortably positive. As rule-of-thumb agents have a static perspective, they do not engage in intertemporal substitution. Instead, they base their consumption decision on current labor income. Since the MEI shock increases output through an expansion in investment, current income increases. Rule-of-thumb consumers therefore increase their consumption, and if a sufficiently high fraction of households are following a rule of thumb, aggregate consumption increases. In sum, rule-of-thumb consumption introduces an expansionary effect in the model that – in combination with nominal rigidities – causes aggregate consumption to increase.

In our baseline calibration, λ is set to 0.5 in order to conform with the original literature on rule-of-thumb consumers, cf. GLV (2007) or Campbell and Mankiw (1989). This may be an unrealistically high value given the more recent empirical evidence (López-Salido and Rabanal, 2008, estimate λ

³In fact, the impact response is very similar to the one in Justiniano, Primiceri and Tambalotti (2010). This is not surprising given that our model without rule-of-thumb consumers is similar to the one in their paper. Their model also features habit persistence in consumption, variable capacity utilisation and indexation in prices and wages. These ingredients do not play an important role in the transmission of MEI shocks, however (cf. Furlanetto and Seneca, 2010). Notice that the response is less persistent than in Justiniano, Primiceri and Tambalotti (2010) because we use capital adjustment costs instead of investment adjustment costs.

equal to 0.39 in the model with separable preferences, Cogan, Cwik, Taylor and Wieland, 2011, find a value of 0.28, Coenen and Straub, 2005, obtain values between 0.25 to 0.37 depending on the specification for taxes)⁴. Figure 2 shows that the positive response of consumption is robust to reducing λ to 30 per cent (dashed lines).⁵ The figure also shows that our result does not rely on both price and wage rigidity. Wage rigidity alone is enough to generate a positive consumption response (dashed-dotted line). However, some degree of nominal rigidity is needed; when both wages and prices are flexible, the consumption response is negative (dotted line).⁶

4 The Role of Wage Rigidity

We have augmented the New Keynesian model with rule-of-thumb consumers developed by GLV with nominal wage rigidity. Aside from empirical relevance, our main motivation for imposing wage rigidity is that rule-of-thumb consumption makes equilibrium dynamics highly sensitive to specific assump-

⁴Kaplan and Violante (2011) provide a micro-foundation for rule-of-thumb behavior. They argue that it reflects not only the behavior of credit constrained households (below 10% of US households according to data on the wealth distribution) but also the behavior of "wealthy hand-to-mouth" households. These households (around 30% of the total) hold some illiquid wealth but optimally choose to consume all disposable income to avoid transaction and liquidation costs.

⁵Importantly, for a given share of constrained agents the consumption multiplier could become much larger with higher price rigidity, or in a more complex model with strategic complementarities in price setting or non-separabilities in the utility function. In the baseline version of our model the minimum value of λ consistent with a positive consumption response is 0.22.

⁶This can be seen analitically by considering the equilibrium condition for the labor market, which, in the absence of nominal rigidities and monopolistic competition, equalizes the marginal rate of substitution with the marginal product of labor.

tions if wages are flexible. For example, the labor supply elasticity must be very high and the steady-state tax schedule must be highly egalitarian in order for the model to have a determinate equilibrium. This is no longer the case with a moderate degree of wage rigidity as shown by Colciago (2011) for the labor supply elasticity and by Natvik (2011) for the steady state tax schedule, respectively. Similarly, wage rigidity makes equilibrium dynamics robust to variation in the degree of substitutability between the labor services provided by the two types of households, cf. Furlanetto (2011) and Natvik (2011). Hence, with sticky wages, we may base our analysis on a labor supply elasticity within the range normally considered in macro models, and our results are not driven by arbitrary assumptions regarding the steady state distribution of wealth or the substitutability between labor services.

In addition to this, we now point to a further implication of wage rigidity. Wage rigidity matters for the distinction between rule-of-thumb behavior and non-separable preferences, both of which may explain the co-movement of consumption with other macroeconomic variables following MEI shocks (see Furlanetto and Seneca, 2010, for a discussion of non-separable preferences in this regard). While these explanations are conceptually different – with the former alluding to credit market imperfections and the latter to preferences – they give rise to similar consumption dynamics in standard models. Specifically, when wages are flexible the two explanations lead to observationally equivalent Euler equations for aggregate consumption, cf. e.g. GLV (2007), Linnemann (2006) and Basu and Kimball (2002). When wages are sticky, however, the Euler equation derived from a model with rule-of-thumb behavior is no longer observationally equivalent to one derived from a model with optimizing agents with non-separable preferences.

