Essays on Money, Credit and Fiscal Policy

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A chi c'è, e a chi non più.

Abstract

This thesis tackles three different issues of relevance for economic policy, with an explicit reference to the euro area. Does monetary targeting improve macroeconomic stability? Which role does the banking sector play in the impulse and transmission of shocks? Which fiscal tools have the greatest and the most persistent impact on the real economy, helping effective stabilization policy design? Answers to each question, derived from data-matching dynamic general equilibrium models, imply noteworthy indications for policy-makers.

Resumen

Esta tesis afronta tres temas de relevancia en lo que se refiere a la política económica en la zona euro. ¿Establecer un objetivo monetario en la conducción de la política monetaria contribuye a alcanzar una estabilidad macroeconómica? ¿Qué papel desempeña el sector banquero en el impulso y en la transmisión de choques macroeconómicos? ¿Cuales son los instrumentos de política fiscal con el mayor y más persistente impacto sobre la economía real, capaces de ayudar en el diseño de políticas de estabilización eficaces? Las respuestas a cada pregunta, derivadas desde modelos de equilibrio económico general dinámicos ajustados a los datos, permiten extraer indicaciones útiles para las autoridades responsables de las políticas económicas.

Foreword

This thesis tackles three different issues of relevance for economic policy, with an explicit reference to the euro area. Does monetary targeting improve macroeconomic stability? Which role does the banking sector play in the impulse and transmission of shocks? Which fiscal tools have the greatest and the most persistent impact on the real economy, helping effective stabilization policy design? We organize the discussion of these themes in individual chapters.

The objective of the first chapter (titled *Economic (In)Stability under Monetary Targeting*) is to check out whether the monetary policy conduct of targeting a monetary aggregate may or may not favor the stability properties of an economy. The literature has identified a number of reasons why monetary growth targeting can be an effective way of supporting macroeconomic stability. One reason is related to its ability to avoid sunspot instability associated with self-fulfilling multiple equilibria, whose risk has been detected under interest-rate-feedback policy rules. In the chapter we scrutinize this property of monetary targeting by checking whether multiplicity of equilibria, in the form of local indeterminacy (LI), can or cannot be both a possible and a plausible outcome of a basic model with an exogenous money growth policy rule. We address the question in different versions of the Sidrauski-Brock-Calvo framework, which, abstracting from real and nominal rigidities and from market imperfections, isolates the contribution of monetary non-neutralities and monetary targeting. In line with previous literature, real effects of money are found to be a necessary condition for LI: we identify a single pattern for their magnitude if they are to be sufficient too. While the most elementary setups are unable to plausibly generate large enough real effects, LI becomes significantly more likely as one realistically considers additional channels of transmission of monetary expansions onto the real economy. In particular, we show that models factoring in a slight amplification of monetary non-neutrality, like a model that we lay down in which holding money is valuable to both households and firms, may yield a LI outcome for empirically relevant parameterizations. This hints to greater chances of sunspot equilibria - under monetary targeting - in models including a larger set of economically relevant sources of monetary non-neutrality (like nominal rigidities or financial frictions). Therefore, making monetary targeting a part of a monetary policy strat-

egy, while still helpful for a long-run guide, may neither guarantee that expectations remain anchored to fundamentals nor serve to help immunize the economy against the instability associated with possible multiple equilibria. Hence, it would still be prudent and natural to reccommend that monetary authorities adopt a mixed strategy, relying on the composite use of various policy tools and on attentive monitoring of a wide spectrum of monetary and real aggregates.

The second chapter (written with A. Gerali, S. Neri and F.M. Signoretti and titled *Credit and Banking in a DSGE Model of the Euro Area*) studies the role of credit-supply factors in business cycle fluctuations and in particular in: *i)* the transmission of monetary policy and technological shocks; *ii)* the transmission of shocks independently originating in the credit sector itself. To do so, it develops a dynamic stochastic general equilibrium model with financial frictions enriched with an imperfectly competitive banking sector. Banks issue collateralized loans to both households and firms, obtain funding via deposits, accumulate capital out of retained earnings and must comply with banking capital requirements. Margins on loans depend on bank capital-to-assets ratio and on the degree of interest rate stickiness. Bank balance-sheet constraints establish a link between the business cycle, which affects bank profits and thus capital, and the supply and cost of loans. The model is estimated with Bayesian techniques using data for the euro area. The analysis delivers the following results. First, banking activity dampens the effects of monetary policy shocks on borrowing constraints and hence on real activity, resulting in an 'attenuator' effect opposite in sign with respect to the 'financial accelerator' effect: the imperfect pass-through of policy and market rates to retail bank rates is mainly accountable for the result. An attenuating effect of banking, associated to a larger persistence, also characterizes technology shocks. Second, an historical decomposition exercise based on the estimated model highlights the remarkable contribution of credit supply shocks to the cyclical pattern of euro area economic variables in the recent years: shocks originating in the banking sector explain the largest share of the contraction of economic activity in 2008, while macroeconomic shocks played a limited role. Finally, the model also allows analyzing the consequences of a bank capital loss on the real economy, which, mainly hitting on firms, turn out to be particularly severe on investment.

The third chapter (written with L. Forni and L. Monteforte and titled *The General*

Equilibrium Effects of Fiscal Policy: Estimates for the Euro Area) sets up a DSGE model featuring a fraction of non-Ricardian agents in order to estimate the effects of fiscal policy in the Euro area. The model, which enlarges the one described in Galí J., J.D. López-Salído and J. Vallés (2007), takes into account distortionary taxation on labor and capital income and on consumption, and breaks down public expenditures into purchases of goods and services, compensation of public employees and transfers to households. Our model further generalizes the previous paper in that it introduces modifications in preferences (among which, introduction of habits and non-logarithmic preferences) and in labor market structure (e.g., sticky wages). A newly computed quarterly data set of fiscal variables is used to set up a bayesian estimate of the enlarged model. Evaluating the effectiveness of different fiscal tools in stimulating the economic activity in the euro area at different horizons, our results point to the prevalence of mild Keynesian effects of public expenditures. In particular, although innovations in fiscal policy variables tend to be rather persistent, government purchases of goods and services and compensations for public employees have small and short-lived expansionary effects on private consumption, while innovations in transfers to households show a slightly more sizeable and lasting effect. The effects are more significant on the revenue side: decreases in labor income and consumption tax rates have sizeable effects on consumption and output, while a reduction in capital income tax favors investment and output in the medium run. Consistency of data with the new-keynesian paradigm is also displayed by the dynamic responses of labor market variables. Finally, our estimates suggest that, overall, fiscal policy variables contribute little to the cyclical variability of the main macro variables.

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Chapter 1

Economic (In)Stability under Monetary Targeting

1.1 Introduction

In the last decade – also following the adoption by the ECB of a monetary policy strategy assigning a prominent role to a monetary pillar – a number of studies have inquired into the role of monetary aggregates in the conduct of monetary policy. In reaction to new-keynesian and econometric criticisms (see, e.g., Dotsey and Hornstein, 2003, Ireland, 2004, Svensson and Woodford, 2003, Woodford, 2008), some authors have identified theoretical or empirical reasons supporting the relevance of money as an information variable for monetary policy decisions (see, e.g., Amisano and Fagan, 2010, Coenen *et al.*, 2005, Gerlach and Svensson, 2003, Nelson, 2003, or the overview in ECB, 2010). A more general consensus, also shared by the ECB monograph, appears to have emerged on the usefulness of money as a policy guide, acknowledging either the stability of the relations between money and other variables of interest in the conduct of monetary policy (e.g., Assenmacher Wesche and Gerlach, 2007, Dreger and Wolters, 2010, Hafer *et al.*, 2007), its robustness as a policy instrument in the face of model uncertainty (e.g., Gerdesmeier *et al.*, 2002, Kilponen and Leitemo, 2008), or its ability to prevent bad or multiple equilibria that could be caused by simple interest rate feedback rule strategies (see Christiano and Rostagno, 2008, Benhabib *et al.*, 2002, or more recently Christiano *et al.*, 2008, Atkeson *et al.*,

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2009, and Minford and Srinivasan, 2009). Here we examine the property highlighted by this last set of papers, according to which targeting (also) a monetary aggregate would effectively support economic stability, by checking whether and how, under such a policy, multiple equilibrium paths, in the form of local indeterminacy (LI), can arise. To this extent, it is crucial to distinguish between the possibility and the plausibility of LI. One issue is whether there exist theoretical conditions for LI in the model which describes the economy, another is whether such conditions would find empirical support.

We address both issues in several versions of a framework as generic as the Sidrauski-Brock model with flexible prices, characterized by a money growth rule monetary policy.[1] In this model, money is held because it gives utility directly, proxying its role in providing services such as reducing transaction costs. We augment the framework *à la* Calvo (1979) by including money as a possible direct production input, representing working capital or the services that liquidity can provide to a firm, like for paying wages, purchasing inputs, marketing, and in general running plants: as firms too must execute transactions, the money-in-the-production-function (MIPF) approach is just as valid as money-in-the-utility-function (MIUF).[2] Both these ways of factoring money in are clearly shortcuts. Nevertheless, we find the Sidrauski-Brock(-Calvo), or SBC, framework a very convenient tool for our exercise. It introduces in a simple way both a motive for holding money and a role for monetary non-neutralities and monetary targeting; it allows studying the stability properties of monetary targeting in isolation, as it abstracts from market imperfections, and therefore from renown routes to indeterminacy (IRS, externalities, and imperfect competition); and it ensures tractability and comparability with previous literature, while being general enough to encompass other approaches.[3]

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[1] See Sidrauski (1967) and Brock (1974, 1975).

[2] Fischer (1974) offered microfoundations for MIPF. Finance theory offers many additional reasons why non-financial firms hold liquid assets - as part of the decision to hold a portfolio of assets, say, or as a buffer against cash-flow variability: a precautionary motive would induce firms to demand money in order to avoid the opportunity costs related to missed investment opportunities and/or the costs of external finance to meet unanticipated cash needs. But the strong correlation between M3 holdings of non-financial corporations and gross value added in the sector suggests that the transaction motive is a major determinant of firms' money demand. For empirical evidence, among others, Mulligan (1997), Lotti and Marcucci (2007) and Bover and Watson (2005).

[3] The cash-in-advance, shopping time and transaction costs models all imply reduced forms that are special cases of the SBC framework: LI has been shown to be a possible outcome of these models

In the SBC framework, the possibility of multiple equilibria hinges on the interplay between money and price expectations, which can be self-fulfilling. In steps, we develop the intuition of Benhabib and Farmer (1999) that in this kind of models LI can arise whenever around the steady state an excess supply of real balances turns into a net excess demand, since it is only then that self-fulfilling inflation expectations become compatible with stationary equilibria, giving rise to as many possible converging real allocations as there are price sequences of this sort. In line with those authors, we argue that a necessary condition for this reversal is that money be non-neutral, i.e. that it have real effects, impinging on marginal utilities and productivities, and ultimately on agents' propensity to demand money balances. If the growing nominal money supply is somehow able to stimulate the real economy enough to considerably alter agents' need for money for transaction or other purposes, alternative conjectures on sequences for prices, and hence real balances, and therefore for all real variables in the economy, could result in a converging equilibrium. Absent sufficiently large real effects, only explosive paths (if consistent with equilibrium) could constitute an alternative to the saddlepath equilibrium. We measure these real effects by the marginal proportional reaction of the propensity to hold real balances or consume goods to the monetary expansion. This enables us to define the necessary and sufficient conditions for LI in terms of a unique pattern for the (steady-state) elasticities of marginal utilities and productivities to monetary changes.

In the framework chosen, the real effects of money will be brought about either by preferences with a nonseparability in real balances or by MIPF. Benhabib and Farmer (1999, 2000) have shown that LI could be the outcome of a calibrated SBC economy with endogenous labor choice, but only if real balances can affect labor supply or demand decisions strongly enough to induce a non-standard slope in one of the labor market schedules. Dissatisfaction with this assumption provides additional motivation for our work and justifies one of the restrictions we impose that, in order to identify possible sources of LI independent of a labor channel of this sort, the labor supply is assumed inelastic. In the most basic models that we examine, only unreasonable assumptions about the impact of money on the real economy

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under an exogenous money growth policy rule by, respectively, Wilson (1979), Woodford (1994), and Gray (1983).

could yield LI. However, as we include additional channels through which money can affect the real economy in general equilibrium, the chances of an indeterminate outcome increase substantially. In fact, in this chapter they will be greater in our models featuring money both in the utility and in the production functions, creating conditions for LI that calibrated exercises will show to be compatible with the data. We also use versions of the SBC framework used in other papers (e.g., Gray, 1983, Matsuyama, 1990, Obstfeld, 1984, or the survey by Benhabib and Farmer, 1999). In this respect, what distinguishes our work is the aim of checking whether LI could be both a possible and a plausible outcome of simple money growth rule economies, by examining new and old models in perspective and looking for a single pattern inducing LI in the framework, focusing only on local analysis (informative enough for our purposes), and imposing fewer a-priori restrictions on preferences and technology than in previous work.[4]

Sections 1.2 and 1.3 study how LI could arise, first in the basic SBC models where the mechanism at work is neater, and then applying that same mechanism in MIUF-MIPF models which include more channels for real effects of money. Section 1.4 concludes.

1.2   Local indeterminacy lessons from basic models

In this section, first we sketch out the general framework in which we conduct our analysis. Then, we review in a somewhat new and unified perspective its simplest versions, where driving forces and intuitions for indeterminacy are more readily grasped. The aim is to clarify the basic mechanisms inducing LI in the framework for immediate application in the slightly richer but analogous setups of Section 1.3. The Sidrauski-Brock framework assumes perfect competition, no externalities, and flexible prices. Given the equivalence between indeterminacy in the neighborhood of a deterministic steady state and the existence of stationary sunspot equilibria (see Woodford, 1986), it is consistent with our aims to assume perfect foresight too. There is a unit-measure continuum of a single type of agent: infinitely-lived

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[4] Our exercise recalls that of Benhabib *et al.* (2001), who looked at LI not only in flexible but also in sticky prices economies, under interest rate rules and alternative fiscal policies.

households that both consume and produce. In continuous time, they maximize

$$\int_0^\infty e^{-\beta t} U(c, m) \, dt \,,$$

where β is the rate of time preference, c is consumption, m is real balances, and utility U is assumed to satisfy the Inada conditions and to be strictly increasing, strictly concave and twice continuously differentiable, in each of its arguments. The flow budget constraint for each agent is of the form

$$\dot{m} = y - c + T - \pi m$$

where a dot indicates a time derivative, y is income, which may be exogenous or endogenous, T is fiscal transfers, and π is the actual and (given perfect foresight) also the expected rate of change in the price level P. Notice that wealth is diminished by the inflation tax if it is kept in the form of money. A no-Ponzi-game constraint is also imposed: with real total household wealth given by m, it simply amounts to $m_t \geq 0 \; \forall \, t$.

Money, M, is injected into the economy by the monetary authority according to an exogenous constant-growth rule

$$\frac{\dot{M}}{M} = \phi \tag{1.1}$$

i.e., in real terms, $\dot{m} = m(\phi - \pi)$: the steady state rate of inflation is constant and equal to the rate of monetary growth ϕ, assumed to be non-negative. Fiscal policy simply grants a lump-sum transfer T to each agent, financed by seignorage. The government budget constraint is then

$$PT = \dot{M} \,. \tag{1.2}$$

First, in order to derive some basic intuitions, we abstract from production and assume a fixed endowment. First-order conditions lead to the monetary Euler equation $-\dot{U}_c/U_c + \beta = U_m/U_c - \pi$ (with $\dot{U}_c = U_{cc}\dot{c} + U_{cm}\dot{m}$, and with a subscript indicating a derivative with respect to the corresponding argument). Equilibrium requires consumption to be always equal to endowment ($\dot{c} = 0$). Consider the separable utility case ($U_{cm} = 0$), so that a monetary expansion has no effect on the real part of the economy.[5] Taking policies (1.1) and (1.2) into account, the equilibrium solution is

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[5] This is one of the models originally studied by Brock (1974, 1975), who considered only stationary, hyperinflationary, and hyperdeflationary equilibria, ignoring non-stationary locally converging equilibria.

governed by a single differential equation

$$\frac{\dot{m}}{m} = \beta + \phi - \frac{U_m}{U_c} \; . \tag{1.3}$$

together with a transversality condition here amounting to $\lim_{t \to \infty} e^{-\beta t} m_t = 0$.
In order to explain how could LI be generated here, we resort to a thought experiment
outlined by Benhabib and Farmer (1999). Starting from a monetary steady state
m^* (itself a trivial stationary sequence), identified by setting (1.3) equal to zero,
consider an unexpected, permanent, sufficiently small increase in M alone, without
any accompanying change, and in particular holding prices and price expectations
constant. An excess supply of real balances will result. If m were to increase from
m^*, given fixed income the only change in (1.3) would be a decrease in U_m. Hence
$\frac{\dot{m}}{m}$ would become positive in equilibrium. In other words, $\dot{P} < 0$: the excess supply
could be driven down only by self-fulfilling expectations of lower prices, which would
increase the return on holding money (equal to $-\pi$), and thus the demand for m. But
on this pattern, immediately thereafter real balances will be even higher, so clearing
the money market would require even greater price deflation to push demand further
up. With this feedback process, steadily decreasing prices would cause real balances
to explode: the differential equation is unstable, as depicted in Figure 1.1. Such a
sequence would leave the neighborhood of the steady state; and it can be ruled out
as an equilibrium sequence by the transversality condition.[6] In this case, the only
equilibrium path is the stationary sequence that coincides with the steady state,
achieved by means of an immediate offsetting jump in P.
The question is: can the excess supply in this thought experiment be absorbed
without an immediate offsetting jump in prices? That is, under what conditions will
it be possible for the economy to follow an equilibrium path towards m^* different
from permanent steady state? Such multiplicity could be induced if the monetary
expansion, by stimulating the economy, determined a suitable modification in the
propensity to consume or to hold real balances, enough to transform the excess
supply of real balances into excess demand. If expanding money stimulates real
activity so that agents modify their demand for money for transactions or asset
holding, then the extra demand for m that derives from this non-neutrality or *real*

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[6] The transversality condition requires m to grow asymptotically less rapidly than rate β. With
Inada conditions in place and $\phi \geq 0$, violation obtains since $\lim_{m \to \infty} \frac{\dot{m}}{m} = \beta + \phi \geq \beta$.
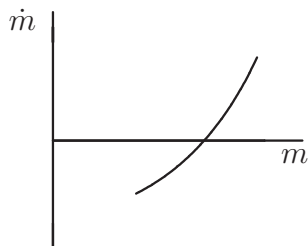
Figure 1.1:
Instability ≡ Local Determinacy
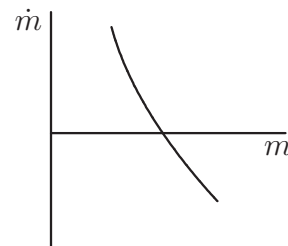
Figure 1.2:
Stability ≡ Local Indeterminacy

effect of money could make alternative conjectures for price sequences compatible with a stationary equilibrium. In fact, if the effects on the real side of the economy of a rise of m from m^* are such that a net excess demand for money is generated, then self-fulfilling expectations of future inflation can decrease the demand by depressing the rate of return of money as an asset (equal to the negative of the inflation rate). And steadily decreasing inflation will make it possible, at every following instant, to maintain equilibrium while real balances shrink to their original stationary level, and then hold constant again. This would hold for every sufficiently small jump in M: therefore, in the neighborhood of the steady state there will exist a continuum of converging perfect foresight equilibrium paths, each associated with a different initial condition for m and a different path for the price level. We emphasize that this intuition extends to the entire framework that we analyze. In the simple model above, let us suppose counterfactually that real effects of money exist. By acting either on output or directly on marginal utilities in (1.3) they could drive U_c down more than U_m after the monetary expansion: a marginal rate of substitution U_m/U_c *increasing* in m at m^* would invert the excess supply of m, turn the slope of the phase line negative and make the differential equation stable, thus yielding a multiplicity of possible equilibrium paths (as in Figure 1.2).

Proposition 1 *In the Sidrauski-Brock class of models, real effects of money are a necessary condition for local indeterminacy.*

Consistent with the foregoing, we measure the real effects of money as the marginal proportional reaction that the monetary expansion induces on the propensity to consume and to hold money balances and use this metric to identify conditions for LI. As an instrument, it is useful to define, for any two generic variables z and w, the elasticity of z with respect to w evaluated at the steady state as $\varepsilon_{z|w} \equiv -w^* z_w^*/z^*$.

The channel whereby the real effects of money can be added most readily to this basic setup is nonseparability between consumption and real balances ($U_{cm} \neq 0$), which yields a first set of necessary and sufficient conditions for LI (all proofs are in the Appendix):

Proposition 2 *In a Sidrauski-Brock economy with fixed endowment, equilibrium paths are locally indeterminate if and only if*

$$either \qquad \varepsilon_{U_m|m} > \varepsilon_{U_c|m} > 1 \qquad\qquad (1.4)$$

$$or \qquad \varepsilon_{U_m|m} < \varepsilon_{U_c|m} < 1 \,. \qquad\qquad (1.5)$$

Proposition 2 spells out the pattern that in this simple model the impact of money on real activity should follow in order to create conditions for self-fulfilling inflation expectations compatible with stationarity of equilibrium. We will see how this same pattern will be confirmed, though in an enlarged format, in more general versions of the model. In any case, a closer look at this first, basic set of conditions reveals that condition (1.5) is associated with a rather pathological behavior, i.e. non-normality of m[7] and that a single explanatory feature underlies both conditions:

Proposition 3 *In a Sidrauski-Brock economy with fixed endowment, $U_{cm} < 0$ is a necessary condition for local indeterminacy.*

A statement analogous to Proposition 3 is already present in Matsuyama (1990), but on closer inspection in that model the condition is actually necessary to ensure just the positive autocorrelation of stationary sunspot equilibria, and not, as claimed, their existence. In either case the economic intuition underlying the proposition is as follows. A negative U_{cm} is a necessary condition for LI because if real balances are high today and expected to be lower tomorrow, then a rising inflation tax increases the opportunity cost of holding money today; however, increasing inflation under $U_{cm} < 0$ raises the expected U_c, creating an incentive to defer consumption, hence a greater propensity to hold money now. Forcing the explanation in terms of that outlined for the case of separability, a negative cross-derivative in the case of nonseparability is necessary to create conditions for the MRS to be increasing in m

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[7] Real balances are in fact normal if $U_{mm} < U_{cm}U_m/U_c$ (which amounts to $\varepsilon_{U_m|m} > \varepsilon_{U_c|m}$), as is assumed in the early works on this nonseparable case by Gray (1983) and Obstfeld (1984), who were therefore ruling out condition (1.5). As for condition (1.4), Obstfeld had something like $\varepsilon_{U_c|m} > 1$.

at m^*, but it might not be sufficient, as the magnitude of the overall variation in U_c induced by a change in m might not be large enough – in fact, it would be large enough only under non-normalities.[8]

As for plausibility, though, on the theoretical side $U_{cm} < 0$ is not the sort of restriction that one could derive starting from more detailed ways of introducing money.[9] On the empirical side, early work by Koenig (1990) is also against the hypothesis of $U_{cm} < 0$, while the ML estimations of DSGE models for the U.S. and the euro area by, respectively, Ireland (2004) and Andrés *et al.* (2006) both favor separability.