To illustrate this point, we construct an aggregate Euler equation for our

model economy by combining equations (1), (2) and (3):

$$c_t = E_t c_{t+1} - \lambda \frac{WN}{PC} (E_t \Delta n_{t+1} + E_t \Delta (w_{t+1} - p_{t+1})) - (1 - \lambda) (r_t - E_t \pi_{t+1}). \quad (4)$$

Here, Δ is the difference operator. Now, if wages were flexible, the real wage term on the right-hand side could be replaced by the marginal rate of substitution between consumption and leisure, leaving us with the following aggregate Euler equation:

$$c_t = E_t c_{t+1} - \Psi E_t \Delta n_{t+1} - \frac{1}{\tilde{\sigma}} (r_t - E_t \pi_{t+1}), \quad (5)$$

where $\Psi = \frac{\lambda(1+\varphi)\frac{WN}{PC}}{1-\lambda\frac{WN}{PC}}$, and $\tilde{\sigma} = \frac{1-\lambda\frac{WN}{PC}}{1-\lambda}$. This equation has the same form as one derived from a model with non-separable preferences.⁷ By contrast, when wages are rigid, we cannot substitute in the marginal rate of substitution for the real wage and go from (4) to (5). Hence, the two Euler equations are no longer observationally equivalent. In principle, therefore, wage rigidity provides a way to empirically distinguish non-separable preferences from rule-of-thumb consumers. This is interesting from a policy perspective because rule-of-thumb behavior, unlike non-separable preferences, may reflect a friction, that policy should address.

5 Conclusion

We have shown that rule-of-thumb behavior can explain why consumption and investment co-move after shocks to the marginal efficiency of investment.

⁷For instance, with preferences of the type proposed by King, Plosser and Rebelo (1988), the Euler equation for the representative household is given by (5). Only, now, the coefficients have a slightly different composition as $\Psi = (1 - \sigma^{-1}) WN/PC$ and $\tilde{\sigma} = \sigma$, where σ is the representative household's coefficient of relative risk aversion.

This feature can potentially improve the empirical performance of standard New Keynesian models, which struggle to account for co-movement patterns observed in the data. Because recent evidence points to MEI shocks as the historically most important driver of business cycles, our finding constitutes an additional reason why rule-of-thumb behavior should be accounted for in macroeconomic models, beyond their role in the transmission of fiscal and technology shocks emphasized elsewhere.

References

- Basu, S., Kimball, M.S., 2002. Long-Run Labor Supply and the Elasticity of Intertemporal Substitution for Consumption. Manuscript, University of Michigan.
- Bilbiie, F., 2008. Limited Asset Market Participation, Monetary Policy and (Inverted) Aggregate Demand Logic. *Journal of Economic Theory* 140, 162-196.
- Campbell, J.Y., Mankiw, N.G., 1989. Consumption, Income, and Interest Rates: Reinterpreting the Time Series Evidence. NBER Macroeconomics Annual 1989.
- Coenen, G., Straub, R., 2005. Does Government Spending Crowd in Private Consumption? Theory and Empirical Evidence for the Euro-Area. *International Finance* 8, 435-470.
- Cogan, J.F., Cwik, T., Taylor, J.B., Wieland, V., 2010. New Keynesian versus old Keynesian government spending multipliers. *Journal of Economic Dynamics and Control* 34, 281-295.
- Colciago, A., 2011. Rule-of-Thumb Consumers Meet Sticky Wages. *Journal of Money, Credit and Banking* 43, 325-353.
- Eusepi, S., Preston, B., 2009. Labor Supply Heterogeneity and Macroeconomic Co-movement. NBER working paper 15561.
- Furlanetto, F., 2011. Fiscal Stimulus and the Role of Wage Rigidity. *Journal of Economic Dynamics and Control* 35, 512-527.
- Furlanetto, F., Seneca, M., 2010. Investment-Specific Technology Shocks and Consumption. Norges Bank Working Paper 2010/30.