We then consider a second immediate, simple way to introduce real effects of money into the Sidrauski-Brock framework, namely including real balances directly as an input (the only variable input) in a strictly concave production function, as in the analysis of Calvo (1979) and Benhabib and Farmer (1996, 1999). This simple MIPF economy naturally fulfils a necessary condition for LI analogous to the foregoing for the case of nonseparable utility: by increasing output and therefore equilibrium consumption, an increase in real balances would indirectly decrease U_c.[10] As for sufficiency, however, as above, after an increase in m from m^* the excess supply could actually be reversed, and LI occur, only if U_c were to fall sharply, i.e. if: *i*) m were so productive that y and hence, in equilibrium, c increase discretely, or else *ii*) U_c were very elastic to changes in consumption. More generally, LI would arise if and only if $\varepsilon_{U_c|c}\varepsilon_{y|m} > 1$, which, given the equilibrium equality between output and consumption, could be interpreted – if synthetically read as $\varepsilon_{U_c|m} > 1$ – as a subset of the conditions (1.4) derived for the case of nonseparable utility.[11]

How plausible is LI in this simple MIPF model? Specifying $y = m^\omega$ and a CRRA utility $U = \frac{c^{1-\alpha}}{1-\alpha}$, the necessary and sufficient condition for it tested by Benhabib and Farmer (1996) is $\alpha\omega > 1$. By a property of perfect competition, Benhabib and

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[8] $U_{cm} < 0$ would also be the key to LI in an MIUF model with capital k and a strictly concave technology $y = f(k)$ as in Calvo (1979) and Fischer (1979), who nevertheless assumed, respectively, $U_{cm} > 0$ and the weaker $U_{mm} < U_{cm}U_m/U_c$.

[9] Feenstra (1986) shows that the CIA model can be approximated by an MIUF model with $U_{cm} > 0$, and the same applies to a cash-good/credit-good model, while Croushore (1993) shows that the shopping-time model can be approximated by an MIUF model with $U_{cm} \geq 0$. Woodford (1990) and Mulligan and Sala i Martín (1997) argue that a possible justification of MIUF is that money is complementary with consumption, i.e. it helps to enjoy real consumption goods.

[10] With $U = U(c)$ and $y = h(m)$ and strict concavity, at the margin the effect of an increase in m is $U_{cc}h_m < 0$.

[11] The elasticity of output with respect to real balances is defined in positive terms, as $\varepsilon_{y|m} = h_m m/y$.

Farmer compute ω as the share of money in GDP, finding a value of about 0.01 for the U.S., which would imply unrealistically high values of α to induce LI.[12]

The conclusion of this section is therefore that, despite including the fundamental mechanisms that might in principle be conducive to LI, basic exogenous-money-growth-rule economies seem immune to the *effective* risk of local instability.

1.3   Local indeterminacy in MIUF-MIPF economies

In this section we outline the simplest versions of the SBC framework which turn out to be compatible with possible and plausible LI. Given the driving forces and mechanisms for LI indicated by the most basic models, all relying on real effects of money large enough to alter substantially the relative propensity to consume and to hold money, LI should be more likely in economies that have more channels through which a monetary expansion can affect real allocations. In the framework chosen, a natural first approximation to such a richer setup is given by a joint consideration of households' and firms' motives to hold money, i.e., a joint MIUF-MIPF economy.

1.3.1   MIUF-MIPF economies

Let us consider a version of the SBC framework with $U = U(c, m)$ and $y = h(m)$, $h(\cdot)$ strictly concave and twice continuously differentiable. This is a model sketched out in Benhabib and Farmer (1999) with very incomplete conclusions about conditions for LI, which we instead identify and relate to the pattern found for the basic models analyzed above.

The single equilibrium law of motion obviously combines MIUF and MIPF features:

$$\frac{\dot{m}}{m} = \frac{\beta + \phi - h_m - \frac{U_m}{U_c}}{1 + m h_m \frac{U_{cc}}{U_c} + m \frac{U_{cm}}{U_c}} \; . \tag{1.6}$$

Linearizing around a monetary steady state, one gets the following proposition:

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[12] By endogenizing the choice of leisure and making it dependent on m, Benhabib and Farmer (1996, 2000) strengthen the output response of money through an indirect labor channel, which induces LI for a "wrong" labor supply slope. (They then exploit the indeterminacy to explain the output effect of money in the data – but, as they began by fulfilling the necessary condition for LI, i.e. that money has real effects, the exercise appears circular.)

Proposition 4 *In a Sidrauski-Brock-Calvo economy with nonseparable preferences $U = U(c, m)$ and strictly concave technology $y = h(m)$, equilibrium paths are locally indeterminate if and only if*

$$either \quad \varepsilon_{U_m|m} + \varepsilon_{U_m|c}\varepsilon_{y|m}[1 + \frac{\varepsilon_{h_m|m}}{\varepsilon_{U_c|m}}] > \varepsilon_{U_c|m} + \varepsilon_{U_c|c}\varepsilon_{y|m} > 1 \qquad (1.7)$$

$$or \quad \varepsilon_{U_m|m} + \varepsilon_{U_m|c}\varepsilon_{y|m}[1 + \frac{\varepsilon_{h_m|m}}{\varepsilon_{U_c|m}}] < \varepsilon_{U_c|m} + \varepsilon_{U_c|c}\varepsilon_{y|m} < 1 \,. \qquad (1.8)$$

These conditions are a natural extension of conditions (1.4)-(1.5) of the case of nonseparable-utility MIUF: the additional presence of indirect effects on the demand for money and for consumption goods deriving from MIPF (more precisely, from money that affects output and thus, in equilibrium, marginal utilities) reveals the full pattern for the real effects of money that could induce self-fulfilling inflation expectations compatible with stationary equilibria. This general pattern strictly includes the conditions from all the SBC models presented so far, and can be specified as

> either (direct + indirect proportional change of U_m after a change in m) >
>
> > > (direct + indirect proportional change of U_c after a change in m) > 1
>
> or (direct + indirect proportional change of U_m after a change in m) <
>
> > < (direct + indirect proportional change of U_c after a change in m) < 1 .

Conditions (1.7)-(1.8) show where and how the direct and indirect effects of money would play a role in making LI possible in this simple MIUF-MIPF economy: in this setup, only slightly more general than the basic ones, the number of monetary transmission channels in place is already so large that this possibility exists even without giving up normality of c or m, $U_{cm} \geq 0$, low elasticity of marginal utility or mild direct output effects of money. Evidently, conditions (1.7)-(1.8) for LI are more general than the previous ones and thus have a better chance of being realized in the empirical data.

In fact, unlike the simple MIUF model, even with the restrictions of normality of goods and no direct effect in utility, by setting $U_{cm} = 0$, there is a simple set of conditions under which LI can emerge:

$$either \quad \varepsilon_{U_m|m} > \varepsilon_{U_c|c}\varepsilon_{y|m} > 1$$

$$\text{or} \qquad \varepsilon_{U_m|m} < \varepsilon_{U_c|c}\varepsilon_{y|m} < 1 .$$

We focus on this more realistic case of separability to evaluate the meaning, extent and plausibility of conditions for LI in a MIUF-MIPF economy. We take a specific example of this economy, namely a model characterized by a Cobb-Douglas technology with real balances as the only variable input

$$y = m^\omega$$

with $\omega \in (0,1)$, and by separable CRRA preferences in consumption and real balances

$$U = \frac{c^{1-\alpha}}{1-\alpha} + Q\frac{m^{1-\gamma}}{1-\gamma}$$

Q being an arbitrary positive constant. The parameters α and γ are required to be positive in order to ensure concavity of the objective functional; as we know, they are equal to the elasticities of, respectively, U_c with respect to c and U_m with respect to m, and also to the reciprocal of the intertemporal elasticities of substitution of, respectively, c and m, labelled IES_c and IES_m: the smaller α (respectively, γ) is, the more slowly marginal utility falls as consumption (real money) rises, and so the more willing the household is to allow its consumption (or its real money balances) to vary over time. Under this specification, the single equilibrium law of motion is

$$\frac{\dot{m}}{m} = \frac{1}{1-\alpha\omega}\left[\beta + \phi - \omega m^{\omega-1} - Qm^{\alpha\omega-\gamma}\right]$$

and the necessary and sufficient conditions for LI are

$$\text{either} \quad \gamma > \alpha\omega > 1 \tag{1.9}$$

$$\text{or} \qquad \gamma < \alpha\omega < 1 . \tag{1.10}$$

In terms of the thought experiment outlined in Section 1.2, both conditions refer to cases in which the demand for real balances might rise following a sudden expansion of the nominal money supply, sustaining self-fulfilling expectations on prices compatible with a multiplicity of real allocations. Under inequality (1.9), this could happen because of a strong motive for firms to want to hold money, when it plays a significant role in production ($\alpha\omega > 1$). Under inequality (1.10), instead, LI would mainly be the outcome of households' money preference. In fact, in this case LI is possible when both $IES_m > 1$ and $IES_m > IES_c$. This means that in order

for multiple equilibrium paths to be possible, the representative household must be indifferent enough about when to hold real money balances. When households are sufficiently free in tailoring their real balances intertemporal profiles, an equilibrium sequence for m (and consequently for all variables in the economy) can be made out of a certain self-fulfilling expectation on prices. How much is "sufficiently"? Here, enough for the household to be quite willing to substitute real balances intertemporally, and more willing to do so for real balances than for consumption. Otherwise, according to the thought experiment, when there is an increase in the money supply the conditions for a sufficient increase in the demand could not exist. Or, in case of a change in marginal utilities, for whatever reason, the household would adjust its intertemporal choice profile mainly on the consumption side, damping the contribution to multiplicity that may come from the interaction between money balances and expectations.

The magnitude of ω, which measures the direct effect of real balances on output, does affect these inequalities. To assign a data-based range of values to ω, we use the strategy of Benhabib and Farmer (1996). Positing perfect competition, we compute ω as the share of real balances in production (im/y, where i is the nominal interest rate), both for the euro area and for the U.S. For the euro area (source: Statical Data Warehouse), averaging for the period 2003-2009, we compute a weighted average of gross interest rates on M2 deposits of non-financial corporations scaled it by gross value added in that sector. We find a value of 0.025. For the U.S., we use both a micro and a macro approach. At micro level, using data from Compustat for more than 15,000 non-farm non-financial corporations for the period 1982-2000 (to limit the effects of the swings induced by the use of "sweep" deposit accounts), we compute the panel ratio of cash plus short-term investments to sales, and multiply it by the M2 own rate provided by the FRED database, finding a value of 0.085. At the macro level, for the same years we use the Federal Reserve's flow-of-funds data for non-financial corporations[13] to compute the ratio of total deposits to sectoral gross value added, and multiply it by the 3-month T-Bill rate, finding a value of

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[13] In the flow-of-funds data, non-financial sector liabilities might be underestimated because, while the holdings of each sector are computed exactly, households are assigned any money whose ownership cannot be accounted for (i.e., households' liabilities are computed subtracting the holdings of the other sectors from the aggregate values for the whole economy and assigning any difference to the households sector).

0.01, i.e. the same value as in Benhabib and Farmer (1996). Further considering that these values should be slightly increased to account for currency in circulation and for other monetary items whose allocation is not sectoralized,[14] we consider any value of ω in the range $[0.01, 0.1]$ as plausible.

For four values of ω in this range, Figure 1.3 shows (in red-solid) the LI loci for the current MIUF-MIPF model. The other parameters are calibrated as: $Q = 1$, $\beta = 0.025$, and $\phi = 0.02$ (implying steady state inflation of 2%).[15] The LI area on the left of each panel in Figure 1.3 corresponds to the high IES_m case of condition (1.10); the upper-right area, visible only in the bottom panels, corresponds to the case of a significant supply-side role of money, as in condition (1.9). This latter condition is shown to lead to LI only for values of ω on the high side of the interval: with $\omega = 0.1$, by condition (1.9) there would be LI for $\alpha \geq 10$ and $\gamma > 1$. On the low side, for ω equal to 0.01 or 0.03, condition (1.9) would support LI only for unrealistically high values of α.[16] By condition (1.10), however, LI could emerge for any ω, for the full range of realistic values of α and for $\gamma < 1$. How to calibrate a realistic range of values for γ? The inverse of this parameter is equal to the IES_m: in a simple MIUF model with separable preferences, it would also be equal to the absolute value of the interest rate elasticity of the demand for money. In this case, taking, say, 0.39, the value estimated by Chari *et al.* (2000) on U.S. data, γ should be set equal to 2.56; or taking the value of 1.2 (estimated by Kremer *et al.* (2003) for pre-euro Germany, a monetary-targeting country), γ should be set equal to 0.83, which is a value compatible with condition (1.10). But in a MIUF-MIPF model, in which money is demanded not only by households but also by firms with different

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[14] For the euro area, the items that are included in the definition of money but are not sectoralized (and are therefore excluded from our calculations, which are based on official sectoralized data) are currency in circulation, money market fund shares/units and MFI debt securities with maturity up to two years. In the first quarter of 2006, these items accounted for 7.4%, 8.5% and 2.1% of the stock of M3 in the euro area, respectively, and, according to estimates by the ECB (2006), euro-area non-financial corporations were holding slightly less than 15% of the currency in circulation, more than one quarter of the money market fund shares/units, and 62.5% of the MFI debt securities with a maturity up to two years not held by non-monetary financial intermediaries.

[15] Robustness exercises with respect to these baseline parameters do not alter the basic picture depicted by Figure 1.3, although a lower value of Q, attenuating the impact of real balances on preferences, will obviously shrink in part the LI areas.

[16] This implausibility for low values of ω stems from the right hand side of condition (1.9), and corresponds to the implausibility found by Benhabib and Farmer (1996) in the simple MIPF model surveyed in our Section 1.2 (nested in the current model).

objective functions and constraints, the CRRA parameter γ would no longer be equal to the inverse of the interest rate elasticity of the demand for money. In fact, in the current model with a single state variable, it would be a nonlinear function of m and of its ratio with c, which prevents a mapping with any empirically evaluated relation. The MIUF-MIPF model set out in Section 1.3.2, which distinguishes the demand for money by sector, will allow closer comparison between available estimates and the set of conditions for LI. Those results will further strengthen the conclusions that we draw here: on the one hand, the possibility of LI does exist in this simple MIUF-MIPF model (and is greater, the greater the output effect of money in the chosen range); on the other hand, its plausibility cannot be ruled out by empirical investigations to date.

Figure 1.3 - LI in an MIUF-MIPF economy

(LI in solid-red, saddlepath in dotted-blue)
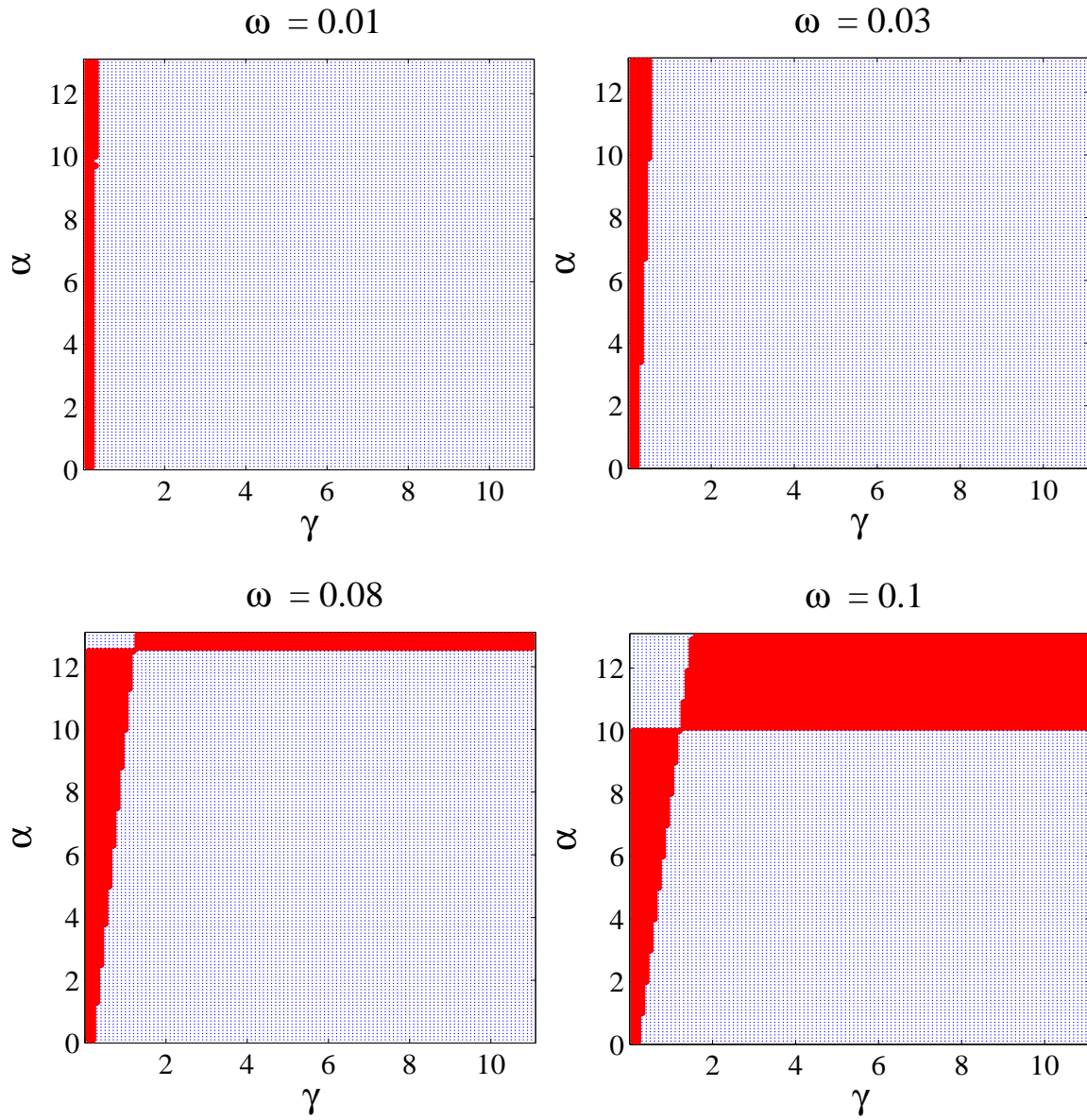
1.3.2 MIUF-MIPF economies with distinct money

In the foregoing model, there is just one type of agent, a household-firm unit whose single holding of money facilitates at once both consumption and production. This specification thus does not allow extension to a decentralized economy, unless one distinguishes explicitly between households' money and productive money. In what follows we consider a model in which money used for utility purposes is distinguished from money used in production, as in the Taylor-rule model of Benhabib *et al.* (2001). Preferences are then defined over consumption and real balances for non-productive use, $U = U(c, m_{np})$; technology has instead real balances for productive use as the only variable input $y = h(m_p)$. With respect to the previous MIUF-MIPF model with no distinction, this setup delivers both a neater aggregate consistency condition on the money market (in nominal terms, it requires $M^s = M_{np}^d + M_p^d$ for equalization of supply and demand) and a modification of the LI sets that leaves the door open to an empirically effective possibility of multiple equilibria, hence of sunspot fluctuations.

In the equilibrium of this model with two distinct uses of money,[17] conditions $\frac{U_m}{U_c} = h_m$ and $h(m_p) = c$ lead to the following single law of motion in total real balances governing the economy

$$\frac{\dot{m}}{m} = \frac{\beta + \phi - h_m}{1 + \frac{\frac{[U_{cc}U_{mm}-(U_{cm})^2]}{U_c}mh_m+h_{mm}U_{cm}m}{\left(\frac{U_m}{U_c}U_{cc}-U_{mc}\right)h_m+\left(U_{mm}-\frac{U_m}{U_c}U_{cm}\right)+U_ch_{mm}}} \quad . \tag{1.11}$$

Fixing one monetary steady state $m^* = m_{np}^* + m_p^*$, one has the following proposition.

Proposition 5 *In a Sidrauski-Brock economy with nonseparable preferences $U = U(c, m_{np})$ and strictly concave technology $y = h(m_p)$, equilibrium paths are locally indeterminate if and only if*

$$\frac{m^*}{U_c}\left(U_{cc}U_{mm} - U_{cm}^2 + h_{mm}\frac{U_{cm}}{U_m}U_c^2\right) > \left(U_{cm} - \frac{U_m}{U_c}U_{cc}\right) + \left(\frac{U_m}{U_c}U_{cm} - U_{mm}\right)\frac{U_c}{U_m} + \frac{U_c}{m_p^*}\varepsilon_{h_m|m_p} \tag{1.12}$$

As in the previous cases, condition (1.12) would be more likely to be fulfilled assuming $U_{cm} < 0$ and non-normality of both c and m_{np}. To avoid relying on these unrealistic features, we focus on conditions under which LI may emerge in the more

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[17] When distinguishing, the subscript m refers to derivatives with respect to the correspondent type of real balances.

restrictive case of $U_{cm} = 0$ (which implies normalities). This also ensures analytical convenience and comparability with our earlier results. In fact, with separable preferences the necessary and sufficient condition (1.12) translates into

$$\frac{\varepsilon_{U_c|c}\, \varepsilon_{y|m_p}\, \varepsilon_{U_m|m_{np}}}{m_p^*} + \frac{\varepsilon_{U_c|c}\, \varepsilon_{y|m_p}\, \varepsilon_{U_m|m^{np}}}{m_{np}^*} > \frac{\varepsilon_{U_c|c}\, \varepsilon_{y|m_p}}{m_p^*} + \frac{\varepsilon_{U_m|m_{np}}}{m_{np}^*} + \frac{\varepsilon_{h_m|m_p}}{m_p^*} \qquad (1.13)$$

which we interpret as a condition on how important money has to be in the economy for LI to occur: it has to be that the weighted multiplicative impact of money on the economy be greater than the weighted additive impact. This is easier to see in an example economy: assuming the same functional forms as in the previous MIUF-MIPF model with no distinction between uses of money (i.e., assuming $U = \frac{c^{1-\alpha}}{1-\alpha} + Q\frac{m_{np}^{1-\gamma}}{1-\gamma}$ and $y = m_p^\omega$), condition (1.13) becomes

$$\frac{\alpha\omega\gamma}{m_p^*} + \frac{\alpha\omega\gamma}{m_{np}^*} > \frac{\alpha\omega}{m_p^*} + \frac{\gamma}{m_{np}^*} + \frac{1-\omega}{m_p^*} \qquad (1.14)$$

The greater the impact of money on the economy, the more likely the interplay between money and price expectations that can result in multiple equilibrium real allocations.

We parameterize this economy just as in the previous Section 1.3.1, but with one additional refinement. While ω still ranges from 0.01 to 0.1, the calibration of γ can now be more precise. In fact, in the current model with distinct money the inverse of this parameter does correspond to (the absolute value of) the interest rate elasticity of the demand for money of the household sector. Most logarithmic estimates of demand for money performed on sectoral micro-data for both the euro area and the U.S. put this elasticity between 0.1 and 0.7: this is the interval covered by the estimates on U.S. data in Mulligan and Sala i Martín (2000), while point estimates for single European countries – e.g. by Attanasio *et al.* (2002) and Lippi and Secchi (2009) for Italy – range throughout that interval. Such values for the interest elasticity of household demand would correspond to values of γ between 1 and 11.[18] For this parameterization, Figure 1.4 shows that there is now a single boundary to the LI area, which has the shape of a translated equilateral hyperbola.

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[18] The range should not to be seen as in contrast with the possibility of γ being below 1 in the MIUF-MIPF model with no distinction of money uses. In fact, the literature (ECB, 2006 and 2010, or Calza and Zaghini, 2010) reports that a greater weight of the portfolio motive for firms' demand for money induces much greater interest-rate sensitivity for that sector, and hence a greater interest-rate elasticity of the aggregate demand for money.

In fact, condition (1.14) can be rewritten in homographic form as

$$\alpha\omega\gamma > \alpha\omega\frac{m_{np}^*}{m^*} + \gamma\frac{m_p^*}{m^*} + (1-\omega)\frac{m_{np}^*}{m^*}$$

Above the boundary is the locus of combinations of α and γ that engender multiple equilibria: while for low ω no combination is plausible, as ω increases the area of plausibility expands. These are the cases in which around the steady state a sudden excess supply of real balances turns into an excess demand, which happens whenever the immediate consequence of an increase in money is a larger decrease in U_c than in U_m. How might this come about? Notice that a higher ω implies a lower own-elasticity of marginal productivity of real balances ($\varepsilon_{MP_m|m_p}$, here equal to $1-\omega$). Suppose m rises from m^*, affecting m_{np} and m_p. If firms use more money, the decrease in h_m will be the smaller, the larger ω is. Equilibrium production, hence consumption, would increase, lowering U_c the more substantially, the higher the own-elasticity of marginal utility of consumption $\varepsilon_{U_c|c} = \alpha$. This would justify an increase in the demand for money holding on the part of households as well: in fact, by decreasing U_m, such an increase maintains the equilibrium condition $U_m/U_c = h_m$. At this point, larger aggregate money demand can trigger self-fulfilling inflation expectations compatible with equilibrium.

In this model with distinct money uses, the LI loci are different from our previous model. The area of possible multiplicity for low levels of γ disappears, while the upper-right area in the panels not only remains and is increasing in ω, but also intersects with a wider and more significant range of empirically relevant parameterizations. We take the existence of these areas in the current and previous MIUF-MIPF models as showing that LI is both a possible and a plausible outcome of SBC models with monetary targeting. Economic and policy analysis would do well to take this possibility into account when using models at least as complex as those posited here, like the typical DSGE models typically used as a basis for policy recommendations.

Figure 1.4 - LI in an MIUF-MIPF economy with distinct money

(LI in solid-red, saddlepath in dotted-blue)
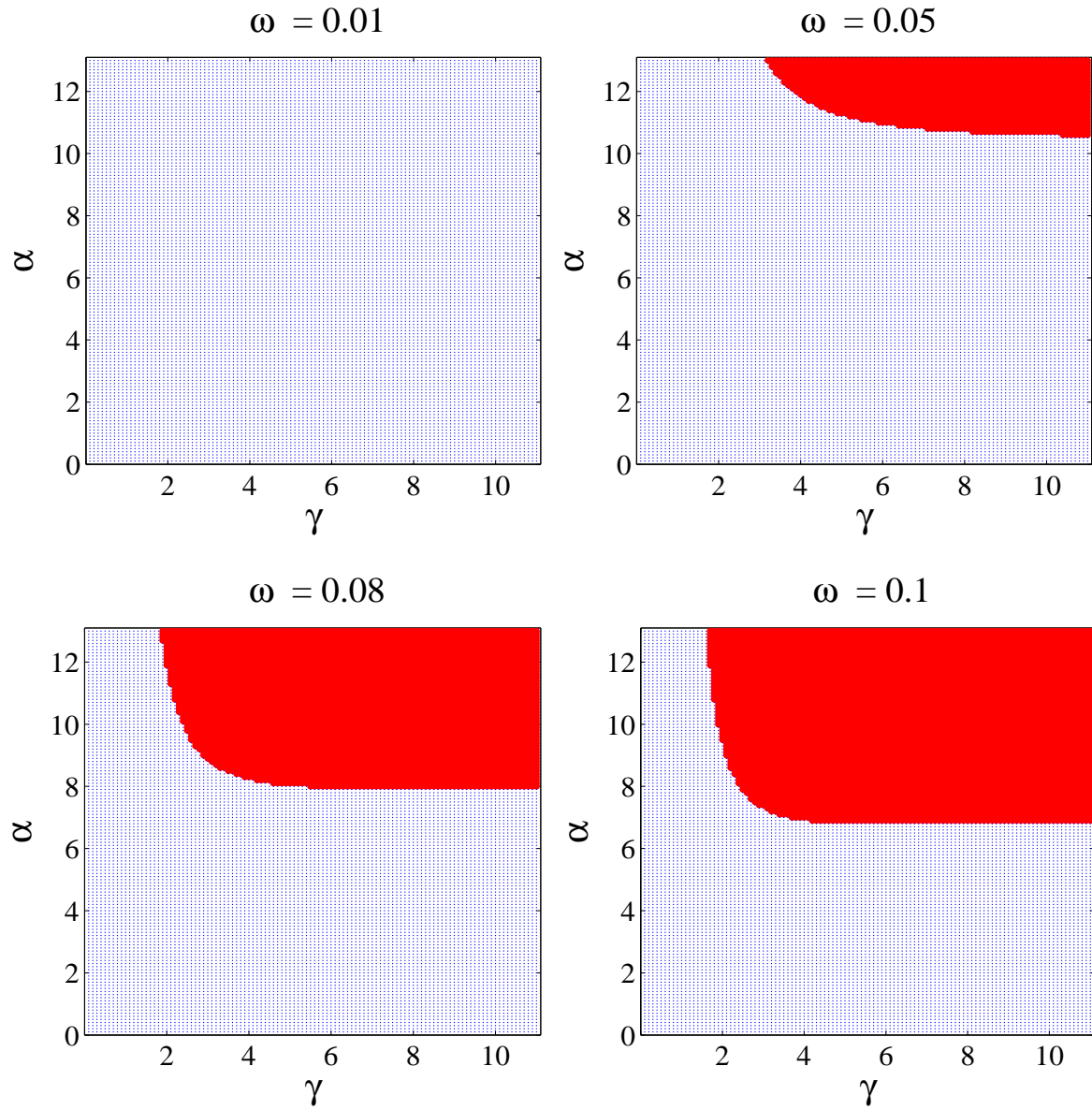
1.4 Conclusions

The inclusion of monetary targeting among policy instruments is sometimes advocated as a tool for inoculating the economy from the instability risk associated with possible sunspot equilibria. This chapter has checked the validity and scope of this property in the SBC framework, characterized by an exogenous money growth rule, a meaningful role for real balances, and perfect markets, thus isolating the role of money and monetary targeting. Benhabib and Farmer (1999, 2000) showed that local instability, in the form of multiple equilibria, might be induced by the interplay between the non-neutrality of real balances and price expectations. That is, a monetary expansion might stimulate the real economy to the point of generating excess net demand for real balances, which would make self-fulfilling inflation expectations compatible with stationary equilibria. In their analysis, however, this indeterminacy was deemed to be empirically relevant only when the effects of real balances spill over to labor supply and demand, heightening the impact on the real economy but inducing the considerable modeling cost of having non-standard slopes in labor market schedules.

This chapter posits a basic economy with money and monetary targeting and produces two findings.

First, it identifies a general pattern for the real effects of money that can induce the shift in the propensity to demand real balances that is necessary for LI to occur. The pattern is identified by relating these real effects to the proportional reactions to a monetary change of marginal utilities and productivities. This pattern includes both direct and indirect effects; indirect effects via the labor market might play a role, but are not necessary – and are in fact excluded ex-ante from the analysis. Looking at the conditions that are nested in the pattern, we show that in more basic models LI can only arise under "wrong" assumptions on factors like cross-derivatives, normality of commodities, intertemporal elasticities of substitution, or direct output effects of money.

Based on the pattern found, we then pursued our principal purpose, which is to check whether LI could ever be both a possible and a plausible outcome in a monetary targeting economy with no non-standard features. We have shown that with some modest generalizations that enrich the ways in which a monetary expansion affects

the real economy, such as jointly recognizing both to household and to firms a motive for holding money, LI can occur without unsatisfactory assumptions (on the labor market, say) and for empirically relevant parameter values. The conditions for LI that we derive in our simple MIUF-MIPF models are shown to have a reasonable chance of fitting the data.

One conclusion might be drawn in terms of model analysis and comparison to the real world. We have shown in a simple framework that with monetary targeting real effects of money are crucial for LI. But we have also shown that allowing multiple channels for these non-neutralities of money may make them "large enough" overall, and magnify their impact on the determinacy properties of the model. Thus our admittedly very simple model already serves to show the risks of instability that monetary targeting would entail in an economy in which money plays a significant role. But the point made by our simple model goes beyond its seemingly narrow scope, suggesting that in a model factoring in even a fraction of the larger set of sources of monetary non-neutrality that characterize actual economies there would be a much greater chance that LI will be both possible and plausible under monetary targeting. Along these lines, a model including features like nominal rigidities or financial frictions – which alter variables as relevant for economic choices as the real marginal cost of supplying a given output or the marginal productivity of non-monetary inputs – would be not only more realistic economically but also more likely to display multiple equilibria. The implication is that under monetary targeting a real-world economy would have an even greater risk of instability than in our simple examples.

A natural policy recommendation emerges as a bottom line. Our analysis warns of some limitations of policy rules based on monetary aggregates, and as such it could help define a correct monetary policy strategy. Making monetary targeting a part of the strategy may still be helpful for a long-run guide, but may neither guarantee that expectations remain anchored to fundamentals nor serve to help immunize the economy against the instability associated with possible multiple equilibria. In a world in which not only interest rate rules but also monetary targeting rules induce a risk of such instability, it would still appear to be prudent for monetary authorities to adopt a mixed strategy, with the composite use of various policy tools and attentive monitoring of a wide spectrum of monetary and real aggregates.

Appendix to Chapter 1

Proof of Proposition 2: The equilibrium differential equation is

$$\frac{\dot{m}}{m} = \frac{\beta + \phi - \frac{U_m}{U_c}}{1 + m\frac{U_{cm}}{U_c}} .$$

Linearizing it in the neighborhood of the monetary steady state, so that derivatives are local, one has

$$\dot{m} = -\frac{\frac{m^*}{U_c}[U_{mm} - \frac{U_m}{U_c}U_{cm}]}{1 + m^*\frac{U_{cm}}{U_c}} \left(m - m^*\right) . \tag{.15}$$

Given $U_c > 0$, stability of the linearized differential equation, and hence LI, will obtain if and only if the coefficient in (.15) has a negative sign, i.e. if and only if

$$\text{sign}\left[m^*\left(U_{mm} - \frac{U_m}{U_c}U_{cm}\right)\right] = \text{sign}\left[1 + m^*\frac{U_{cm}}{U_c}\right].$$

The left-hand sign will be negative if $m^*\frac{U_{mm}}{U_m} < m^*\frac{U_{cm}}{U_c}$, which can be restated in the form $\varepsilon_{U_m|m} > \varepsilon_{U_c|m}$. The right-hand sign will be negative if $\varepsilon_{U_c|m} > 1$. Considering also the case of positive signs and combining, the Proposition holds. □

Proof of Proposition 3: In inequality (1.4), $\varepsilon_{U_c|m} > 1$ implies $U_{cm} < -\frac{U_c}{m^*}$, i.e. U_{cm} large and negative. Inequality (1.5) has $\varepsilon_{U_c|m} < 1$, so in principle U_{cm} either positive or negative but small; but it also has $\varepsilon_{U_m|m} < \varepsilon_{U_c|m}$, and hence $U_{cm} < \frac{U_c}{U_m}U_{mm}$. Given strict concavity, satisfying (1.5) therefore implies $U_{cm} < 0$. □

Proof of Proposition 4: Linearizing (1.6) around m^*, one has the following coefficient of the equilibrium equation in deviation form:

$$-\frac{m^*\{h_{mm} + \frac{1}{U_c}[(U_{mc} - \frac{U_m}{U_c}U_{cc})h_m + U_{mm} - \frac{U_m}{U_c}U_{cm}]\}}{1 - \varepsilon_{U_c|c}\varepsilon_{y|m} - \varepsilon_{U_c|m}} .$$

Again, LI obtains whenever the sign of the numerator is the same as that of the denominator, which, recalling the proof of the analogous Proposition 2, is when one of the two inequalities (1.7) or (1.8) holds. □

Proof of Proposition 5: The steady state coefficient of the linearized monetary Euler equation (1.11) is

$$-\frac{h_{mm}m^*}{1 + \frac{\frac{h_m m^*}{U_c}\left(|H_U| + h_{mm}U_c^2\frac{U_{cm}}{U_m}\right)}{\left(\frac{U_m}{U_c}U_{cc} - U_{cm}\right)h_m + \left(U_{mm} - \frac{U_m}{U_c}U_{cm}\right) + U_c h_{mm}}} .$$

Using strict concavities and the equilibrium relation $U_m/U_c = h_m$, this coefficient will be negative if and only if the inequality in the Proposition is satisfied. □

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Chapter 2

Credit and Banking in a DSGE Model of the Euro Area

2.1 Introduction

This chapter seeks to understand the role of financial frictions and banking inter-
mediation in shaping the business-cycle in the euro area. To this end, we set up
and estimate a dynamic general equilibrium model incorporating a banking sector
characterized by monopolistic competition where intermediaries accumulates capital
subject to a capital adequacy requirement. We use the model to: (i) investigate how
the transmission mechanisms of monetary and technology impulses are modified by
the introduction of banking; (ii) study how shocks that destroy bank capital are
transmitted to the real economy; (iii) quantify the contribution of financial shocks
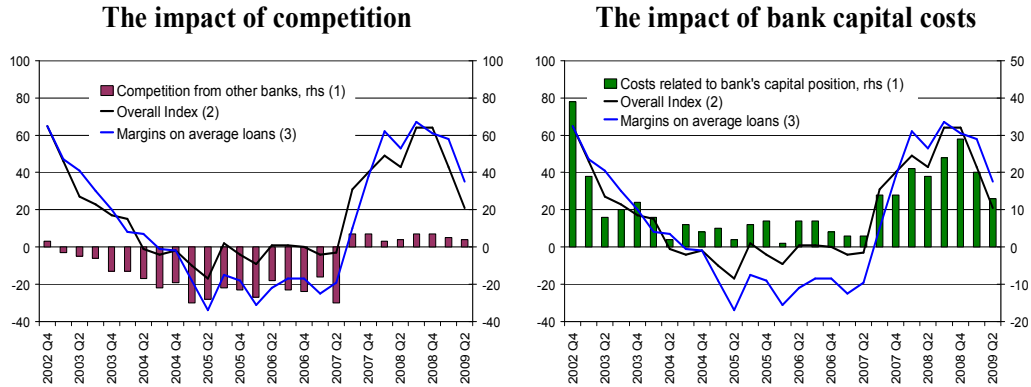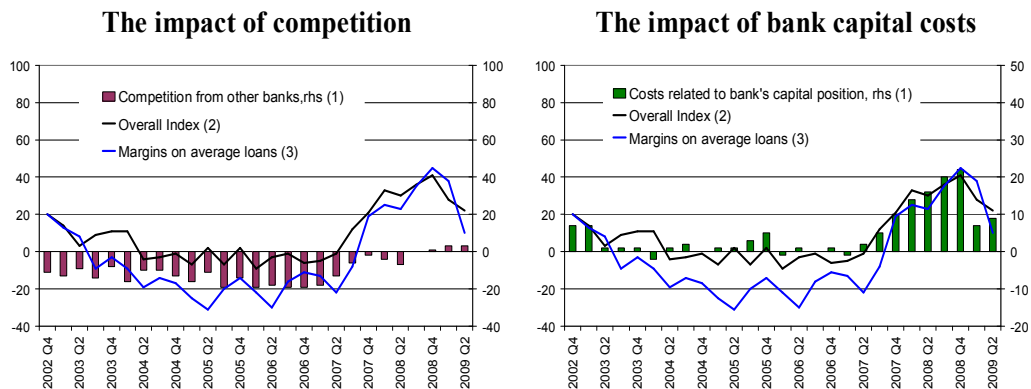to the 2008 slowdown in economic activity.

The financial crisis that started in 2007 has shown that the interaction between
financial and credit markets and the rest of the economy is crucial for explaining
macroeconomic fluctuations. While policy-makers have traditionally highlighted the

importance of these interactions, until recently most quantitative models used in academia as well as policy institutions either abstracted from them or approached the problem emphasizing only the *demand* side of credit: credit spreads in those models generally only reflect the riskiness of borrowers, while perfectly competitive banks accommodate the changing conditions on the demand side (e.g. Bernanke *et al.*, 1999).

Conditions from the *supply* side of credit markets – such as the degree of competition in the banking sector, or banks' rate-setting strategies and financial soundness – are, instead, at least as important. Figure 2.1 reports evidence from the Bank Lending Survey of the Eurosystem suggesting how the interest rate margin on the average loan is affected by supply factors such as the degree of competition and the costs related to banks' capital position (in particular since the onset of the financial crisis). We focus on banks as they represent by far the main funding source for households and firms in the euro area.

In modelling credit supply, we add a stylized banking sector to a model with credit frictions and borrowing constraints *à la* Iacoviello (2005). Banks have three distinctive features. *First*, they enjoy some degree of market power in loan and deposit markets and set different rates for households and firms. We do not try to pinpoint the source of market power, which theoretical literature has typically linked to asymmetric information problems, long-term customer relationships or the presence of switching costs; instead, we calibrate the average elasticities of loan and deposit demands to reproduce the degree of market power observed in the euro area. *Second*, banks face costs of adjusting retail rates and the pass-through on loan and deposit rates of changes in the policy rate is incomplete on impact. This is an important ingredient if the model is to capture the different speeds at which banks' rates react to changes in monetary conditions: the empirical evidence in favor of a partial and heterogenous adjustment of bank rates in the euro area is, indeed, overwhelming. *Third*, banks accumulate capital out of retained earnings and aim at keeping their capital-to-assets ratio as close as possible to an exogenous target level. Banks' capital position affects the amount and price of loans, introducing a feedback loop between the real and the financial side of the economy.

Figure 2.1 - Bank Lending Survey of the euro area (net percentages)

Loans and credit lines to enterprises

The impact of competition

The impact of bank capital costs

Loans to households for house purchase

The impact of competition

The impact of bank capital costs

(1) Net percentage of banks reporting the factor as contributing to tightening of lending standards.
(2) Net percentage of banks reporting an overall tightening in lending standards.
(3) Net percentage of banks reporting to have increased margin.

Note: The Figure reproduces, separately for entrepreneurs' and households' loans, the behavior of an indicator of credit tightness (i.e. the net percentage of responding banks indicating a tightening in lending standards in any given quarter), an indicator of interest rate margins (as reported by the responding banks) and indicators of the impact of, respectively, competitive pressure (left panels) and costs related to banks' capital position (right panels) on lending standards.

These modeling choices allow us to introduce shocks that originate on the *supply* side of credit and to study their propagation to the real economy. In particular, we introduce shocks to the interest rate spreads charged on loans to households, loans to firms and deposits that are meant to capture, for example, fluctuations in the price and amount of risk that could affect credit market spreads but are not explicitly accounted for in the model. We also introduce shocks to loan-to-value ratios that are interpreted as disturbances that affect credit availability. Finally, we introduce a shock to bank capital to study the effects of a drastic weakening in the balance sheet of banks.

The model is estimated with Bayesian techniques using data for the euro area over the period 1998Q1-2009Q1. Three results emerge. *First*, banking attenuates the response of output to a monetary policy shock; this mainly reflects the presence of sticky bank rates, which moderate the impact of changes in the policy rate on both consumption and investment. Financial intermediation induces some attenuation on output after a technology shock too, due to the presence of monopolistic power; in this case, however, banking also enhances the endogenous propagation mechanism of the model. *Second*, we estimate that the largest contribution to the contraction of euro area economic activity in 2008 has come from shocks originating in the banking sector, i.e. factors that either pushed up the cost of loans or reduced the amount of credit available to the private sector. *Finally*, we find that a credit crunch induced by an unexpected and persistent destruction of bank capital has substantial negative effects on real activity. The sudden fall in bank capital triggers an increase of lending margins and a contraction of credit volumes, as a consequence of banks' need to deleverage. The restriction on credit supply severely affects firms' investment; aggregate consumption is also hit, despite a temporary improvement in labor income.

Recently, a number of papers have developed models with financial intermediaries and a time-varying spread between deposits and lending rates (for example, Christiano *et al.*; 2008, Cúrdia and Woodford, 2009; Andrés and Arce, 2008; Gilchrist *et al.*, 2009; Goodfriend and McCallum, 2007). Other authors have studied the role of equity and bank capital for the transmission of macroeconomic shocks (de Walque *et al.*, 2008; van den Heuvel, 2008; Meh and Moran, 2010). Our contribution is to combine the main insights from these strands of literature in a setting featuring

stickiness in bank rates and to estimate the resulting model to assess its quantitative implications. Our analysis admittedly omits some elements of the current financial crisis (e.g., the increase in risk in financial markets and the freezing up of money markets). However, we think it constitutes an important step in the direction of quantifying the effects of credit sector shocks on the business cycle.

The rest of the chapter is organized as follows. Section 2.2 reviews theoretical arguments and empirical evidence supporting our key modeling choices. Section 2.3 describes the model. Section 2.4 presents the results of the estimation. Section 2.5 studies the propagation of shocks. Section 2.6 quantifies the role of financial shocks in the 2008 downturn of economic activity in the euro area and studies the effects of a credit crunch on the economy. Section 2.7 concludes.

2.2 Market power and sluggish rates in banking

In this section we discuss the key modeling assumptions concerning the banking sector, namely the presence of monopolistic power in the deposit and loan markets and the sticky adjustment of bank rates to movements in the corresponding market rates, reviewing both theoretical and empirical arguments in their support.

As regards *monopolistic competition*, microeconomic theory typically considers market power as a distinctive feature of the banking sector (Freixas and Rochet, 1997). One often cited reason is the presence of switching costs, for both customers and lenders, which generate a "lock-in" effect that gives banks market power. Switching costs might be the result of asymmetric information which typically leads to long-term relationships between banks and borrowers;[1] they could also arise due to the presence of pure "menu costs", like technical fees charged to close or to open a bank account, or fees incurred into when applying for a loan or renegotiating the terms of an outstanding debt.[2] Another frequently cited source of bank rents is market structure. The traditional *structure-conduct-performance* approach links market concentration to market power and interest rate-setting behavior (Berger *et al.*, 2004); other approaches highlight the importance of market contestability and regulatory restrictions as a source of market power (Demirguc-Kunt *et al.*, 2004). Empirically, the presence of market power in the banking sector, as well as its de-

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[1] See, for example, Diamond (1984), Greenbaum *et al.* (1989), and Sharpe (1990).
[2] See, among others, Kim *et al.* (2003) and Von Thadden (2004).

terminants over the business cycle, are well documented. Berger *et al.* (2004) and Degryse and Ongena (2008) provide extensive surveys and conclude that the degree of competition does indeed influence interest rate spreads and banks' profitability.[3] In the model, the measure of banks' market power is the interest rate elasticity of deposit and loan demand. We calibrate these elasticities at 1.5 for deposits and at about -3.0 for loans so that the steady state spreads in the model between the loan and the policy rate and between the policy and the deposit rate equal the average corresponding spreads in our sample (respectively, 1.7 and 1.2 percent on annual basis).[4]

The second unconventional assumption about the banking sector, namely that interest rates are *sticky*, is also supported by theoretical and empirical findings. From a theoretical point of view, infrequent adjustment of bank rates may be optimal if customers' demand is inelastic in the short run due to switching costs (Calem *et al.*, 2006), if there are menu costs of adjusting rates (Berger and Hannan, 1991) or if the importance of preserving customer relationships leads banks to smooth rates over the business cycle to shield borrowers from market rate fluctuations (Berger and Udell, 1992). From an empirical standpoint, the evidence in favor of bank rate stickiness is overwhelming and does not seem to come solely from bankers' practice of indexing bank rates to market rates. For example, Kok Sørensen and Werner (2006) study the interest rate pass-through for various types of loans and deposits in euro area countries and find that, even where the speed of adjustment is the highest, only 23% of the disequilibrium is adjusted in just one period.