- Furlanetto, F., Seneca, M., 2011. Rule-of-Thumb Consumers, Productivity and Hours. *Scandinavian Journal of Economics*, forthcoming.
- Galí, J., López-Salido, D., Valles, J., 2004. Rule-of-Thumb Consumers and the Design of Interest Rate Rules. *Journal of Money, Credit and Banking* 36, 739-764.
- Galí, J., López-Salido, D., Valles, J., 2007. Understanding the Effects of Government Spending on Consumption. *Journal of the European Economic Association* 5, 227-270.
- Gertler, M, Sala, L., Trigari, A., 2008. An Estimated Monetary DSGE Model with Unemployment and Staggered Nominal Wage Bargaining. *Journal of Money, Credit and Banking* 40, 1713-1764.
- Greenwood, J., Hercowitz, Z., Huffman, G.W., 1988. Investment, Capacity Utilization and the Real Business Cycle. *American Economic Review* 87, 342-362.
- Guerrieri, L., Henderson, D., Kim, J., 2010. Interpreting Investment-Specific Technology Shocks. Manuscript, International Finance Discussion Papers 1000, Board of Governors of the Federal Reserve System.
- Jaimovich, N., Rebelo, S., 2009. Can News about the Future Drive the Business Cycle? *American Economic Review* 99, 1097-1118.
- Justiniano, A., Primiceri G., Tambalotti, A., 2010. Investment Shocks and Business Cycles. *Journal of Monetary Economics* 57, 132-145.
- Justiniano, A., Primiceri G., Tambalotti, A., 2011. Investment Shocks and the Relative Price of Investment. *Review of Economic Dynamics*, forthcoming.
- Kahn, H., Tsoukalas, J., 2011. Investment Shocks and the Co-movement Problem. *Journal of Economic Dynamics and Control* 35, 115-130.

- Kaplan, G., Violante, G.L., 2011. A Model of the Consumption Response to Fiscal Stimulus Payment. Manuscript, New York University.
- King, R., Plosser, C., Rebelo, S., 1988. Production, Growth and Business Cycles: I. The Basic Neoclassical Model. *Journal of Monetary Economics* 21, 195-232.
- Linnemann, L., 2006. The Effect of Government Spending on Private Consumption: A Puzzle? *Journal of Money, Credit and Banking* 38, 1715-1736.
- López-Salido, J.D., Rabanal, P., 2008. Government Spending and Consumption Hours Preferences. Manuscript, "La Caixa".
- Natvik, G.J., 2009. Government Spending and the Taylor Principle. *Journal of Money, Credit and Banking* 41, 57-77.
- Natvik, G.J., 2011. Government Spending Shocks and Rule-of-Thumb Consumers with Steady State Inequality. *Scandinavian Journal of Economics*, forthcoming.
- Peersman, G., Straub, R., 2007. Putting the New Keynesian Model to a Test. Manuscript, University of Ghent.
- Smets, F., Wouters, R., 2007. Shocks and Frictions in US Business Cycles: A Bayesian DSGE approach, *American Economic Review* 97, 586-606.
- Woodford, M., 2003. Interest and prices: foundations of a theory of monetary policy. Princeton University Press.