We introduce sticky rates by assuming that banks face quadratic costs for adjusting retail rates. This assumption is a modeling short-cut and as such begs the question of its microfoundations. However, it captures a stylized fact in a tractable way, similarly to the assumption of costly price adjustment in goods markets, which has now become standard in New Keynesian models. In addition, we estimate the parameters pinning down the degree of stickiness for differentiated loans and deposits (see Section 2.4), thus letting the data tell us whether this is a reasonable

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[3] Among the paper included in the surveys, Claessens and Laeven (2004), using bank-level data for 50 countries for the period 1994-2001, show that most banking markets can be classified as monopolistically competitive. For the euro area, see De Bandt and Davis (2000).

[4] These numbers are in line with the empirical evidence. On interest rate demand elasticities, see Dick (2002) for the U.S. and Neven and Röller (1999) for European countries; on loan-deposit margins in European countries, see Claeys and Van der Vennet (2008).

assumption or not.[5] Our estimates suggest an incomplete short-run pass-through of policy rates to retail rates.

2.3   The model economy

The economy is populated by two groups of households (patient P and impatient I) and by entrepreneurs (E), each group having unit mass. Households consume, work and accumulate housing (in fixed supply), while entrepreneurs produce homogenous intermediate goods using capital, bought from capital-good producers, and hired labor. One key difference among agent types is the degree of impatience: the discount factor of patient households (β_P) is higher than those of impatient households (β_I) and entrepreneurs (β_E).

Two types of one-period financial instruments, supplied by banks, are available: saving contracts (deposits) and borrowing contracts (loans). When taking out a bank loan, agents face a borrowing constraint, tied to the value of tomorrow's collateral holdings: households can borrow against the value of their stock of housing, while entrepreneurs against physical capital. The heterogeneity in agents' discount factors determines positive financial flows in equilibrium: patient households purchase a positive amount of deposits and do not borrow, while impatient households and entrepreneurs borrow a positive amount of loans. The banking sector is monopolistically competitive: banks set interest rates on deposits and on loans so as to maximize profits. The amount of loans issued by each intermediary can be financed through deposits and bank capital, which is accumulated out of profits.

On the production side, workers supply their differentiated labor services through unions which set wages to maximize members' utility subject to adjustment costs. In addition to entrepreneurs, there are two other producing sectors: a monopolistically competitive retail sector and a capital goods producing sector. Retailers buy intermediate goods from entrepreneurs in a competitive market, differentiate and price them subject to nominal rigidities. Capital goods producers are introduced so to derive a market price for capital.

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[5] The estimated stickiness does not reflect compositional issues or the choice of a particular bank rate. As data refer to new-business coverage, they do *not* embed sluggishness by construction, as it would have been the case if we had used rates on outstanding amounts that are influenced by rates set in the past.

2.3.1   Patient households

The representative patient household i maximizes the expected utility

$$E_0 \sum_{t=0}^{\infty} \beta_P^t \left[(1 - a^P)\varepsilon_t^z \log(c_t^P(i) - a^P c_{t-1}^P) + \varepsilon_t^h \log h_t^P(i) - \frac{l_t^P(i)^{1+\phi}}{1+\phi} \right]$$

which depends on current individual (and lagged aggregate) consumption c_t^P, housing h_t^P and hours worked l_t^P. There are external and group-specific habits in consumption; premultiplication by one minus the habit coefficient a^P offsets their impact on the steady-state marginal utility of consumption. Labor disutility is parameterized by ϕ. Preferences are subject to two disturbances: one affecting consumption (ε_t^z) and one housing demand (ε_t^h).[6] Household's choices must obey to the following budget constraint (in real terms)

$$c_t^P(i) + q_t^h \Delta h_t^P(i) + d_t^P(i) \leq w_t^P l_t^P(i) + \left(1 + r_{t-1}^d\right) d_{t-1}^P(i)/\pi_t + t_t^P(i) \qquad (2.1)$$

The flow of expenses includes current consumption, accumulation of housing (with real house price q_t^h) and real deposits to be made in the period d_t^P. Resources consist of wage earnings $w_t^P l_t^P$ (where w_t^P is the real wage rate for the labor input of each patient household), gross interest income on last period deposits $(1 + r_{t-1}^d)d_{t-1}^P/\pi_t$ (where $\pi_t \equiv P_t/P_{t-1}$ is gross inflation) and lump-sum transfers t_t^P which include a labor union membership net fee and dividends from firms and banks (of which patient households are the only owners).

2.3.2   Impatient households

The representative impatient household i maximizes the expected utility

$$E_0 \sum_{t=0}^{\infty} \beta_I^t \left[(1 - a^I)\varepsilon_t^z \log(c_t^I(i) - a^I c_{t-1}^I) + \varepsilon_t^h \log h_t^I(i) - \frac{l_t^I(i)^{1+\phi}}{1+\phi} \right]$$

which depends on consumption c_t^I, housing services h_t^I and hours worked l_t^I. The parameter a^I measures consumption habits; ε_t^h and ε_t^z are the same shocks that affect the utility of patient households. Household decisions have to match the budget constraint

$$c_t^I(i) + q_t^h \Delta h_t^I(i) + (1 + r_{t-1}^{bH}) b_{t-1}^I(i)/\pi_t \leq w_t^I l_t^I(i) + b_t^I(i) + t_t^I(i)$$

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[6] With the exception of a white noise shock for monetary policy, we assume that any generic shock ε_t in the model follows a stochastic AR(1) process of the type $\varepsilon_t = (1 - \rho_\varepsilon)\,\bar{\varepsilon} + \rho_\varepsilon\,\varepsilon_{t-1} + \eta_t^\varepsilon$ where ρ_ε is the autoregressive coefficient, $\bar{\varepsilon}$ is the steady-state value and η_t^ε follows a NIID$(0, \sigma_\varepsilon)$ process.

in which resources spent for consumption, housing and gross reimbursement of borrowing b_{t-1}^I (with a net interest rate of r_{t-1}^{bH}) have to be financed with labor income (w_t^I is the wage of impatient households) and new loans b_t^I (t_t^I only includes net union fees).

In addition, impatient households face a borrowing constraint: the expected value of their housing stock must guarantee repayment of debt and interests,

$$\left(1 + r_t^{bH}\right) b_t^I(i) \leq m_t^I E_t \left[q_{t+1}^h h_t^I(i)\pi_{t+1}\right] \tag{2.2}$$

where m_t^I is the (stochastic) loan-to-value ratio (LTV) for mortgages. From a microeconomic point of view, $(1\text{-}m_t^I)$ can be interpreted as the proportional cost of collateral repossession for banks in case of default. At a macro-level, the value of m_t^I determines the amount of credit that banks can provide to households, for a given (discounted) value of their housing stock. We assume that LTV ratios follow exogenous stochastic processes.

2.3.3 Entrepreneurs

Each entrepreneur i only cares about deviations of his own consumption $c_t^E(i)$ from aggregate lagged group habits (parameterized by a^E) and maximizes the utility function

$$E_0 \sum_{t=0}^{\infty} \beta_E^t \log(c_t^E(i) - a^E c_{t-1}^E)$$

by choosing consumption, physical capital k_t^E, loans from banks b_t^E, the degree of capacity utilization u_t and the labor inputs $l_t^{E,P}$ and $l_t^{E,I}$, for patient and impatient households respectively. His decisions are subject to the budget constraint

$$c_t^E(i) + w_t^P l_t^{E,P}(i) + w_t^I l_t^{E,I}(i) + \frac{1+r_{t-1}^{bE}}{\pi_t} b_{t-1}^E(i) + q_t^k k_t^E(i) + \psi(u_t(i))k_{t-1}^E(i) =$$
$$= \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k(1-\delta)k_{t-1}^E(i)$$

where δ is the depreciation rate of capital, q_t^k is the price of capital in terms of consumption, $\psi(u_t)k_{t-1}^E$ is the real cost of setting a level u_t of utilization rate, $P_t^W/P_t = 1/x_t$ is the relative competitive price of the wholesale good y_t^E produced according to the technology

$$y_t^E(i) = a_t^E[k_{t-1}^E(i)u_t(i)]^\alpha l_t^E(i)^{1-\alpha}$$

with a_t^E being stochastic total factor productivity. Aggregate labor l_t^E combines inputs from patient and impatient households according to $l_t^E = (l_t^{E,P})^\mu (l_t^{E,I})^{1-\mu}$ where μ measures the labor income share of patient households (see Iacoviello and Neri, 2010).

The amount of resources that banks are willing to lend to entrepreneurs is constrained by the value of the collateral, which is given by entrepreneurs' holdings of capital. This assumption, which differs from Iacoviello (2005) where entrepreneurs borrow against housing (commercial real estate), seems a more realistic choice, as overall balance-sheet conditions give the soundness and creditworthiness of a firm. The borrowing constraint is thus

$$(1 + r_t^{bE})b_t^E(i) \leq m_t^E \mathrm{E}_t[q_{t+1}^k \pi_{t+1}(1 - \delta)k_t^E(i)] \tag{2.3}$$

where m_t^E is the stochastic LTV ratio for type E. Our assumption on discount factors is such that, absent uncertainty, households' and entrepreneurs' borrowing constraints would bind in a neighborhood of the steady state. As in Iacoviello (2005), we take the size of the shocks to be "sufficiently small" so that these constraints always bind in that neighborhood.

2.3.4   Loan and deposit demand

We model market power in the banking industry assuming a Dixit-Stiglitz framework for the retail credit and deposit markets.[7] In particular, we assume that units of loan and deposit contracts bought by households and entrepreneurs are a composite CES basket of slightly differentiated financial products – each supplied by a branch of a bank j – with elasticity terms equal to $\varepsilon_t^{bH} (> 1)$, $\varepsilon_t^{bE} (> 1)$ and $\varepsilon_t^d (< -1)$, respectively. These terms will be a major determinant of spreads between bank rates and the policy rate. We introduce an exogenous component in credit market spreads by assuming that each of these elasticity terms is stochastic. Innovations to interest rate elasticities of loans and deposits can be interpreted as innovations to bank spreads arising independently of monetary policy.

Demand by household i seeking an amount of real loans equal to $\bar{b}_t^I(i)$ can be derived from minimizing over $b_t^I(i, j)$ the total repayment due to the continuum of banks j,

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[7] Benes and Lees (2007) take a similar shortcut. In Andrés and Arce (2008) imperfectly competitive banks are finite in number and customers buy a bank service at a higher cost the farer they are from that bank.

$\int_0^1 r_t^{bH}(j)b_t^I(i,j)dj$, subject to $[\int_0^1 b_t^I(i,j)^{(\varepsilon_t^{bH}-1)/\varepsilon_t^{bH}}dj]^{\varepsilon_t^{bH}/(\varepsilon_t^{bH}-1)} \geq \bar{b}_t^I(i)$. Aggregating over symmetric households, aggregate demand for loans at bank j by impatient households, $b_t^I(j)$, turns out to depend on the overall volume of loans to households b_t^I and on the interest rate charged on loans to households by bank j relative to the rate index for that kind of loans $r_t^{bH} = [\int_0^1 r_t^{bH}(j)^{1-\varepsilon_t^{bH}} dj]^{\frac{1}{1-\varepsilon_t^{bH}}}$. Applying the same reasoning to loans to entrepreneurs results in the following demand schedules:

$$ b_t^I(j) = \left(\frac{r_t^{bH}(j)}{r_t^{bH}}\right)^{-\varepsilon_t^{bH}} b_t^I \qquad\qquad b_t^E(j) = \left(\frac{r_t^{bE}(j)}{r_t^{bE}}\right)^{-\varepsilon_t^{bE}} b_t^E \quad . \qquad (2.4) $$

Demand for deposits of patient household i, seeking an overall amount of real savings $\bar{d}_t^P(i)$, is obtained by maximizing over $d_t^P(i,j)$ the revenue of total savings, $\int_0^1 r_t^d(j)d_t^P(i,j)dj$, subject to $[\int_0^1 d_t^P(i,j)^{(\varepsilon_t^d-1)/\varepsilon_t^d}dj]^{\varepsilon_t^d/(\varepsilon_t^d-1)} \leq \bar{d}_t^P(i)$. Combining FOCs, aggregate households' demand for deposits at bank j, $d_t^P(j)$, is given by

$$ d_t^P(j) = \left(\frac{r_t^d(j)}{r_t^d}\right)^{-\varepsilon_t^d} d_t \qquad\qquad\qquad (2.5) $$

where d_t are the aggregate deposits in the economy and $r_t^d = [\int_0^1 r_t^d(j)^{1-\varepsilon_t^d} dj]^{\frac{1}{1-\varepsilon_t^d}}$ is the deposit rate index.

2.3.5 The labor market

We assume that workers provide differentiated labor types, sold by unions to perfectly competitive labor packers who assemble them in a CES aggregator with stochastic parameter ε_t^l and sell the homogeneous labor to entrepreneurs. For each labor type m there are two unions, one for patient households and one for impatient households (indexed by s). Each union (s,m) sets nominal wages $W_t^s(m)$ for its members by maximizing their utility subject to a downward sloping demand and to quadratic adjustment costs (parameterized by κ_w), with indexation to a weighted average of lagged (weight ι_w) and steady-state inflation (weight $1-\iota_w$). The union, which charges each member household lump-sum fees to cover adjustment costs, maximizes

$$ E_0 \sum_{t=0}^{\infty} \beta_s^t \left\{ U_{c_t^s(i,m)}\left[\frac{W_t^s(m)}{P_t}l_t^s(i,m) - \frac{\kappa_w}{2}\left(\frac{W_t^s(m)}{W_{t-1}^s(m)} - \pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)^2 \frac{W_t^s}{P_t}\right] - \frac{l_t^s(i,m)^{1+\phi}}{1+\phi} \right\} $$

subject to demand from labor packers $l_t^s(i, m) = l_t^s(m) = (\frac{W_t^s(m)}{W_t^s})^{-\varepsilon_t^l} l_t^s$. In a symmetric equilibrium, labor supply for a household of type s is given by

$$\kappa_w(\pi_t^{w^s} - \pi_{t-1}^{\iota_w}\pi^{1-\iota_w})\pi_t^{w^s} = \beta_s E_t \left[\frac{\lambda_{t+1}^s}{\lambda_t^s} \kappa_w(\pi_{t+1}^{w^s} - \pi_t^{\iota_w}\pi^{1-\iota_w})\frac{\pi_{t+1}^{w^s\,2}}{\pi_{t+1}} \right] + (1 - \varepsilon_t^l)l_t^s + \frac{\varepsilon_t^l l_t^{s\,1+\phi}}{w_t^s \lambda_t^s}$$

where, for each type, ω_t^s is the real wage and $\pi_t^{w^s}$ is the nominal wage inflation.

2.3.6 Banks

Banks enjoy market power in conducting their intermediation activity, which allows them to adjust rates on loans and deposits in response to shocks or to the cyclical conditions of the economy, and have to obey a balance sheet identity of the form *loans = deposits + capital*.[8] Bank capital is almost fixed in the short-run; it is adjusted only slowly through accumulation of retained earnings.[9] Furthermore, we assume that banks have an "optimal" exogenous target for their capital-to-assets ratio (i.e. the inverse of leverage), deviations from which imply a quadratic cost. The optimal leverage ratio in this context can be thought of as capturing the trade-offs that would arise in the decision of how much own resources to hold, or alternatively as a simple shortcut for studying the implications and costs of regulatory capital requirements. Given these assumptions, bank capital will have a key role in determining credit supply, since it potentially generates a feedback loop between the real and the financial side of the economy. As macroeconomic conditions deteriorate, banks profits and capital might be negatively hit; depending on the nature of the shock hitting the economy, banks might respond to the ensuing weakening of their financial position by reducing lending, hence exacerbating the original contraction. The model might thus potentially account for the type of "credit cycle" observed in the 2008 recession, with a weakening real economy, a reduction of bank profits and capital and the ensuing credit restriction.

Modeling banks' leverage position and interest rate-setting activity of loans subject to collateral requirements allows us to introduce a number of shocks that originate from the *supply side of credit* and to study their effects on the real economy. In particular, we introduce shocks to the LTV ratios that capture an exogenous decrease

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[8] When estimating the model we add a shock ε_t^{kb} to liabilities to avoid near stochastic singularity.

[9] In the benchmark calibration, all the profits are retained and used to accumulate bank capital (zero-dividend policy). Assuming positive dividends does not change the properties of the model.

in loans availability and shocks to the demand elasticities for loans and deposits that are used to simulate an exogenous increase in loan and deposit rates.[10] In Section 2.6.2 we will also introduce a shock to bank capital to simulate an unexpected destruction of bank equity.

To highlight more clearly the distinctive features of the banking sector and to facilitate exposition, we can think of each bank $j \in [0, 1]$ in the model as actually composed of two "retail" branches and one "wholesale" unit. The first retail branch is responsible for giving out differentiated loans to households and to entrepreneurs; the second for raising differentiated deposits. These branches set rates in a monopolistically competitive fashion, subject to adjustment costs. The wholesale unit manages the capital position of the group.[11]

Wholesale branch

Each wholesale branch operates under perfect competition: on the liability side, it combines net worth, or bank capital (K_t^b), and wholesale deposits (D_t) while, on the asset side, it issues wholesale loans (B_t) (all in real terms). We impose a cost on this wholesale activity, related to the capital position of the bank. In particular, the bank pays a quadratic cost (parameterized by a coefficient κ_{Kb} and proportional to outstanding bank capital) whenever the capital-to-assets ratio K_t^b/B_t moves away from the target value ν^b.

Bank capital is accumulated out of retained earnings:

$$\pi_t K_t^b = \left(1 - \delta^b\right) K_{t-1}^b + j_{t-1}^b$$

where j_t^b are overall real profits made by the three branches of each bank, and δ^b measures resources used up in managing bank capital. The problem for the wholesale bank is to choose the sequence of loans B_t and deposits D_t so to maximize the discounted sum of expected (real) cash flows

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[\left(1 + R_t^b\right) B_t - B_{t+1} \pi_{t+1} + D_{t+1} \pi_{t+1} - \left(1 + R_t^d\right) D_t + \left(K_{t+1}^b \pi_{t+1} - K_t^b\right) - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{B_t} - \nu^b\right)^2 K_t^b \right]$$

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[10] See Cúrdia and Woodford (2009) for similar interpretations of "financial" shocks that affect bank rates.

[11] An alternative setup where the two retail branches are not distinct would produce identical results. However, the role of bank capital in the market for loanable funds is best outlined by keeping the wholesale unit separated from the retail branches (see equation 2.6 below).

subject to the balance sheet constraint $\left(B_t = D_t + K_t^b\right)$ and taking R_t^b (the net wholesale loan rate) and R_t^d (the net wholesale deposit rate) as given.[12] Using the constraint twice (at date t and $t+1$), the objective boils down to

$$\max_{\{B_t, D_t\}} R_t^b B_t - R_t^d D_t - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{B_t} - \nu^b\right)^2 K_t^b$$

The FOCs deliver a condition linking the spread between wholesale rates on loans and on deposits to the degree of leverage B_t/K_t^b, i.e.

$$R_t^b = R_t^d - \kappa_{Kb} \left(\frac{K_t^b}{B_t} - \nu^b\right) \left(\frac{K_t^b}{B_t}\right)^2$$

To close the model, we assume that banks have access to unlimited finance at the policy rate r_t from a lending facility at the central bank: hence, by arbitrage the wholesale deposit rate is equal to the policy rate $(R_t^d = r_t)$ and the above equation becomes

$$S_t^W \equiv R_t^b - r_t = -\kappa_{Kb} \left(\frac{K_t^b}{B_t} - \nu^b\right) \left(\frac{K_t^b}{B_t}\right)^2 \tag{2.6}$$

where S_t^W is the spread prevailing at the wholesale level. The left hand side of the equation represents the marginal benefit from increasing lending (an increase in profits equal to the spread); the right hand side is the marginal cost from doing so (an increase in the costs for deviating from ν^b). Therefore, banks choose a level of loans that at the margin equalizes costs and benefits of reducing the capital-to-assets ratio.

Retail banking

Retail banks are monopolistic competitors on both the loan and the deposit markets. *Loan branch:* The retail loan branch of bank j obtains wholesale loans $B_t(j)$, in real terms, from the wholesale unit at rate R_t^b, differentiates them at no cost and resells them to households and firms applying two different markups. In doing so, each retail bank faces quadratic adjustment costs for changing over time the rates it charges on loans; these costs are parameterized by κ_{bE} and κ_{bH} and are proportional to aggregate returns on loans. Retail loan bank j maximizes, over $\{r_t^{bH}(j), r_t^{bE}(j)\}$,

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[12] Since banks are owned by patient households, they value future profits using the discount factor $\Lambda_{0,t}^P$.

the objective

$$E_0\sum_{t=0}^{\infty}\Lambda_{0,t}^{P}\Big[r_t^{bH}(j)b_t^{I}(j)+r_t^{bE}(j)b_t^{E}(j)-R_t^{b}B_t(j)-\frac{\kappa_{bH}}{2}\Big(\frac{r_t^{bH}(j)}{r_{t-1}^{bH}(j)}-1\Big)^{2}r_t^{bH}b_t^{I}-\frac{\kappa_{bE}}{2}\Big(\frac{r_t^{bE}(j)}{r_{t-1}^{bE}(j)}-1\Big)^{2}r_t^{bE}b_t^{E}\Big]$$

subject to demands (2.4) and with $B_t(j) = b_t(j) = b_t^{I}(j) + b_t^{E}(j)$. FOCs for interest rates to households and firms (indexed by s) yield (after imposing a symmetric equilibrium)

$$1-\varepsilon_t^{bs}+\varepsilon_t^{bs}\frac{R_t^{b}}{r_t^{bs}}-\kappa_{bs}\Big(\frac{r_t^{bs}}{r_{t-1}^{bs}}-1\Big)\frac{r_t^{bs}}{r_{t-1}^{bs}}+\beta_P E_t\Big\{\frac{\lambda_{t+1}^{P}}{\lambda_t^{P}}\kappa_{bs}\Big(\frac{r_{t+1}^{bs}}{r_t^{bs}}-1\Big)\Big(\frac{r_{t+1}^{bs}}{r_t^{bs}}\Big)^{2}\frac{b_{t+1}^{s}}{b_t^{s}}\Big\}=0 \tag{2.7}$$

where λ_t^{P} is the multiplier on the budget constraint (2.1). The log-linearized version of (2.7) is

$$\hat{r}_t^{bs}=\frac{\kappa_{bs}\,\hat{r}_{t-1}^{bs}}{\varepsilon^{bs}-1+(1+\beta_P)\kappa_{bs}}+\frac{\beta_P\kappa_{bs}\,E_t\hat{r}_{t+1}^{bs}}{\varepsilon^{bs}-1+(1+\beta_P)\kappa_{bs}}+\frac{(\varepsilon^{bs}-1)\,\hat{R}_t^{b}}{\varepsilon^{bs}-1+(1+\beta_P)\kappa_{bs}}-\frac{\hat{\varepsilon}_t^{bs}}{\varepsilon^{bs}-1+(1+\beta_P)\kappa_{bs}}$$

Solving forward, this equation highlights how loan rates are set based on current and expected future values of the shock to the markup and of the wholesale rate, the relevant measure of marginal cost for this type of bank, which in turn depends on the policy rate and the capital position of the bank, as highlighted in the previous section. The adjustment to changes in the wholesale rate depends inversely on the intensity of the adjustment costs κ_{bs} and positively on the degree of competition in the bank loans sector (measured by $1/\varepsilon^{bs}$).

Under flexible rates the spread between the loan and the policy rate is

$$S_t^{bs}\equiv r_t^{bs}-r_t=\frac{\varepsilon_t^{bs}}{\varepsilon_t^{bs}-1}S_t^{W}+\frac{1}{\varepsilon_t^{bs}-1}r_t$$

which is obtained combining the flexible rate $r_t^{bs}=\frac{\varepsilon_t^{bs}}{\varepsilon_t^{bs}-1}R_t^{b}$ with the expression for S_t^{W} in (2.6). The spread on retail loans is thus increasing in the policy rate, and is proportional to the wholesale spread S_t^{W}, determined by the bank's capital position. In addition, the degree of monopolistic competition also plays a role; an increase in market power (i.e. a reduction in ε_t^{bs}) determines – *ceteris paribus* – a wider absolute spread.

Deposit branch: Similarly, the retail deposit branch of bank j collects deposits $d_t^{P}(j)$ from households and passes the raised funds on to the wholesale unit, which

remunerates them at rate r_t. The problem for the deposit branch is

$$\max_{\left\{r_t^d(j)\right\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[r_t D_t(j) - r_t^d(j) d_t^P(j) - \frac{\kappa_d}{2} \left(\frac{r_t^d(j)}{r_{t-1}^d(j)} - 1 \right)^2 r_t^d d_t \right]$$

subject to demand (2.5) and with $D_t(j) = d_t^P(j)$. Quadratic adjustment costs for changing the deposit rate are parameterized by κ_d and are proportional to aggregate interest paid on deposits. After imposing symmetry, the FOC for deposit interest rate setting reads

$$-1 + \varepsilon_t^d - \varepsilon_t^d \frac{r_t}{r_t^d} - \kappa_d \left(\frac{r_t^d}{r_{t-1}^d} - 1 \right) \frac{r_t^d}{r_{t-1}^d} + \beta_P E_t \left\{ \frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_d \left(\frac{r_{t+1}^d}{r_t^d} - 1 \right) \left(\frac{r_{t+1}^d}{r_t^d} \right)^2 \frac{d_{t+1}}{d_t} \right\} = 0 \quad (2.8)$$

yielding a log-linearized version similar to that for loan rate setting. Solving forward one could see that banks set the deposit rate taking into account expected future levels of the policy rate. Adjustments to changes in the policy rate depend inversely on how important adjustment costs are (i.e. on κ_d) and positively on the degree of competition in banks fund raising (as measured by the inverse of ε^d). With fully flexible rates, r_t^d is just a markdown over the policy rate, i.e. $r_t^d = \frac{\varepsilon_t^d}{\varepsilon_t^d - 1} r_t$.

Bank profits: Overall bank profits are the sum of net earnings from the wholesale unit and the two retail branches. Deleting intra-group transactions yields (in real terms)

$$j_t^b = r_t^{bH} b_t^H + r_t^{bE} b_t^E - r_t^d d_t - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{B_t} - \nu^b \right)^2 K_t^b - Adj_t^B \quad (2.9)$$

where Adj_t^B indicates adjustment costs for changing interest rates on loans and deposits. Note that equation (2.9) implies that our definition of profits is a narrow one as it coincides (net of adjustment costs) with the interest rate margin and does not include other items of the income statement.

2.3.7 Capital and final goods producers

Perfectly competitive firms buy last period undepreciated capital $(1-\delta)k_{t-1}$ at price Q_t^k from entrepreneurs (owners of these firms) and i_t units of of final goods from retailers at price P_t. With these inputs, firms' flow output $\Delta \bar{x}_t = k_t - (1-\delta)k_{t-1}$ increases the stock of effective capital $\bar{x}_t$, which is then sold back to entrepreneurs at the price Q_t^k. The transformation of the final good i_t into new capital is subject to adjustment costs. Firms choose $\bar{x}_t$ and i_t as to maximize $E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^E (q_t^k \Delta \bar{x}_t - i_t)$

subject to $\bar{x}_t = \bar{x}_{t-1} + [1 - \frac{\kappa_i}{2}(\frac{i_t \varepsilon_t^{qk}}{i_{t-1}} - 1)^2]i_t$ where κ_i denotes the cost for adjusting investment, ε_t^{qk} is a shock to the efficiency of investment and $q_t^k \equiv \frac{Q_t^k}{P_t}$ is the real price of capital.

The retail goods market is assumed to be monopolistically competitive as in Bernanke *et al.* (1999). Retailers' prices are sticky and are indexed to a combination of past and steady-state inflation, with relative weights parameterized by ι_p; if retailers want to change their price beyond what indexation allows, they face a quadratic adjustment cost parameterized by κ_p. They choose $\{P_t(j)\}$ so as to maximize $E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P [P_t(j)y_t(j) - P_t^W y_t(j) - \frac{\kappa_p}{2}(\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{\iota_p}\pi^{1-\iota_p})^2 P_t y_t]$, subject to the demand derived from consumers' maximization, $y_t(j) = (\frac{P_t(j)}{P_t})^{-\varepsilon_t^y} y_t$ where ε_t^y is the stochastic demand price-elasticity.

2.3.8 Monetary policy and market clearing

The central bank sets the policy rate r_t according to

$$(1 + r_t) = (1 + r)^{(1-\phi_R)} (1 + r_{t-1})^{\phi_R} \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi(1-\phi_R)} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y(1-\phi_R)} \varepsilon_t^r$$

where ϕ_π is the weight assigned to inflation and ϕ_y to output growth, r is the steady-state policy rate, and ε_t^r is a white noise monetary policy shock with standard deviation σ_r.

The market clearing condition in goods market is

$$y_t = c_t + q_t^k [k_t - (1 - \delta)k_{t-1}] + k_{t-1}\psi(u_t) + \delta^b \frac{K_{t-1}^b}{\pi_t} + Adj_t$$

where $c_t \equiv c_t^P + c_t^I + c_t^E$ is aggregate consumption, k_t is aggregate physical capital and K_t^b aggregate bank capital. The term Adj_t includes all adjustment costs. In the housing market, equilibrium is given by $\bar{h} = h_t^P(i) + h_t^I(i)$, where $\bar{h}$ is the fixed housing stock.

2.3.9 Log-linearization and model solution

The model is log-linearized around the steady state. This means that we cannot capture precautionary or buffer-stock behaviors or other nonlinearities. Furthermore, perturbation methods are valid only in a neighborhood of the steady state: as we move away from it not only the quality of the linear approximation deteriorates, but

also the conditions that ensure that the borrowing constraints bind in the steady state might not hold.

2.4   Estimation

The model is estimated with Bayesian methods. In this section we first discuss the data, the calibrated parameters and the priors, and then we report the parameter estimates and some robustness checks. We estimate the parameters driving the model dynamics, while we calibrate those determining the steady state so as to match key statistics in the data.

2.4.1   Data

We use twelve observables: real consumption, real investment, real house prices, real deposits, real loans to households and firms, the overnight rate, interest rates on deposits, loans to firms and households, quarter-on-quarter nominal wage and consumer price inflation rates. For a description of the data see the Appendix. The sample period is 1998Q1-2009Q1. Data with a trend are made stationary using the HP filter (smoothing parameter equal to 1,600), while all interest and inflation rates are demeaned. Figure 2.2 plots the transformed data.

2.4.2   Calibrated parameters and prior distributions

Calibrated parameters - Table 2.1 reports the values of the calibrated parameters. We set the discount factor of patient households at 0.9943 in order to match the average monthly rate on M2 deposits in our sample. As for impatient households' and entrepreneurs' discount factors β_I and β_E, we set them at 0.975 as in Iacoviello (2005). The weight of housing in households' utility function ε^h is set at 0.2, close to the value in Iacoviello and Neri (2010). As for the loan-to-value (LTV) steady-state ratios, for households we set m^I at 0.7, in line with evidence in Calza *et al.* (2009). For entrepreneurs, the calibration of m^E is somewhat more problematic. Christensen *et al.* (2007) estimate a much lower value (0.32) in a model for Canada, in which firms can borrow against capital. We computed, for the euro area, an average ratio of long-term loans to the value of shares and other equities for the

Figure 2.2 - Euro area observable variables used in estimation
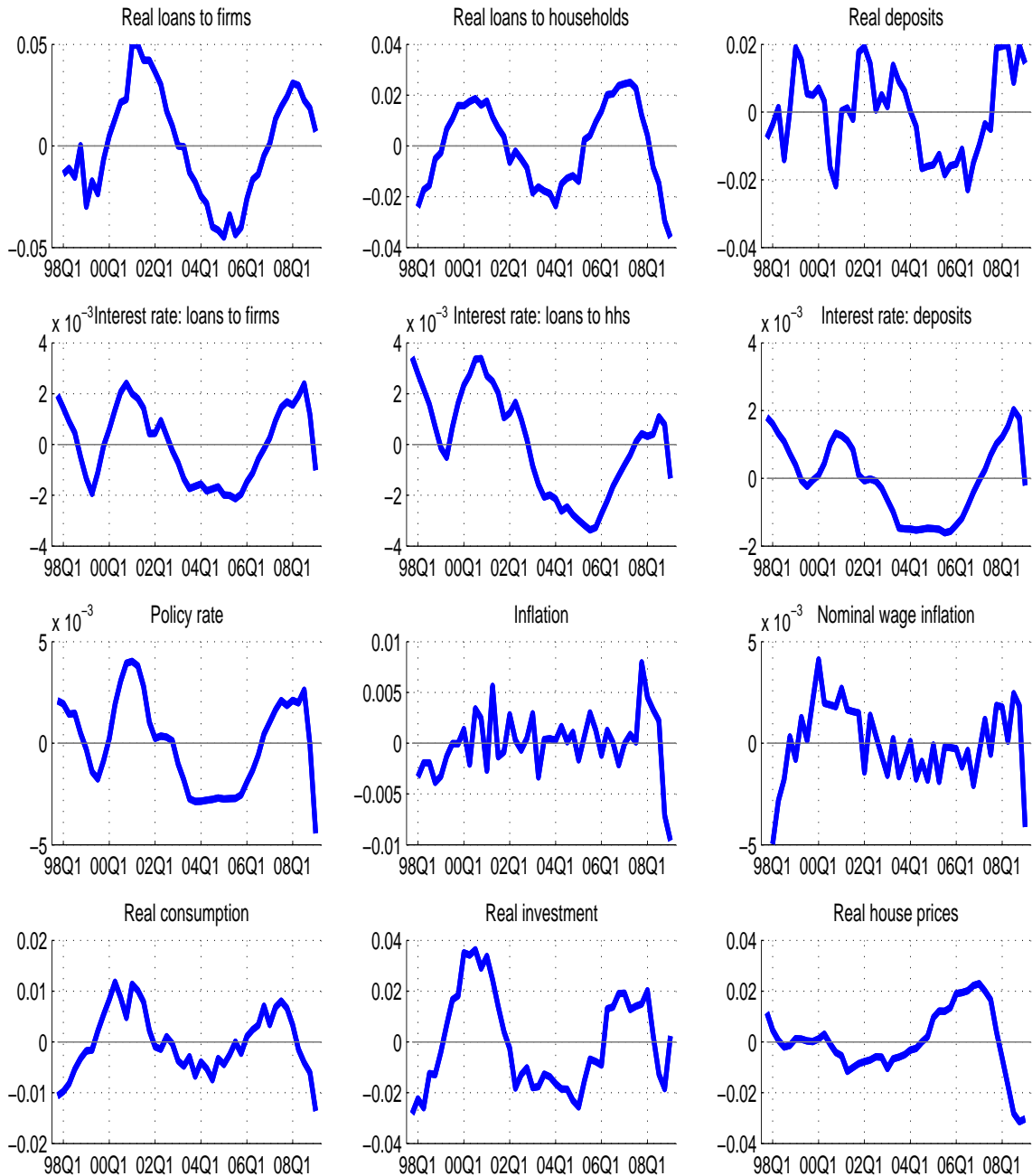
Note: Real variables (loans to firms and households, consumption, investment and house prices) are expressed as log deviations from the HP-filter trend. Interest rates and inflation rates are net rates expressed on a quarterly basis and in absolute deviations from the sample mean.

Table 2.1 - Calibrated parameters

Parameter	Description	Value
β_P	Patient households' discount factor	0.9943
β_I	Impatient households' discount factor	0.975
β_E	Entrepreneurs' discount factor	0.975
ϕ	Inverse of the Frisch elasticity	1.0
μ	Share of unconstrained households	0.8
ε^h	Weight of housing in households' utility function	0.2
α	Capital share in the production function	0.25
δ	Depreciation rate of physical capital	0.025
ε^y	$\frac{\varepsilon^y}{\varepsilon^y-1}$ is the markup in the goods market	6
ε^l	$\frac{\varepsilon^l}{\varepsilon^l-1}$ is the markup in the labour market	5
m^I	Households' LTV ratio	0.7
m^E	Entrepreneurs' LTV ratio	0.35
ν^b	Target capital-to-loans ratio	0.09
ε^d	$\frac{\varepsilon^d}{\varepsilon^d-1}$ is the markdown on deposit rate	-1.46
ε^{bH}	$\frac{\varepsilon^{bH}}{\varepsilon^{bH}-1}$ is the markup on rate on loans to households	2.79
ε^{bE}	$\frac{\varepsilon^{bE}}{\varepsilon^{bE}-1}$ is the markup on rate on loans to firms	3.12
δ^b	Cost for managing the bank's capital position	0.1049
ξ_1	Parameter of adjustment cost for capacity utilisation	0.0478
ξ_2	Parameter of adjustment cost for capacity utilisation	0.00478

Note: The adjustment cost for capacity utilisation is specified as $\psi(u_t) = \xi_1(u_t - 1) + \frac{\xi_2}{2}(u_t - 1)^2$ (see Schmitt-Grohé and Uribe, 2006).

non-financial corporations sector of 0.40. Based on this evidence we set m^E at 0.35. The capital share α is set at 0.25 and the depreciation rate of capital δ at 0.025. In the labor market we assume a markup of 25 per cent and set ε^l at 5. In the goods market, a value of 6 for ε^y delivers a markup of 20 percent, a value commonly used in the literature. We specify $\psi(u_t)$ as in Schmitt-Grohé and Uribe (2006). The patient households' labor income share μ is calibrated at 0.8 in line with the findings in Iacoviello and Neri (2010).

We calibrate the banking parameters so as to replicate sample averages of bank interest rates and spreads. For the deposit rate, the steady-state markdown on the policy rate is given by $\frac{\varepsilon^d}{\varepsilon^d-1}$; given an average spread between retail deposit rates and the Eonia of about 125 basis points in annualized terms in our sample, we calibrate ε^d at -1.46. Similarly, for loan rates we calibrate ε^{bH} and ε^{bE} to 2.79 and 3.12,

exploiting the steady-state expressions for the markups over the policy rate $\frac{\varepsilon^{bs}}{\varepsilon^{bs}_t - 1}$. The steady-state ratio ν^b of bank capital to total loans $(B^H + B^E)$ is set at 9 per cent. The parameter δ^b is set at the value (0.1049) which ensures that the ratio of bank capital to total loans is exactly 0.09.

Prior distributions - Our priors are listed in Tables 2.2a and 2.2b. Overall, they are either consistent with the previous literature or relatively uninformative. As for the parameters governing interest rates adjustment costs, their prior means are set at values between 3 and 10, chosen so that the coefficients in the log-linearized rate-setting equations imply immediate pass-through of the magnitude documented in ECB (2009). The prior on the parameter governing the adjustment costs in banking (κ_{Kb}) is harder to set. We assume a rather widespread distribution, with a mean of 10 and a standard deviation of 5.

Table 2.2a - Prior and posterior distribution of the structural parameters

	Parameter	Type	Prior distribution		Posterior distribution			
			Mean	Std.dev.	Mean	2.5%	Median	97.5%
κ_p	p stickiness	Gamma	50.0	20.0	30.57	10.68	28.65	49.89
κ_w	w stickiness	Gamma	50.0	20.0	102.35	70.29	99.90	133.81
κ_i	invest. adj. cost	Gamma	2.5	1.0	10.26	7.57	10.18	12.81
κ_d	dep. rate adj. cost	Gamma	10.0	2.5	3.63	2.28	3.50	4.96
κ_{bE}	firms rate adj. cost	Gamma	3.0	2.5	9.51	6.60	9.36	12.31
κ_{bH}	HHs rate adj. cost	Gamma	6.0	2.5	10.22	7.47	10.09	12.88
κ_{Kb}	leverage dev. cost	Gamma	10.0	5.0	11.49	4.03	11.07	18.27
ϕ_π	T.R. coeff. on π	Gamma	2.0	0.5	2.01	1.72	1.98	2.30
ϕ_R	T.R. coeff. on R	Beta	0.75	0.10	0.77	0.72	0.77	0.81
ϕ_y	T.R. coeff. on y	Normal	0.10	0.15	0.35	0.15	0.35	0.55
ι_p	p indexation	Beta	0.50	0.15	0.17	0.06	0.16	0.28
ι_w	w indexation	Beta	0.50	0.15	0.28	0.16	0.28	0.39
a^h	habit coefficient	Beta	0.50	0.10	0.85	0.81	0.86	0.90

Note: Results based on 10 chains, each with 100,000 draws based on the Metropolis algorithm.

Table 2.2b - Prior and posterior distribution of the structural parameters - exogenous processes

	Parameter	Type	Mean	St.dev.	Mean	2.5%	Median	97.5%
			Prior distribution		Posterior distribution			
AR coefficients								
ρ_z	consumpt. prefer.	Beta	0.8	0.10	0.396	0.260	0.394	0.531
ρ_h	housing prefer.	Beta	0.8	0.10	0.917	0.858	0.921	0.975
ρ_{mE}	Firms' LTV	Beta	0.8	0.10	0.892	0.839	0.894	0.945
ρ_{mI}	HHs' LTV	Beta	0.8	0.10	0.925	0.875	0.929	0.979
ρ_d	dep. markdown	Beta	0.8	0.10	0.830	0.739	0.838	0.917
ρ_{bH}	HHs loans markup	Beta	0.8	0.10	0.808	0.675	0.820	0.949
ρ_{bE}	firms loans markup	Beta	0.8	0.10	0.820	0.688	0.834	0.956
ρ_a	technology	Beta	0.8	0.10	0.936	0.899	0.939	0.975
ρ_{qk}	invest. efficiency	Beta	0.8	0.10	0.543	0.396	0.548	0.694
ρ_y	p mark-up	Beta	0.8	0.10	0.306	0.205	0.305	0.411
ρ_l	w mark-up	Beta	0.8	0.10	0.636	0.511	0.640	0.769
ρ_{Kb}	balance sheet	Beta	0.8	0.10	0.810	0.717	0.813	0.906
Standard deviations								
σ_z	consumpt. prefer.	Inv. Gam	0.01	0.05	0.027	0.019	0.027	0.035
σ_h	housing prefer.	Inv. Gam	0.01	0.05	0.076	0.022	0.071	0.129
σ_{mE}	Firms' LTV	Inv. Gam	0.01	0.05	0.007	0.005	0.007	0.009
σ_{mI}	HHs' LTV	Inv. Gam	0.01	0.05	0.003	0.003	0.003	0.004
σ_d	dep. markdown	Inv. Gam	0.01	0.05	0.033	0.024	0.032	0.043
σ_{bH}	HHs loans markup	Inv. Gam	0.01	0.05	0.067	0.035	0.066	0.115
σ_{bE}	firms loans markup	Inv. Gam	0.01	0.05	0.063	0.034	0.063	0.096
σ_a	technology	Inv. Gam	0.01	0.05	0.006	0.004	0.006	0.007
σ_{qk}	invest. efficiency	Inv. Gam	0.01	0.05	0.019	0.013	0.019	0.025
σ_R	monetary policy	Inv. Gam	0.01	0.05	0.002	0.001	0.002	0.002
σ_y	p mark-up	Inv. Gam	0.01	0.05	0.634	0.274	0.598	0.985
σ_l	w mark-up	Inv. Gam	0.01	0.05	0.577	0.378	0.561	0.761
σ_{Kb}	balance-sheet	Inv. Gam	0.01	0.05	0.031	0.026	0.031	0.037

Note: Results based on 10 chains, each with 100,000 draws based on the Metropolis algorithm.

Figure 2.3 - Prior and posterior marginal distributions
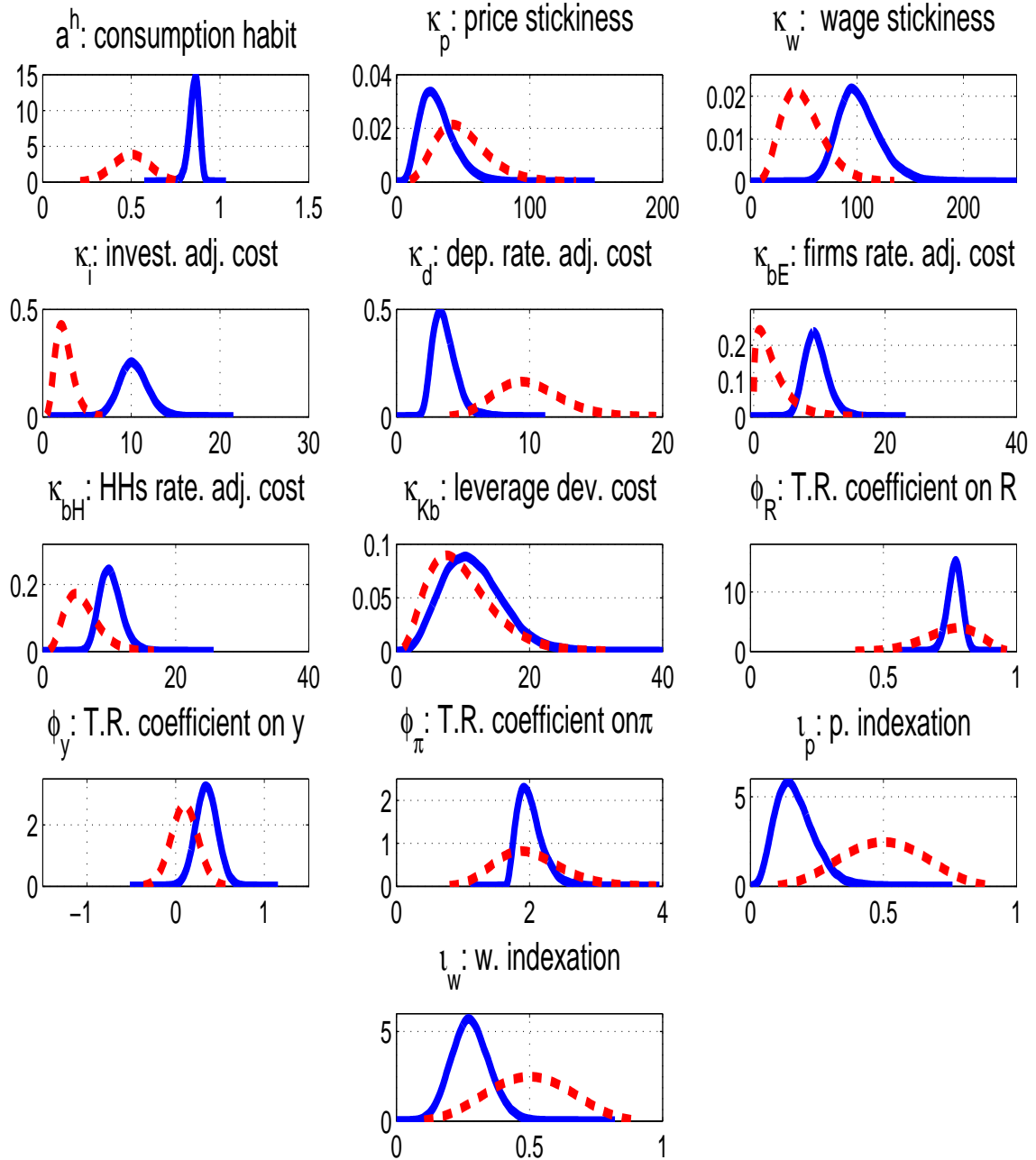
Note: The marginal posterior densities are based on 10 chains, each with 100,000 draws based on the Metropolis algorithm. Blue solid lines denote the posterior distribution, red dashed lines the prior distribution.