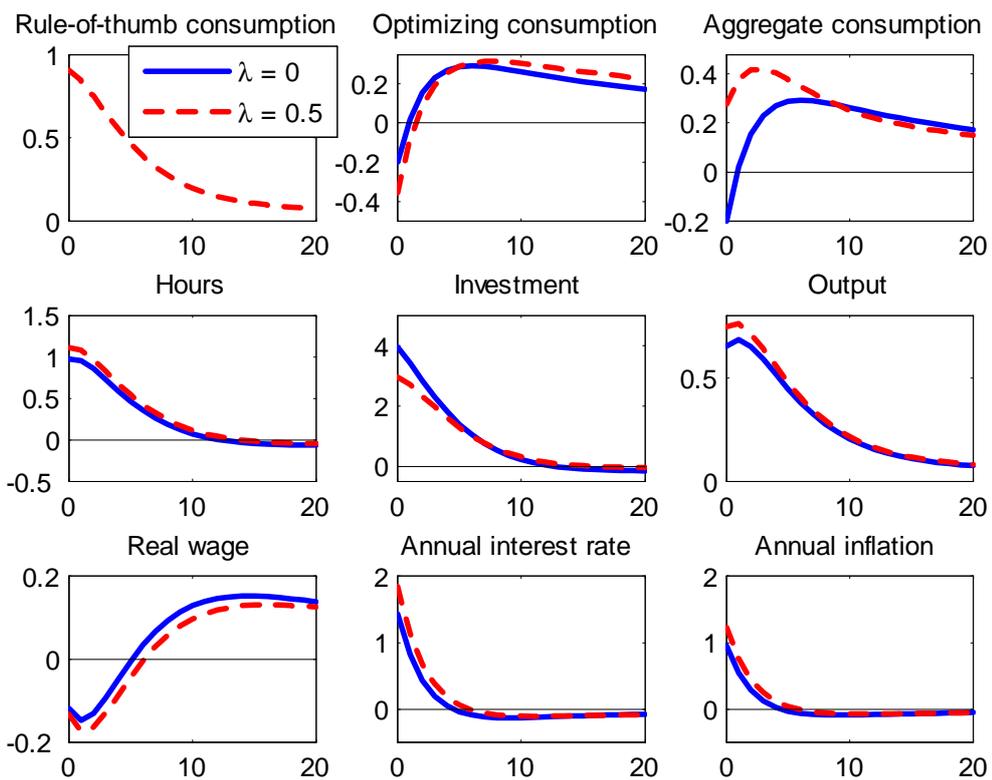


Figure 1: Impulse responses to a MEI shock in the standard New Keynesian model (solid line) and in the model with rule-of-thumb consumers (dashed line).

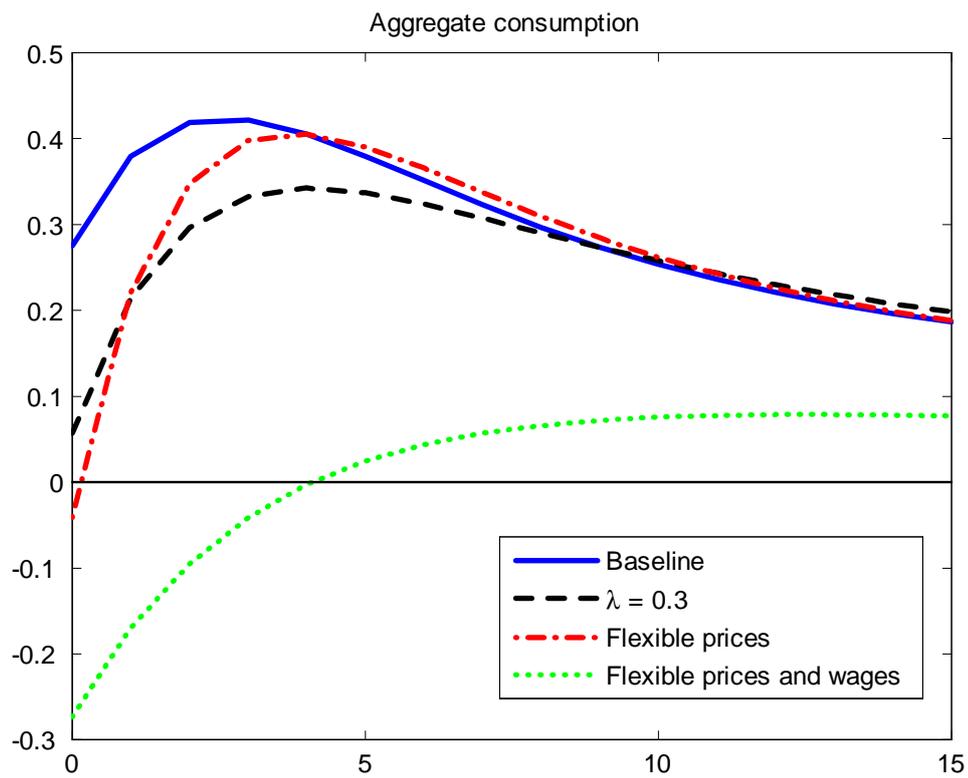


Figure 2: Impulse-response for aggregate consumption under different assumptions about the share of constrained agents and the degree of nominal rigidities