2.4.3   Posterior estimates

Tables 2.2a and 2.2b also report summary statistics of the posterior distribution of the parameters. Draws from the posterior distribution of the parameters were obtained using the Metropolis algorithm. We ran ten chains, each of 100,000 draws. Convergence was assessed both by means of the convergence statistics proposed by Brooks and Gelman (1998) and by computing recursive means of the parameters.[13] Figure 2.3 reports the prior and posterior marginal densities of the structural parameters of the model.[14]

All shocks are quite persistent with the only exception of the price markup shock ε_t^y. The posterior median of the parameter measuring the degree of consumption habits a^h is estimated to be high, at 0.86. The median of the investment adjustment cost κ_i is around 10, slightly above the estimate in Smets and Wouters (2003). For monetary policy, our estimation confirms the weak identification of the response to inflation ϕ_π and the relatively high degree of policy rate inertia ϕ_R; the posterior median of the coefficient measuring the response to output growth ϕ_y is more than three times the prior mean. Concerning nominal rigidities, in line with previous studies we find that wage stickiness is stronger than price stickiness. Concerning the parameters measuring the degree of stickiness in bank rates, we find that deposit rates adjust more rapidly than the rates on loans to changes in the policy rate. This result is not surprising given that our measure of deposits include time deposits, whose interest rates are typically highly reactive to changes in money market rates. Finally, the posterior distribution for the coefficient measuring the cost of deviating from targeted leverage, κ_{Kb}, stays very close to the prior, which might be a signal of weak identification. However, experimenting with larger and smaller values for the prior mean, the posterior distribution moves away from the prior one and towards our estimated median, suggesting that the data do have some informative content for this parameter.

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[13] Assessment of convergence is reported in a Technical Appendix available upon request.

[14] We interpret a substantial difference between the prior and the posterior means as indications that parameters are identified. However, we acknowledge that this is not a sufficient criterion since the mapping between the parameters and the solution of the model is nonlinear.

2.4.4 Robustness

The ability of the model to fit the data depends on the shocks and frictions that are considered. Moreover, the posterior distribution of the structural parameters may depend on the type of transformation used to make the data stationary. In this section we report the results of a series of robustness checks that are meant to shed light on the role of financial shocks, sticky rates, bank capital, and detrending of the data.[15]

To highlight the importance of including financial shocks, we have estimated the model shutting off these shocks, while adding i.i.d. measurement errors to all banking-sector observables so to be able to bring the model to the data with the same set of variables used in the estimation of the benchmark model. This version of the model has a very hard time explaining the dynamics of loans to firms, households' deposits and bank rates; the marginal data density of this model (which is commonly used to compare estimated models), falls to 2018 (log points) from 2311 of the benchmark model. In terms of story-telling (see Section 2.6.1), the model without financial shocks explains the 2008 downturn as the result of unfavorable technology and cost-push shocks.

The importance of sticky rates is assessed by estimating a version of the model with flexible bank rates (i.e. setting κ_d, κ_{bE} and κ_{bH} to zero). The marginal density of this model falls to 2262 (compared with 2311), thus suggesting the importance of this feature. The other structural parameters are hardly affected by removing stickiness in rates. The main difference is in the persistence of the shocks to bank rates, which increases from 0.83, on average across the three rates, to 0.91, and in the degree of price stickiness, which more than doubles. Removing bank capital results in a reduction of the marginal density from 2311 to 2307, suggesting that this feature plays a more limited role compared to the stickiness in bank rates in accounting for the data. However, bank capital does play an important role, for example, in propagating supply shocks (see Section 2.5.2).

Finally, we have estimated the benchmark model using linearly detrended data (with a different trend for each variable) and found no major difference in the posterior distribution of the structural parameters but only an increase in the persistence of

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[15] Detailed results of the experiments discussed here are reported in the Technical Appendix available upon request.

almost all the shocks. Imposing a *common* linear trend on all the non-stationary time series would result in unreasonable dynamics of loans to firms, loans to households and real house prices. These financial variables have indeed been growing at rates significantly higher than those of consumption and investment in our sample period, fueled by financial innovations and the waves of mergers and acquisitions of the '90s and early 2000s.

2.5   Properties of the estimated model

In this section we study how the transmission mechanism of monetary and technology shocks is affected by the presence of financial frictions and financial intermediation. The interest-rate setting behavior of banks introduces an additional layer of complexity on top of the already non-standard transmission channels usually at work in models with heterogeneous agents and borrowing constraints. In order to highlight the contribution of each feature of banking, we compare the benchmark model (BK model, for Bank Capital) with a number of models where we progressively shut down (in order):[16] (*i*) bank capital (yielding a Sticky Rates model, or SR); (*ii*) stickiness in bank rates setting (yielding a Flexible Rates, or FR, model); (*iii*) imperfect competition in banking (yielding a Financial Frictions, or FF, model similar to Iacoviello, 2005); (*iv*) the collateral and debt-deflation channels (yielding a Quasi-New Keynesian model, or QNK).[17]

2.5.1   Monetary policy shock

Figure 2.4 shows the impulse responses from an unanticipated 50 basis points increase in the policy rate (r_t). Parameter values are set at the estimated posterior median. The responses of the BK model (in circled red) are qualitatively very standard. Output and inflation contract; real interest rates for households and entrepreneurs go up, reflecting the increase in bank interest rates, and asset prices decline, determining a reduction in the present discounted value of the collateral.

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[16] We do not re-estimate each model since doing so would make it impossible to attribute any change in the propagation mechanism of shocks to a specific feature of the model since all the parameters may change.

[17] In the QNK model, agents are still credit-constrained but there is no effect of asset prices on the collateral value (fixed at the steady state level), and loans and deposits (plus interests) are repaid in real terms.

As a consequence, loans to both households and firms decline.[18] On impact, bank profits get pushed up by the increase in banks' intermediation spread, which more than offsets the reduction in the amount of intermediated funds; after a few quarters, however, profits turn negative as the increase in bank margins unwinds while loans and deposits remain negative for longer.[19] Following profits, bank capital initially increases but it then turns negative after about ten quarters.

The introduction of banking attenuates the impact of the policy tightening. This is mainly due to sticky rates, which dampen the response of retail loan rates, thus reducing the contraction in loans, consumption and investment (see the difference between the SR and the FR lines in Figure 2.4). The impact of market power in banking (i.e. the difference between the FR and FF lines) on output is rather limited, reflecting the opposite and mutually offsetting effects on borrowers and lenders: the markup on loan rates determines a bigger increase of the relevant rates for impatient households and entrepreneurs, while the markdown on the deposit rate attenuates the restriction for patient households. Finally, the introduction of bank capital has virtually no effect on the dynamics of the real variables (i.e. the difference between the BK and the SR lines is small); this mainly reflects the small median value of κ_{Kb}.[20]

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[18] This contradicts some empirical VAR-based evidence, which has shown that lending to firms tends to increase after a monetary tightening (e.g., Giannone *et al.*, 2009, for the euro area). The explanations rely on factors outside of our model such as banks' tendency to increase the supply of short-term less risky loans (Den Haan *et al.*, 2007), firms' need to keep financing production and inventories (Gertler and Gilchrist, 1994) or firms' attempts to exhaust favorable pre-committed credit lines.

[19] The initial rise of bank profits is a counterfactual implication of the model and is due to the fact that profits almost coincide with the interest rate margin, for which price effects outweigh movements in intermediated funds. Despite some empirical evidence supports countercyclicality of interest rate margins (e.g., Olivero, 2010), overall bank profits have been shown to be procyclical (Albertazzi and Gambacorta, 2008).

[20] Our parameters imply that a reduction of the capital-to-assets ratio by half (from 9 to 4.5 per cent) would increase the spread between the wholesale loan rate and the policy rate by only 10 basis points.

Figure 2.4 - The role of banks and financial frictions in the transmission of a contractionary monetary policy shock
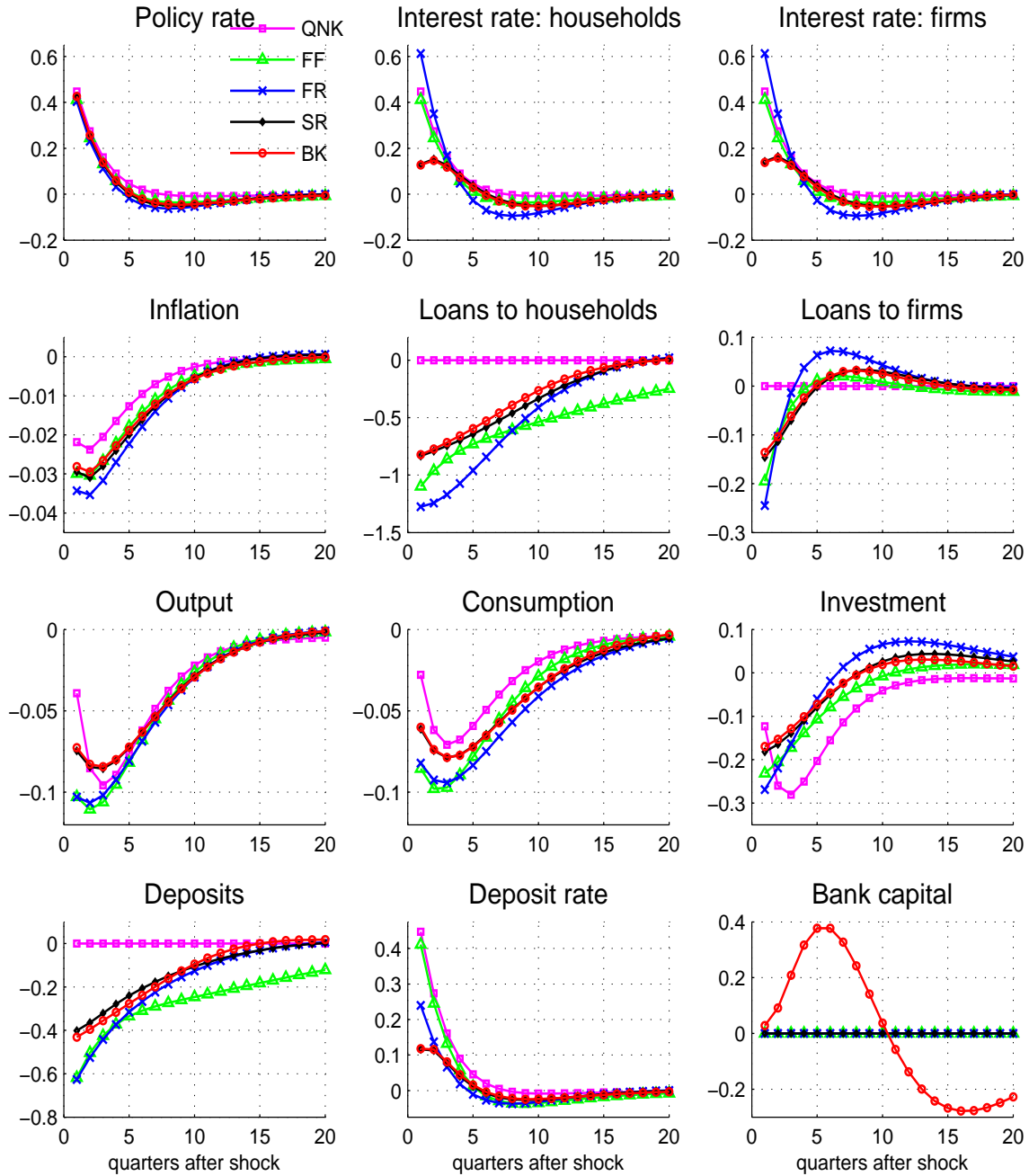
Note: All rates are shown as absolute deviations from steady state, expressed in percentage points. All other variables are percentage deviations from steady state. The red circled line is from the benchmark model (BK). The pink squared line is from the quasi-NK model (QNK). The green line with triangles is from the model with financial frictions but without banks (FF). The blue crossed line is from the model with banks, but with flexible rates and without bank capital (FR). The black line is from the model without bank capital but with sticky rates (SR). Baseline parameters are set at the median of the posterior distribution of the benchmark model.

Our findings of an attenuating effect of banking after a monetary policy shock are in line with the results in Goodfriend and McCallum (2007). In their model, the attenuation effect stems from the presence of procyclical marginal costs and occurs only when the monetary impulse is very persistent. Andrés and Arce (2008) find an attenuation effect in a model with imperfectly competitive banks and flexible rate-setting.

2.5.2 Technology shock

Figure 2.5 shows the responses to a positive one standard deviation shock to a_t^E. Overall, in the three models with banking (FR, SR, BK) the response of consumption and output is attenuated compared to the FF model, while the response of investment is amplified. Banking also seems to enhance the endogenous propagation of the shock as all real variables display a higher persistence: output peaks after about ten quarters, compared to seven in the FF model. To understand these results, it is useful to discuss how the assumption of monopolistic markups in banking modifies the transmission channels usually at work in models with financial frictions.

As for the collateral channel, the presence of markups amplifies and propagates the expansion. With imperfectly competitive banking the decline in the policy rate triggers a larger fall in loan rates. Investment is boosted both by the technology improvement and by the easier access to credit; the increased demand for capital by entrepreneurs and for housing by impatient households pushes asset prices up, so that borrowers also benefit from the wider access to credit that higher collateral values afford. The debt deflation channel yields a somewhat opposite result, as the existence of markups on loan rates raises the cost of debt servicing and exacerbates the already dampening effect of debt deflation, resulting in a smaller expansion after a technology shock. A given deflation leaves debtors with a higher burden of real obligations which weighs more on their resources and spending, so that the dampening of the supply shock due to debt being nominal is initially stronger.

Overall, the debt-deflation attenuating effect prevails on impact; over a longer horizon, however, collateral-channel effects prevail, inducing higher persistence in real variables. Adding stickiness in bank rates limits their fall and hence the expansion of lending, but overall it only marginally affects the dynamics of real variables.

Figure 2.5 - The role of banks and financial frictions in the transmission of a positive technology shock
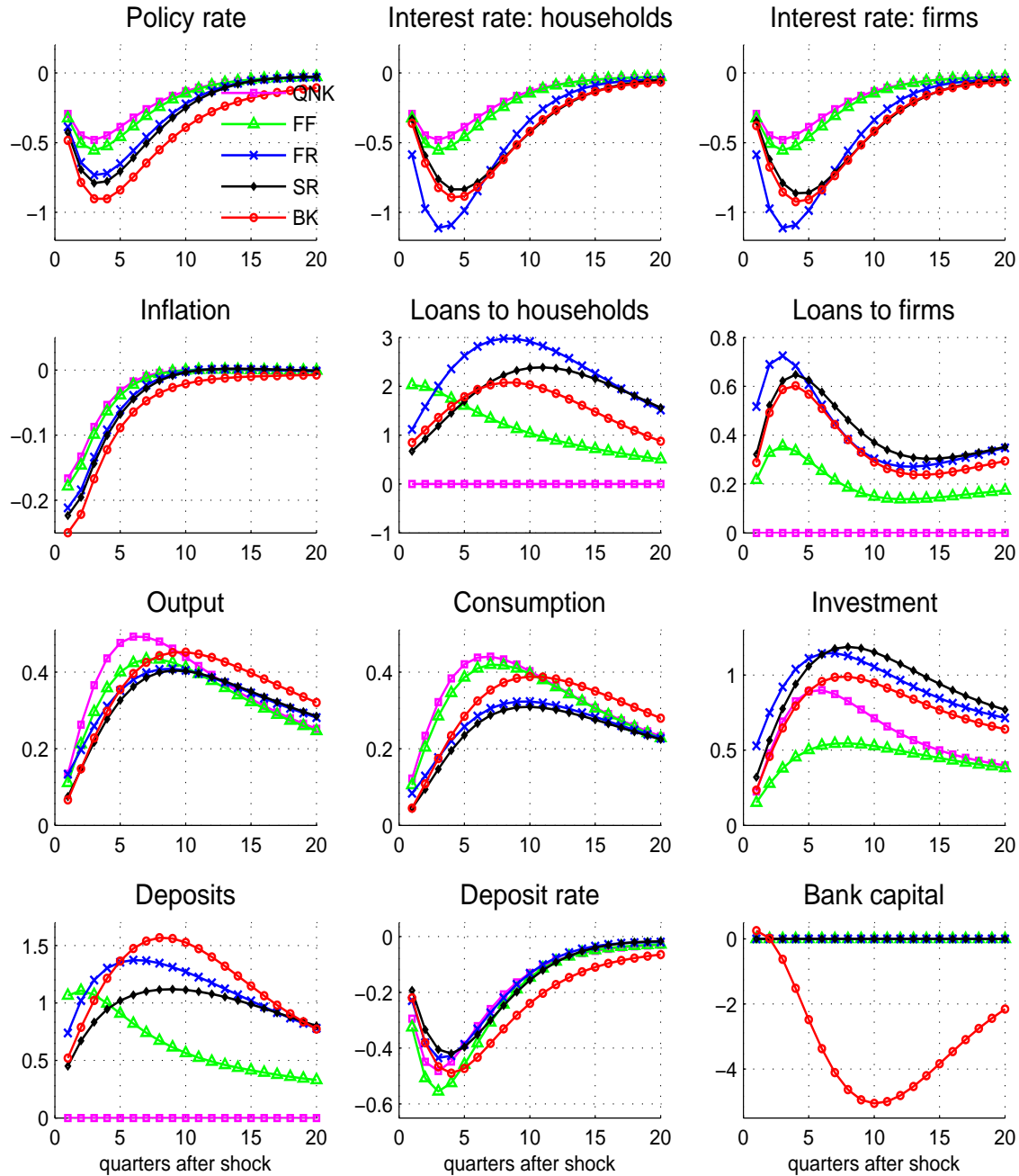
Note: All rates are shown as absolute deviations from steady state, expressed in percentage points. All other variables are percentage deviations from steady state. The red circled line is from the benchmark model (BK). The pink squared line is from the quasi-NK model (QNK). The green line with triangles is from the model with financial frictions but without banks (FF). The blue crossed line is from the model with banks, but with flexible rates and without bank capital (FR). The black line is from the model without bank capital but with sticky rates (SR). Baseline parameters are set at the median of the posterior distribution of the benchmark model.

Finally, the introduction of bank capital affects mainly investment, which peaks almost 30% below what it does in the SR model. In the BK model bank profits fall after a positive technology shock, mainly because the bank interest rates spread falls.[21] This adverse financial sector development spills over to the real sector because less bank profits means lower bank capital and, *ceteris paribus*, a higher bank leverage ratio. Banks react to the increased leverage costs by reducing lending, in particular to entrepreneurs.

2.6 Applications

Once the model has been estimated and its propagation mechanism studied, we can use it to address two issues raised in the Introduction: What role did the shocks to the banking sector play in the 2008 downturn in euro area economic activity? What are the effects of a credit crunch originating from a fall in bank capital?

2.6.1 The role of financial shocks in the business cycle

In order to quantify the relative importance of each shock in the model we perform a historical decomposition of the dynamics of the main macroeconomic and financial variables. The decomposition is obtained by fixing the parameters of the model at the posterior median and using the Kalman smoother to recover the innovations that replicate exactly our observables. The aim of the exercise is to investigate how our financially-rich model interprets both the expansion of 2006-07 and the ensuing slowdown in 2008.

We divide the shocks into three groups. First, there is a "macroeconomic" group, which pools shocks to production technology, to intertemporal preferences, to housing demand, to the investment-specific technology, and to price and wage markups. The "monetary policy" group isolates the contribution of the non-systematic monetary policy. The "financial" group consists of shocks to the LTV ratios on loans to firms and households, shocks to the markup on bank interest rates and shock to banks' balance sheet.

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[21] Bank profits display a countercyclical behavior also conditional on technology shocks. After the initial fall in inflation, and due to market power in banking, the cut in the policy rate triggers a reduction of the banking rate spread; this effect outweighs the increase in intermediated funds, generating a fall in profits.

Figure 2.6 shows the results of the exercise for some key macro variables since 2004. Concerning output (defined as the sum of consumption and investment) the model interprets the rise of 2006-07 as initially fueled by positive financial and monetary policy shocks (up until 2006Q4), while the favorable macroeconomic conditions started to play a significant role only in 2007. The sharp contraction started in 2008 was instead almost entirely caused by adverse financial shocks and, to a smaller extent, to the simultaneous retreat of the positive stimulus coming from macroeconomic shocks. A closer inspection of macroeconomic shocks reveals that price markup shocks were an important contributor; these shocks likely capture the effects of the sharp increase in commodity prices in the first half of 2008. This hypothesis is confirmed by their large contribution to inflation.[22] Less obvious is the finding that financial shocks explain also much of the boom phase of 2006-07. This should not come as a complete surprise, given the available evidence coming from surveys (see Figure 2.1) which points to a loosening of bank lending standards during 2006 and 2007.[23] The model also predicts that the link between financial shocks and the real economy operates mainly via aggregate investment. The decomposition of this variable confirms how unusually large (positive) financial shocks, mainly related to firms' LTV ratios, were responsible for the expansion of investment in 2006 and 2007 and how these same shocks turned negative in 2008, accounting for the fall in investment.

The historical decomposition of the policy rate shows a significant positive contribution of macroeconomic shocks until the third quarter of 2008; this again reflects the strong inflationary pressures coming from commodity prices. At the same time, in 2008 monetary policy appears to have been looser than what a strict adherence to the policy rule would have implied; this could reflect the impact of increasing uncertainty regarding the economic outlook on the ECB's assessment of the policy stance. Since the third quarter of 2008, when the policy rate was rapidly cut by more than 300 basis points, the contribution of financial shocks gradually increased, accounting for the bulk of the reduction of the policy rate.

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[22] We obtain quite similar results using linearly detrended data. In this case, only the last two quarters of the sample show a significant contribution of financial shocks to the downturn in economic activity.

[23] When we shut down financial shocks altogether (see Section 2.4.4), the story is even less palatable as the boom phase is mainly the result of positive technology and preference shocks.

Figure 2.6 - Historical decomposition of main macro variables: 2004Q1 - 2009Q1
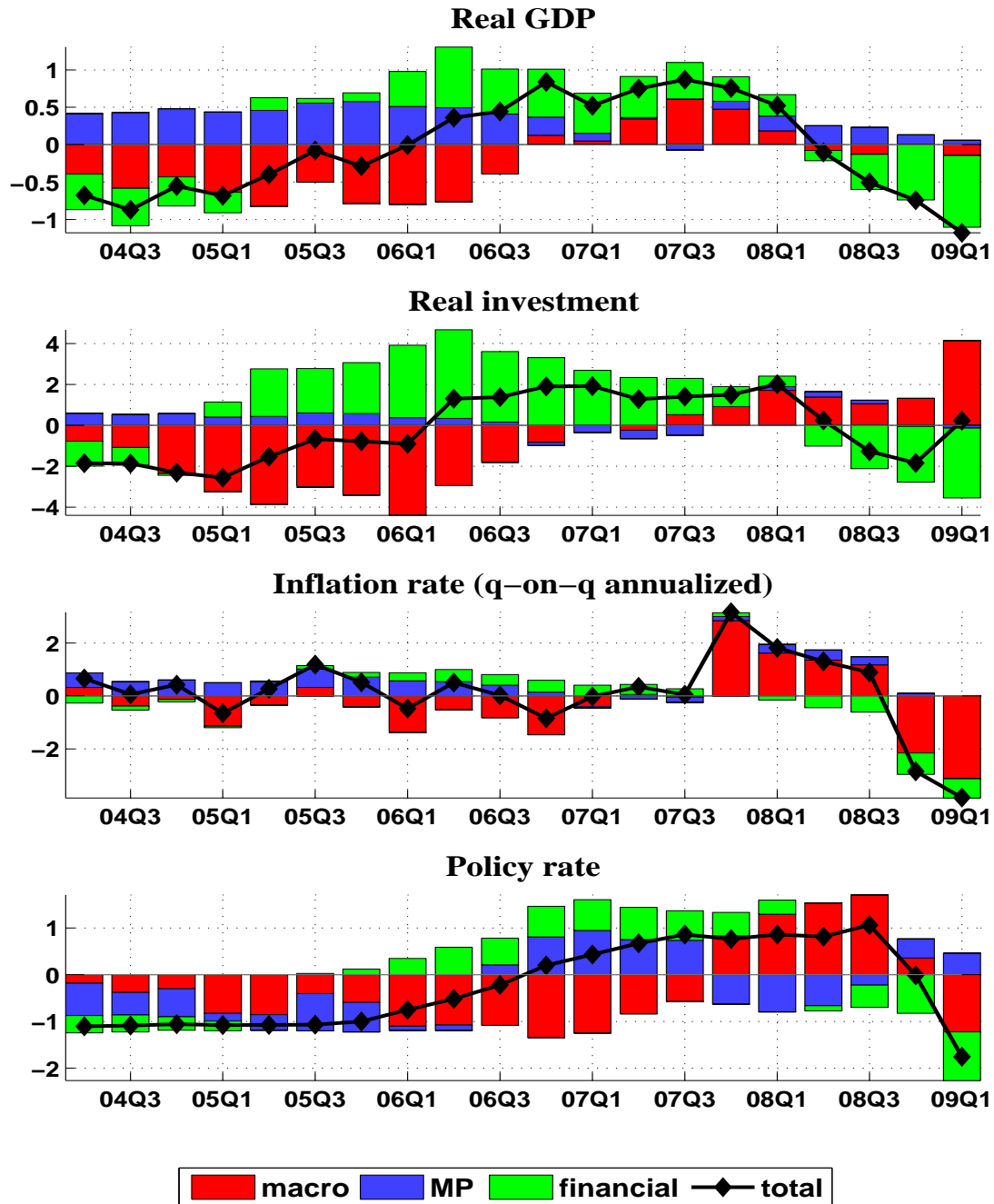
Note: The figure shows as various shocks contribute to the percentage deviations from steady state of real GDP and investment; and to the absolute deviations from steady state (expressed in percentage points) of inflation and the policy rate. The decomposition is computed using the median of the posterior distribution of the benchmark model. Macro shocks include shocks to: price and wage markups, technology, consumption preferences, housing demand, and investment-specific technology. MP refers to monetary policy shocks. Financial shocks include shocks to the loan-to-value ratios on loans to firms and households, shocks to the markup on bank interest rates and balance sheet shocks.

Figure 2.7 reports the historical decomposition of loans to households and firms and the corresponding bank rates. In this case it is convenient to divide the "financial" group in three sub-categories: shocks directly related to loans to households (i.e., shocks to households' LTV ratios and to interest rate markups on their loans), shocks directly related to loans to firms, and other financial shocks (deposit rate markup and bank balance sheet shocks). As regards interest rates on loans to both firms and households, they basically mirrored what observed for the policy rate and were mainly driven by macroeconomic shocks; for firms' loan rate, however, a significant contribution appears to have come also from sector-specific credit shocks. As for lending, loans to firms were mainly driven by sector-specific credit shocks, while the main driver for households' loans turns out to be housing demand shocks, which explain most of the strong rise in 2006 and, at a decreasing pace, in 2007, as well as the subsequent decline in 2008, tracking the house price cycle.

2.6.2   The effects of a bank capital loss

In this section we simulate an exogenous and unexpected destruction of bank capital – taking an agnostic approach on the causes behind it – and study its transmission mechanism to the real variables.[24] We calibrate the shock so as to obtain, on impact, a fall of bank capital equal to 5 percent. We focus on the qualitative results of the experiment and we do not attempt to construct a quantitatively realistic scenario; although our model is a useful instrument to analyse how shocks affecting bank capital affect the real economy, it falls short of addressing most of the mechanisms that were behind the origination of the crisis.

To better highlight the role of bank capital, we also analyze an alternative calibration where we increase (by a factor of 10) the parameter κ_{Kb} measuring the cost for banks to deviate from the targeted capital-to-assets ratio. This amplifies the effects of the shock on the profitability of our banks (see equation (2.9)) and makes the adjustment of balance sheet harder. We interpret this alternative calibration as mimicking a "stress" scenario in which banks are poorly capitalized (so that they are prevented

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[24] We modify the model introducing, in the corresponding accumulation equation, the possibility of an unexpected contraction in bank capital K_t^b. The persistence of the shock is 0.95; the other parameters are set at the median of their posterior distribution.

Figure 2.7 - Historical decomposition of main financial variables: 2004Q1 - 2009Q1
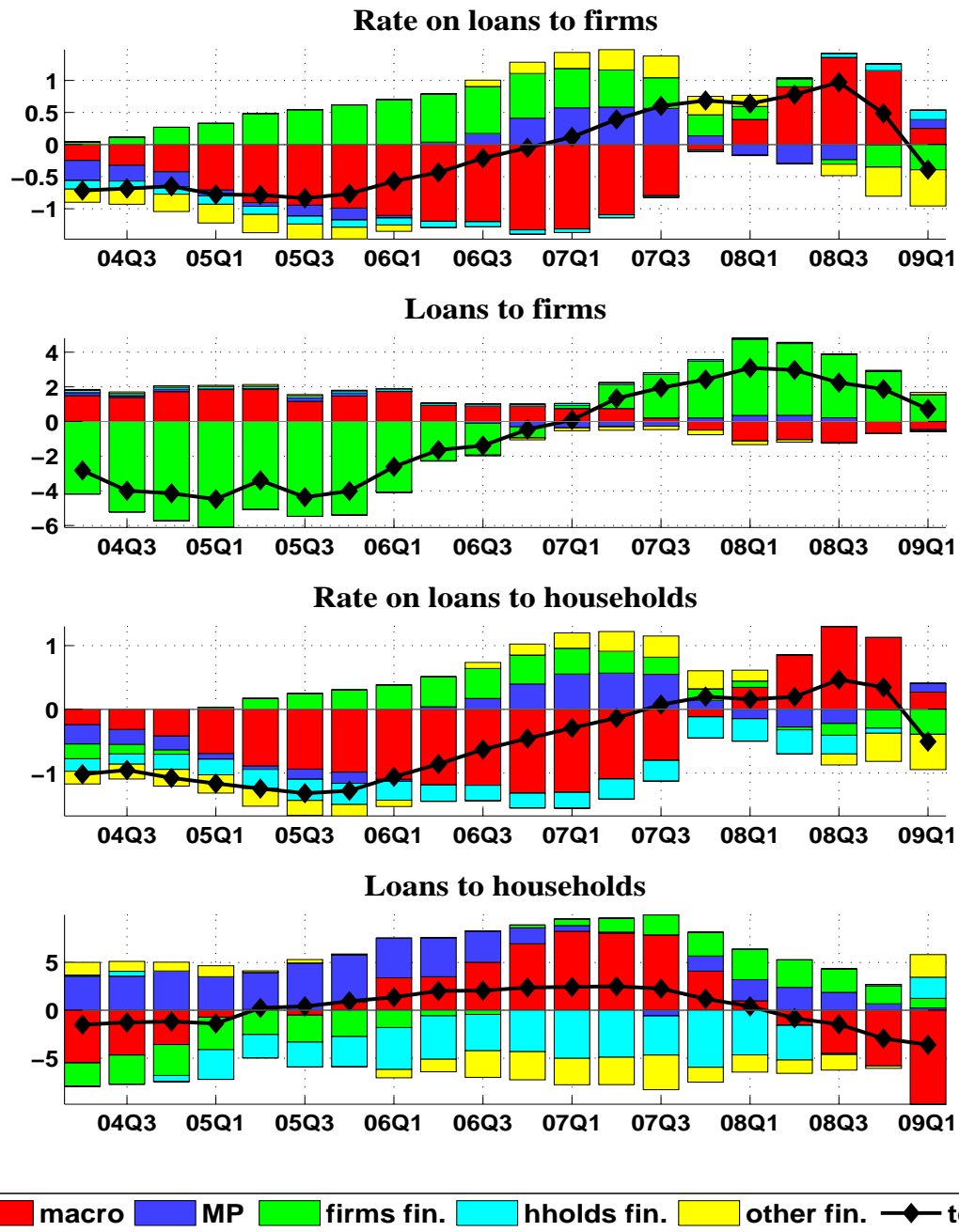
Note: The figure shows as various shocks contribute to the percentage deviations from steady state of loans to firms and to households; and to the absolute deviations from steady state (expressed in percentage points) of the respective interest rates. The decomposition is computed using the median of the posterior distribution of the benchmark model. Macro shocks include shocks to: price and wage markups, technology, consumption preferences, housing demand, and investment-specific technology. MP refers to monetary policy shocks. The firms financial category includes shocks to LTV ratios for loans to firms and shocks to the interest rate markup on their loans. The households financial category includes shocks to LTV ratios for loans to households and shocks to the interest rate markup on their loans. Finally, other financial shocks include shocks to the interest rate markdown on deposits and shocks to banks' balance sheets.

even temporarily from reducing their capital-to-assets ratio) and cannot easily raise new capital in the market.

Figure 2.8 reports the simulation. After the shock, banks are too leveraged and face high costs related to their capital position. In an attempt to re-balance assets and liabilities, they increase loan rates, which weakens loan demand. The contraction in lending induces entrepreneurs to cut investment substantially and to increase capital utilization, given that its relative cost has decreased and that capital is less useful as collateral; at the same time, entrepreneurs increase labor demand, pushing up wages, which sustains consumption and restrains the fall in output. Over a longer horizon, however, the persistently tighter financing conditions for borrowers drag real activity further down and output reaches a trough (-0.3 percent) in the third year. The central bank increases only slightly the policy rate to counteract the increase in inflation that follows higher wages and financing costs.

In the "stress" scenario in which we increase the cost of deviating from the target capital-to-assets ratio, all the responses are harshened as banks can no longer afford a prolonged period of under-capitalization and instead are forced to quickly close the gap between their capital-to-assets ratio and the target level. Such harsh deleveraging in the financial sector results in a stronger contraction of investment and more severe and prolonged falls in consumption and in output, which reaches a trough (-0.5 percent) after five years.

The scenario we have considered has a hard time to account for the magnitudes recorded during the financial crisis and the sharp fall in the policy rate. There are two main reasons behind these results. First, the calibration of the fall in bank capital is likely to underestimate actual losses incurred by euro area banks since the beginning of the crisis.[25] Second, our simulation considers only one shock and disregards others that could be used to capture the surge and fall in commodity prices and the fall in aggregate demand in 2008.[26]

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[25] IMF (2009) estimates that actual and potential write-downs on loans by euro area banks between 2007 and 2010 amount to 480 billion dollars, corresponding to around 20% of their equity.

[26] In a scenario - that we do not report - in which we jointly consider a shock to bank capital, to consumption preference and to the efficiency of investment, we are able to generate a much larger contraction of output and a sharp reduction in the policy rate with no increase in inflation.

Figure 2.8 - Impulse responses to a negative shock to capital
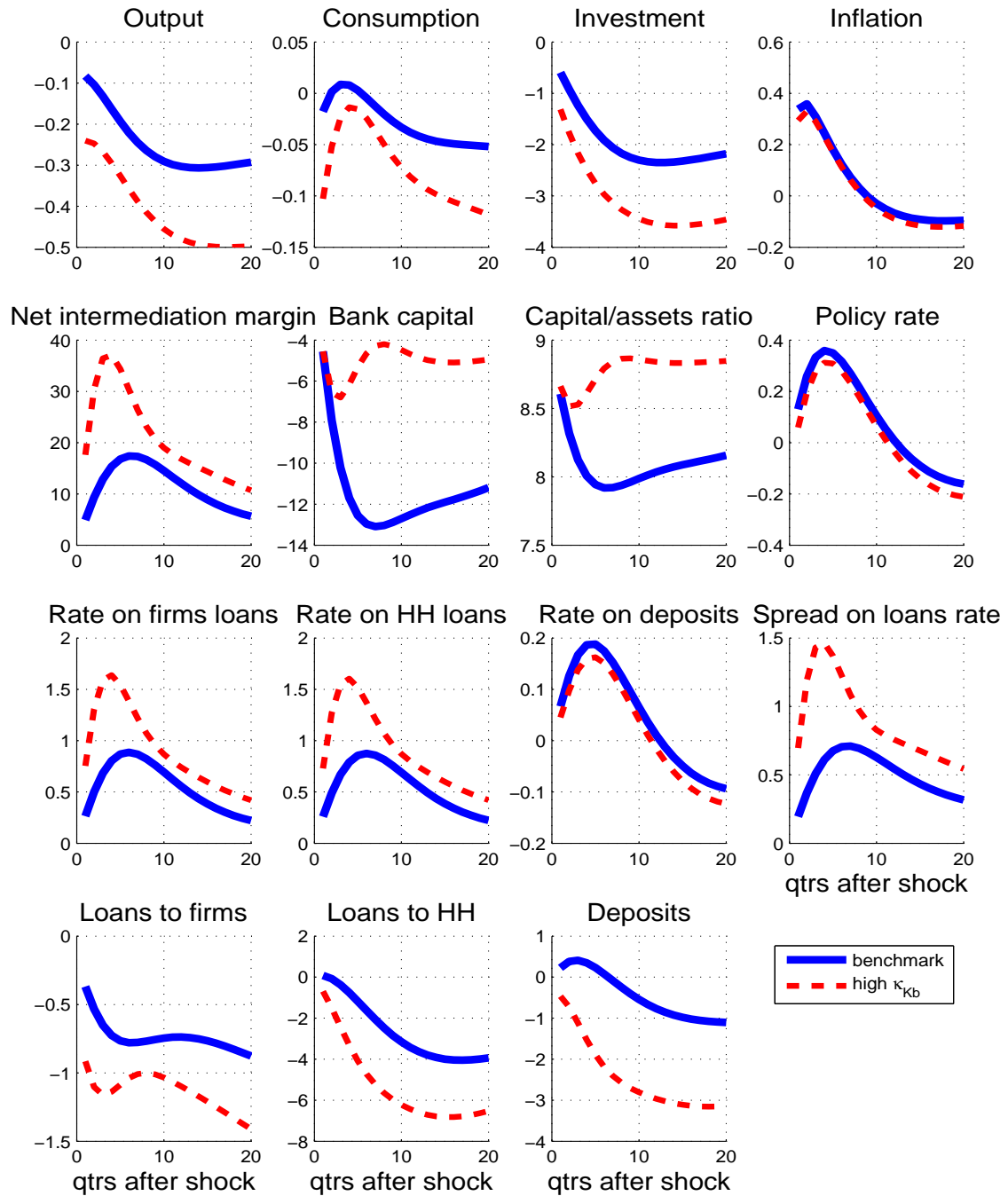
Note: The impulse responses are computed using the median of the posterior distribution of the benchmark model (blue solid lines), and replacing $\kappa_{Kb} = 100$ (red dashed lines), respectively. All rates are shown as absolute deviations from steady state, expressed in percentage points. The capital-to-assets ratio is expressed in percentage points. All other variables are percentage deviations from steady state.

2.7   Concluding remarks

This chapter has presented a model with financial frictions and a role for credit-supply factors in the business cycle. Imperfectly competitive banks supply loans to households and firms, obtain funding through deposits and own capital. Margins on loans depend on the interest rate elasticities of demand, on the degree of interest rate stickiness and on the banks' capital-to-assets ratio. Banks' balance-sheet constraints establish a link between the business cycle, which affects bank profits and capital, and the supply and the cost of loans. Shocks in the credit sector are used to capture changes in lending supply conditions due to factors that are outside the model.

The model has been estimated using Bayesian techniques and data for the euro area over the period 1998Q1-2009Q1. The analysis suggests that the model can rationalize two alternative points of view on the role of banks in the business cycle. On the one hand, financial intermediation can shield - at least to some extent - economic agents from fluctuations in market rates; in this sense, banks may contribute to stabilizing business cycle fluctuations, reducing the potentially disruptive consequences that non-financial shocks have in other models with financial frictions. In the model, this is reflected in an attenuation of the effects of monetary and technology shocks on output. On the other hand, banking may introduce additional volatility to the business cycle; this is the consequence of shocks originating in credit markets and of procyclical loan supply, which is linked to asset prices and borrowers' balance-sheet conditions, via the collateral constraint, and to banks' balance-sheet conditions, via the link between loan margins and the capital-to-assets ratio.

The model presented is a first attempt to incorporate credit supply factors in a dynamic general equilibrium framework and, as such, it suffers from a number of limitations. The model depends heavily on large financial shocks to explain the data. A more satisfactory framework, in which movements in credit spreads and lending arise endogenously due to financial frictions, would be one where uncertainty and risk matter. In addition, the only source of profits for banks is the intermediation margin. This has two main consequences: first, the cyclical properties of bank profits are counterfactual, because countercyclical movements in the spread outweigh fluctuations in intermediated funds; second, the model cannot capture fluctuations in profits stemming from asset-valuation effects, the evolution of trading fees or

other items that have assumed a growing relevance in a bank's income statement. Moreover, the mechanisms behind the sluggish adjustment of bank rates and the existence of a target leverage ratio for financial intermediaries are somewhat *ad hoc*. Finally, a crucial challenge for future research will be to address credit market facts which were of particular relevance for the 2007-08 financial crisis, like the dry-up of funding liquidity or the strong increase in the uncertainty surrounding asset valuation, and the policy responses by governments and central banks.

Appendix to Chapter 2

Data and sources

Real consumption: Consumption of households and non-profit institutions serving households (NPISH), constant prices, seasonally adjusted, not working day adjusted, euro area 15 (Eurostat).

Real investment: Gross fixed capital formation, constant prices, seasonally adjusted, not working day adjusted, euro area 15 (Eurostat).

Real house prices: Nominal residential property prices deflated with the harmonized index of consumer prices (ECB and Eurostat).

Wages: Hourly labor cost index - wages and salaries, whole economy excluding agriculture, fishing and government sectors, seasonally and working day adjusted (Eurostat).

Inflation: HICP overall index, quarterly changes, seasonally adjusted, not working day adjusted, euro area 15 (ECB).

Nominal interest rate (policy): Eonia rate (ECB).

Interest rate on loans to households: Annualized agreed rate (AAR) on loans for house purchases, total maturity, new business coverage (ECB).

Interest rate on loans to firms: AAR on loans other than bank overdrafts to non-financial corporations with maturity of over one year, new business coverage (ECB).

Interest rate on deposits: Weighted average (with weights proportional to outstanding amounts) of AARs on overnight deposits (total maturity), on deposits with agreed maturity of up to two years, and on deposits redeemable at notice of up to three months, households and non-profit institutions serving households, new business coverage (ECB).

Loans to households: Outstanding amounts of loans to households for house purchasing, total maturity, neither seasonally nor working day adjusted (ECB).

Loans to firms: Outstanding amounts of loans to non-financial corporations, total maturity, neither seasonally nor working day adjusted (ECB).

Deposits: Overnight, with agreed maturity up to 2 years, redeemable at notice up to 3 months; outstanding amounts; households and NPISH (ECB).

For bank rates, we merged two ECB data sets. From 2003M1, we use harmonized monthly data from the MFI Interest Rate (MIR) statistics in new business coverage. Data from MIR are extended back to 1998M1 using euro area Retail Interest Rate (RIR) data, compiled by the ECB until 2003M9. Since original national data in RIR are neither harmonized in coverage nor in nature, we check the stability of the relation between comparable MIR-RIR rates series over the overlapping period before using variations in RIR rates to backcast MIR rates. Volumes of loans and deposits refer to outstanding amounts: if data on new businesses were used (available from 2003Q1) their high volatility would not allow a safe backcasting of stocks and would induce instability when aggregating bank rates.

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Chapter 3

The General Equilibrium Effects of Fiscal Policy: Estimates for the Euro Area

3.1 Introduction

This chapter reconsiders the economic effects of fiscal policy using an estimated dynamic stochastic general equilibrium model for the Euro area. We try to better understand how these effects depend on the composition of expenditures and revenues, as well as on the interaction with monetary policy.

Recent years have witnessed significant changes in the fiscal position of both the United States and the Euro area. In many circumstances the main motivation behind these shifts has been related to cyclical considerations as policy makers have tried to support economic activity through fiscal stimulus. However, most of the discretionary measures undertaken, both on the spending and on the revenue side, were backed by little consensus among economists on their short to medium run effects. This lack of consensus stems from the difficulty economists have in building

models able to replicate the main empirical regularities concerning fiscal variables. Frictionless models with optimizing forward-looking agents, as RBC models, for example, seem to be ill-suited to study the effects of government spending. In this context, Baxter and King (1993) have shown that any increase in expenditures brings about - as the government intertemporal budget constraint has to be satisfied - an increase in the discounted value of future taxes. This amounts to a negative wealth effect on households that induces a decrease in their private consumption, a contemporaneous increase in labor supply and, therefore, a decrease in the marginal productivity of labor and in real wages; as in the model the steady state capital labor ratio does not change, investment will increase. These theoretical correlations do not square with the empirical evidence coming from applied research.

The debate on the empirical effects of fiscal policy shocks (in particular on the effects of government expenditure shocks on private consumption) is still unsettled. However, the disagreement mainly concerns the effects of increases in expenditures related to military buildups in the US - Perotti (2007) argues that the response of private consumption is positive, while Ramey (2008) that it is negative. For our purposes military buildups are somehow special events that do not really apply to the European case, as there is no relevant example of such events in European countries over our sample period (1980-2005). The literature on the effects of fiscal policy in "normal times" - that is abstracting from military buildups - mainly finds a moderately positive (or a non negative) response of private consumption to government expenditure shocks;[1] also employment and real wages tend to grow, while the response of private investment is generally negative.[2]

The new-Keynesian paradigm, which mainly adds real frictions and nominal rigidities to an RBC framework, displays the same wealth-effect mechanism that entails a reduction in private consumption and an expansion in labor supply following a government spending shock.[3] In this context, however, real wages may increase as

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[1] Among others, Perotti (2005) provides evidence of this kind for five OECD countries (USA, Germany, UK, Canada, Australia); Mountford and Uhlig (2005) have similar results for the US. Galí *et al.* (2007) provide an extensive review of literature on the topic.

[2] On the response of employment and real wages, see Pappa (2005) for an analysis on US data. On the response of investment, Alesina *et al.* (2002) have shown, on a large sample of OECD countries over the period 1960-2002, the negative effect on investment of a variety of government spending shocks (in particular related to transfers to households and to the public wage bill). Also Perotti (2005) shows that the response of investment is negative in the US and, after 1980, in Germany.

[3] On this see Goodfriend and King (1997) and Linnemann and Schabert (2003).

a result of an outward shift of the labor demand induced by the expanding demand in the presence of sticky prices (with a reduction in price markups).

In order to fill the gap with the evidence, the literature has recently moved away from the representative infinitely-lived rational agent. In particular Mankiw (2000) has argued that a model where Ricardian and non-Ricardian agents (that cannot save or borrow and therefore consume their income period by period) coexist is better suited for fiscal policy analysis with respect to both neoclassical and overlapping generations models.[4] Building on this framework, Galí, López-Salído and Vallés (2007, henceforth GLSV) add rule-of-thumb agents to a standard new-Keynesian model. They show that both price stickiness and the presence of rule-of-thumb consumers are necessary elements in order to have a positive response of private consumption for reasonable calibrations of the parameters. "Rule-of-thumb consumers partly insulate aggregate demand from the negative wealth effects generated by the higher levels of (current and future) taxes needed to finance the fiscal expansion, while making it more sensitive to current disposable income. Sticky prices make it possible for real wages to increase (or, at least, to decline by a smaller amount) even in the face of a drop in the marginal product of labor, as the price markup may adjust sufficiently downward to absorb the resulting gap. The combined effect of a higher real wage and higher employment raises current labor income and hence stimulates the consumption of rule-of-thumb households".[5,6]

This chapter contributes to the debate on the macroeconomic effects of fiscal policy by estimating on Euro area data a DSGE model which puts the idea of GLSV into

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[4] As Mankiw (2000), pg. 124, puts it "A better model would acknowledge the great heterogeneity in consumer behavior that is apparent in the data. Some people have long time horizons, as evident by the great concentration of wealth and the importance of bequests in aggregate capital accumulation. Other people have short time horizon, as evidenced by the failure of consumption-smoothing and the prevalence of households with near zero net worth."

[5] GLSV pg. 260.

[6] As another alternative to a model with a representative infinitely-lived rational agent, Romanov (2003), Sala (2004) and Cavallo (2007), among others, consider agents with a finite horizon by introducing a constant probability of dying *à la* la Blanchard (1985). The idea is that, although higher government expenditures will increase the level of expected future taxes, agents - while fully benefiting from the expansion in expenditures - will not likely live long enough to pay their entire share of the financing. However, since the Keynesian effects of expenditures shocks depend essentially on the probability of (or share of the population) dying before paying taxes and this probability is reasonably small over the short to medium term, these models cannot replicate the positive response of private consumption to a government spending shock.

the framework of Christiano, Eichenbaum and Evans (2005). The latter includes a number of frictions proved to be useful for estimation purposes, as shown in particular on Euro area data by Smets and Wouters (2003, henceforth SW).[7]

We extend this framework with a relatively rich description of the fiscal policy side. In particular, for government revenues we consider and estimate fiscal policy rules defined on distortionary tax rates, while previous literature (GLSV, and Coenen and Straub, 2005, henceforth CS) had essentially focused on lump-sum taxes. In order to do so, we compute quarterly average effective tax rates on labor income, capital income and consumption for the Euro area following the methodology of Mendoza, Razin and Tesar (1994).[8]

On the expenditure side, we take into consideration the fact that the variable generally used in the literature as a proxy for government purchases of goods and services, that is government consumption from National Accounts data, includes both purchases of goods and services and compensations for government employees, as recognized earlier by Rotemberg and Woodford (1992) and later by Finn (1998). In fact, in the case of the Euro area over the last twenty five years (the sample period we consider), the employee's compensations share of government expenditures averaged 60% approximately. While government purchases of goods and services is a direct component of aggregate demand, compensations of government employees affect the economy mainly through their effects on employment and wages. We therefore define government consumption excluding compensations for public employees (an aggregate that we will label *government purchases*) and model public employment separately.

The model is estimated using Bayesian inference methods on the Euro area data from 1980 to 2005. Bayesian technique - as forcefully claimed by Fernandez-Villaverde

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[7] Differently from GLSV and due to the fact that we are interested in estimating the model, we assume sticky wages. Sticky wages might be thought to work against the positive response of private consumption after a government expenditure shock, as real wages would increase less after the shock or even decrease. Our estimates confirm a more muted response of real wages, but still positive. This goes along with a lower increase in marginal costs and inflation, triggering a smaller increase in the real interest rate and a reduced impact decrease in Ricardians' consumption. Therefore, as Furlanetto (2006) shows in the GLSV model, sticky wages are not bound to induce a negative effect of government expenditure innovations on total private consumption.

[8] Appendix B provides a detailed description of the data used, including the methodology we have employed to obtain quarterly series, and some comparison between our data and alternative sources.

and Rubio-Ramirez (2006) - is now the standard tool for the estimation of DSGE models. Fernandez-Villaverde and Rubio-Ramirez (2004) show how, in practical applications, the Bayesian approach delivers very strong performance, especially on small samples.

This chapter tries to assess the response of the main macro variables to a wide range of fiscal shocks, including revenue ones. We are not concerned only with the effects of government spending shocks on private consumption, although the issue has recently attracted considerable attention. In relation to this latter issue, we would like to stress that our estimation strategy allows also for a negative response, as we discuss in some detail in Section 3.5.4 below.

Although fiscal policy is run at national level, the focus of this chapter is on the Euro area. As cross country spillover effects from fiscal policy shocks tend to be limited,[9] shocks in one single country mainly affect that country's variables, so that the effect on Euro area variables mainly depends on the weight of the country within the Euro area. Our estimated effects should therefore be interpreted as the (weighted) average effects of fiscal shocks across Euro area countries. On the other hand, focusing on the Euro area as a whole has advantages: first, we can easily take into account the role of the common monetary policy; second, we can keep the model relatively simple and disregard all the theoretical and empirical issues related to the analysis of a single country in a monetary union; third, we can build on a model specification, the one proposed by SW, proven to match the Euro area data quite well; last, there is not an obvious candidate country for our study, as there are no official quarterly data available for any of the Euro area countries previous to 1999.

To our knowledge, this is the first work that estimates a medium scale DSGE model with a detailed role for fiscal policy (featuring both distortionary taxes and detailing expenditures in its main components) on Euro area data. We use both state of the art econometric techniques for the estimation and a newly computed quarterly data set for fiscal policy variables (as government sector data in the Euro area are mainly available on an annual basis). We believe that the use of a rich set of data (especially for the government sector that is the focus of our work) is necessary for a proper identification of parameters and shocks. In particular, having data

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[9] Evidence in this regard can be found in Marcellino (2006) and De Bandt and Mongelli (2002). For an analysis of fiscal policy in a two-region currency union model using a framework similar to the one of this chapter, see Forni, Gerali and Pisani (2008).

on distortionary taxes can potentially improve the estimates of certain shocks: for example, it might help disentangling the effects of a shock affecting the consumption-leisure intratemporal trade-off from those of a change in the labor income tax rate, or the effects of an investment shock from those of a capital income tax rate shock. Our approach, therefore, overcomes some of the weaknesses related to the interpretation of shocks pointed out by Chari, Kehoe and McGrattan (2008).

Our results point to a significant share of non-Ricardian agents (between 30 and 40%) and to the prevalence of mild Keynesian effects of public expenditures. In particular, although innovations in fiscal policy variables tend to be rather persistent, government purchases of goods and services and compensations for public employees have small and short lived expansionary effects on private consumption, while innovations in transfers to households show a slightly more sizeable and lasting effect. The effects are more significant on the revenue side: decreases in labor income and consumption tax rates have sizeable effects on consumption and output, while a reduction in the capital income tax favors investment and output in the medium run. Finally our estimates suggest that fiscal policy variables contribute little to the cyclical variability of the main macro variables.

The chapter is organized as follows. Section 3.2 describes in detail the model and our assumptions regarding policies. Section 3.3 sketches the techniques we use to solve and estimate the model, and describes the data and the assumptions regarding prior distributions. Section 3.4 presents our estimated parameter distributions, that are then used in Section 3.5 to discuss the effects of fiscal policy innovations. In Section 3.6 we summarize our results.

3.2   The setup

3.2.1   Production and technology

In the private sector there is a continuum of firms j each producing one differentiated final good with the following Cobb-Douglas technology defined in terms of homogeneous labor input L_t^p (where the superscript p refers to the employment level in the private sector) and rented capital services K_t:

$$Y_t(j) = A_t K_t(j)^\alpha (Z_t L_t^p(j))^{1-\alpha} \tag{3.1}$$

where A_t is a stationary technology shock and Z_t a labor-augmenting permanent one. For the processes describing technology we follow, among others, Adolfson *et al.* (2007) and assume:

$$\log(A_t) = \rho^A \log(A_{t-1}) + \varepsilon_t^A$$

$$\log(\nu_t) = (1 - \rho^\nu) \log(\nu) + \rho^\nu \log(\nu_{t-1}) + \varepsilon_t^\nu$$

where $\nu_t = Z_t/Z_{t-1}$ and ν is the steady state growth rate of Z_t. In the following we will present the model expressed in terms of detrended (lowercase) variables, so that for a generic variable X_t we will define:

$$x_t \equiv \frac{X_t}{Z_t}$$

From the solution of firm j's static cost minimization problem, we have input demands

$$k_t(j) = \frac{y_t(j)}{A_t} \left(\frac{W_t}{R_t^k} \frac{\alpha}{1 - \alpha} \right)^{1-\alpha} \nu_t \tag{3.2}$$

$$L_t^p(j) = \frac{y_t(j)}{A_t} \left(\frac{W_t}{R_t^k} \frac{\alpha}{1 - \alpha} \right)^{-\alpha} \tag{3.3}$$

and, defining $\zeta = (1 - \alpha)^{\alpha-1} \alpha^{-\alpha}$, an expression for the nominal marginal cost (here equal to the average one and hence common to all firms)

$$MC_t = \frac{\zeta W_t^{1-\alpha} R_t^{k\,\alpha}}{A_t} \tag{3.4}$$

Each firm chooses its own net (of consumption taxes) price $\widetilde{P}_t(j)$ to maximize intertemporal profits defined as the difference between total revenues and total costs (inclusive of a price adjustment cost, scaled in terms of wholesale total output)

$$\max_{\{\widetilde{P}_t(j)\}} E_0 \sum_{t=0}^{\infty} Q_{0,t} Z_t \left[\widetilde{P}_t(j) y_t(j) - MC_t y_t(j) - \frac{\kappa}{2} \left(\frac{\widetilde{P}_t(j)}{\widetilde{P}_{t-1}(j)} - \pi \right)^2 \widetilde{P}_t y_t \right] \tag{3.5}$$

subject to demand-determined output. $Q_{0,t}$ is the stochastic discount factor for Ricardian households (the only share-owners) and $y_t(j)$ is the (detrended) demand faced by firm j.

3.2.2 Consumers Problem

The economy is populated by a measure one of households. A fraction γ of them are non-Ricardians: they do not have access to financial or capital markets. Asset

markets (not modelled) are assumed to be complete. Ricardian households are the only owners of assets, including capital, which is rented to firms.

All consumers have a preference for variety: for each household i, the consumption index is

$$c_t(i) = \left[\int_0^1 c_t(i,j)^{\frac{\theta_c - 1}{\theta_c}} dj \right]^{\frac{\theta_c}{\theta_c - 1}} \tag{3.6}$$

where $c_t(i,j)$ is i's consumption of the good produced by firm j. The maximization of $c_t(i)$ w.r.t. $c_t(i,j)$ for a given total expenditure leads to a set of demand functions of the type

$$c_t(i,j) = \left(\frac{P_t(j)}{P_t} \right)^{-\theta_c} c_t(i) \tag{3.7}$$

where $P_t(j)$ is the price of the good produced by firm j gross of consumption taxes. An aggregator identical to (3.6) is also assumed for both real government purchases c_t^g and investment i_t, and for each of them isoelastic demand functions of the form of (3.7) obtain. From aggregation over agents, aggregate demand for each component still has the form of (3.7) and total demand for a good produced by firm j can be expressed as $y_t(j) = c_t(j) + c_t^g(j) + i_t(j)$. Therefore each firm will face an isoelastic demand function with price elasticity θ_c for its total demanded output.

Conditional on optimal behavior, it will be true that $\int_0^1 P_t(j)c_t(i,j)dj = P_t c_t(i)$, and similarly for public consumption and investment, although for the latter it is assumed that no indirect tax is levied, so that the relevant price index is $\widetilde{P}_t = P_t/(1 + \tau_t^c)$.

Ricardian households

Lifetime utility of the i-th Ricardian household (R) is a separable function of its consumption $c_t^R(i)$ and labor $L_t^R(i)$ given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \varepsilon_t^b \left[\log \left(c_t^R(i) - h\frac{c_{t-1}^R}{\nu_t} \right) - \varepsilon_t^L \frac{1}{1 + \sigma_L} L_t^R(i)^{1 + \sigma_L} \right] \tag{3.8}$$

Ricardian households have external habits in consumption with parameter $h \in [0, 1)$: c_{t-1}^R is lagged aggregate per capita (and detrended) consumption. Two demand shifters are assumed: ε_t^b affects the overall level of utility in period t while ε_t^L affects the consumption-leisure intratemporal trade-off. The nominal flow budget

constraint for Ricardian agent i is given by

$$(1-\tau_t^w)w_t(i)L_t^R(i) + (1-\tau_t^k)\left[R_t^k\frac{\overline{k}_t^R(i)}{\nu_t}u_t(i) + d_t^R(i)\right] + \frac{b_t^R(i)}{\nu_t} + tr_t^R(i) + \frac{\tau_t^c}{1+\tau_t^c}P_t i_t^R(i) =$$

$$= P_t c_t^R(i) + P_t i_t^R(i) + \frac{b_{t+1}^R(i)}{R_t} + P_t\psi(u_t(i))\frac{\overline{k}_t^R(i)}{\nu_t} + \frac{\phi}{2}\left(\frac{w_t(i)}{w_{t-1}(i)}\nu_t - \pi\right)^2 w_t \qquad (3.9)$$

where $(1-\tau_t^w)w_t L_t^R$ is net labor income, $(1-\tau_t^k)R_t^k \overline{k}_t^R u_t/\nu_t$ is net nominal income from renting capital services $k_t^R = \overline{k}_t^R u_t$ (where the bar indicates physical units of capital, while u_t is utilization intensity) to firms at the rate R_t^k, d_t^R are dividends distributed by firms to Ricardians (by assumption, the only firms' owners). The fiscal authority makes net lump-sum transfers tr_t and finances its expenditures by issuing one period maturity discount nominal bonds b_t and by levying taxes on labor income (τ_t^w), capital income (τ_t^k) and consumption (τ_t^c). Consumption tax introduces a wedge between the producer price index $\widetilde{P}_t$ and the consumers one $P_t = (1 + \tau_t^c)\widetilde{P}_t$. We assume that no indirect taxes are paid on purchases of investment goods, so that the price index of investment goods is the wholesale price $\widetilde{P}_t$. Instead of having two price levels in the consumers' problem, we include among the uses (r.h.s. of the budget constraint) the investment expenditure expressed in terms of prices gross of taxes $P_t i_t^R$ and compensate it with a rebate equal to $\frac{\tau_t^c}{1+\tau_t^c}P_t i_t^R$, so that the difference between the two is equal to the actual expenditure on investment goods $\widetilde{P}_t i_t^R$. Uses also feature the amount of government bonds that Ricardian households carry over to the following period, discounted by the nominal gross interest rate R_t. Finally, adjustment costs are introduced on the household choices of the nominal wage w_t and of capacity utilization u_t. The first is incurred if the nominal wage deviates from the steady state path (along which gross wage inflation π^w is assumed equal to gross price inflation π) and is expressed in terms of the equilibrium wage rate w_t (see Kim, 2000). The second is incurred if the level of capital utilization is different from its steady state value of 1; this cost is described by an increasing convex function $\psi(u_t)$, with $\psi(1) = 0$.

The physical capital accumulation law is

$$\overline{k}_{t+1}^R(i) = (1 - \delta)\frac{\overline{k}_t^R(i)}{\nu_t} + \left[1 - s\left(\frac{\varepsilon_t^i i_t^R(i)}{i_{t-1}^R(i)}\nu_t\right)\right]i_t^R(i) \qquad (3.10)$$

where not all new investment gets transformed into capital and the term $s\left(\frac{\varepsilon_t^i i_t^R}{i_{t-1}^R}\nu_t\right)i_t^R$ describes (in terms of capital loss) the cost of adjustment for varying the investment

level with respect to the previous period, a cost which is subject to a specific efficiency shock ε_t^i.[10]

Non-Ricardian households

Non-Ricardian households have been modeled in various ways in the literature, leading to different responses of their consumption to changes in their current disposable income. Some authors have assumed that non-Ricardian households cannot participate in capital markets, but they can still smooth consumption by adjusting their holding of money (consumption smoothing will be less than complete as the return from money holding has a negative real return). In this latter case, as for example Coenen, McAdam and Straub (2008) show, it is very difficult to get a non negative response of private consumption to a government expenditure shock as the response of non-Ricardian consumers is very similar to that of Ricardians.

Other authors have shown that assumptions implying stronger responses of non-Ricardian agent's consumption to variations in disposable income are necessary in order to allow for the possibility of obtaining a positive response of private consumption to government expenditure shocks. In particular, following Campbell and Mankiw (1989), GLSV assume that in each period non-Ricardian agents consume their current income; in their work, the strong response of non-Ricardian consumption to disposable income variations is a necessary condition (but not sufficient) to obtain a positive response of total consumption to government spending shocks. In this chapter we follow this latter approach and assume that non-Ricardian households (NR) simply consume their after-tax disposable income, as originally proposed by Campbell-Mankiw (1989). That is, their budget constraint is simply:

$$P_t c_t^{NR}(i) = (1 - \tau_t^w)w_t(i)L_t^{NR}(i) + tr_t^{NR}(i) \tag{3.11}$$

We would like to stress that this modeling of non-Ricardians does not impose a positive response of total private consumption to government expenditure shocks. The response will depend, among other things, on the value of the share of non-Ricardians, γ, that we estimate. As we will show, for low values of γ the response of consumption is in fact negative.

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[10] As in Christiano *et al.* (2005), $s(.)$ has the general properties $s(1) = s'(1) = 0$ and $s''(1) > 0$.

3.2.3 The labor market

The labor market is monopolistically competitive, and equilibrium employment is demand-determined. For each type of differentiated labor service, supply comes from both Ricardian and non-Ricardian households and demand gets uniformly allocated among them. Labor is an input for both the public and the private sector. Public sector labor demand is modeled as an autoregressive exogenous shock in logs with i.i.d. error term, of the form

$$\log L_t^g = \rho_{Lg} \log L_{t-1}^g + (1 - \rho_{Lg}) \log L^g + \varepsilon_t^{Lg} \tag{3.12}$$

and one has $L_t^g = \int_0^1 L_t^g(i) di$. We assume that the wage rate in the public sector is equal to the one prevailing in the private sector.[11] Hours can be moved costlessly across the two sectors and L_t^g and L_t^p are perfect substitutes in the utility function, that is $L_t = L_t^g + L_t^p$. This setup is very similar to the one considered by Cavallo (2007), although in a different context.

In the private sector labor market, a perfectly competitive firm buys the differentiated individual labor services supplied by households and transforms them into an homogeneous composite labor input that, in turn, is sold to good-producing firms. This 'labor packer' is a CES aggregator of differentiated labor services which solves:

$$\max_{L_t^p(i)} \ L_t^p = \left[\int_0^1 L_t^p(i)^{\frac{\theta_L - 1}{\theta_L}} di \right]^{\frac{\theta_L}{\theta_L - 1}} \tag{3.13}$$

$$\text{s.t.} \quad \int_0^1 w_t(i) L_t^p(i) di = \overline{E}_t$$

for a given level of the wage bill $\overline{E}_t$. The solution gives the demands for each kind of differentiated labor service in the private sector $L_t^p(i)$:

$$L_t^p(i) = \left(\frac{w_t(i)}{w_t} \right)^{-\theta_L} L_t^p \tag{3.14}$$

where L_t^p is total private sector labor.

The representative Ricardian household solves the intertemporal problem of setting optimally a wage for its type i labor, having regard to the labor demand constraint (3.14) and of the current and future costs of misalignments of wage growth from

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[11] This assumption is not far from reality. In fact, hourly wages in the public sector tend to track private sector ones, at least over medium terms horizons.

steady state inflation. Given that, by assumption, non-Ricardians do not have an intertemporal optimizing behavior, following Erceg *et al.* (2005) our baseline model assumes that the non-Ricardian wage rate simply equals the average of the Ricardians. This way, since all households face the same labor demand in the private sector where wages are set, both the wage rate and hours worked will be equal for every agent in the economy. Although simplifying, this assumption imposes that the hours worked by non-Ricardians respond to shocks in the same way as those worked by Ricardians. In particular, Ricardian labor effort will respond to a public expenditure shock in the standard way: a, say, positive public expenditure shock will induce a standard negative wealth effect that will lead to an increase in labor supply. By assumption, the response will be the same for non-Ricardians, sustaining their labor income and therefore amplifying any Keynesian effect following the shock.

Hence, we consider as a robustness check a more general version of the labor market, able to recognize a role for non-Ricardian preferences in labor choice even if they cannot optimize intertemporally, and in which non-Ricardians do not fully inherit the labor supply consequences from the wealth effect of Ricardians. In particular, we follow the approach proposed by GLSV, according to which a union representing the preferences of both Ricardian and non-Ricardian agents sets wages in a monopolistically competitive labor market. Union bargaining is consistent with the characteristic of the European labor market and moreover will deliver a single wage and employment level (which is desirable for estimation purposes). Details and results of this alternative model are reported in Appendix A. As the results are not substantially different, we have stuck to the simple formulation as our baseline model.

3.2.4   Fiscal policy

Estimates concerning the effects of fiscal policy for the Euro area are usually constrained by the lack of quarterly data on government accounts. Eurostat has recently started to release quarterly data on general government accounts, but only starting from 1999, i.e. a period too short to be used for our purposes. The only quarterly data series easily available are government consumption (G) and public employment. As we have computed quarterly data for government purchases of goods and services, transfers to families, total revenues and average effective tax rates, we can

model the fiscal policy block with more detail than previous work. First, we can distinguish within expenditures and revenues. Moreover, estimating average effective tax rates allows us to use proportional distortionary taxation, a feature that is more realistic, and more appropriate for estimation purposes than assuming lump-sum taxes.[12]

We consider the following budget constraint (in detrended form):

$$\left[\frac{b_{t+1}}{R_t} - \frac{b_t}{\nu_t} \right] = c_t^g + w_t L_t^g + tr_t - t_t \tag{3.15}$$

where c_t^g is government purchases of goods and services (assumed to be pure waste), $w_t L_t^g$ is compensation for public employees and tr_t are transfers to households. Total government revenues t_t are given by the following identity:

$$t_t = \tau_t^w w_t L_t + \frac{\tau_t^c}{1 + \tau_t^c} [P_t c_t + c_t^g] + \tau_t^k \left[R_t^k \frac{k_t}{\nu_t} + d_t \right] \tag{3.16}$$

where tax rates on labor income, capital income and consumption are assumed to be determined according to the following rules:

$$\log \tau_t^w = \rho_{\tau^w} \log(\tau_{t-1}^w) + (1 - \rho_{\tau^w}) \eta_{\tau^w} \log(\tilde{B}_t) + \varepsilon_t^{\tau^w} \tag{3.17}$$

$$\log \tau_t^c = \rho_{\tau^c} \log(\tau_{t-1}^c) + (1 - \rho_{\tau^c}) \eta_{\tau^c} \log(\tilde{B}_t) + \varepsilon_t^{\tau^c} \tag{3.18}$$

$$\log \tau_t^k = \rho_{\tau^k} \log(\tau_{t-1}^k) + (1 - \rho_{\tau^k}) \eta_{\tau^k} \log(\tilde{B}_t) + \varepsilon_t^{\tau^k} \tag{3.19}$$

where $\tilde{B}_t = B_t/P_t Y_t$ and each ε_t^τ is an i.i.d. innovation. Detrended expenditure items, c_t^g and tr_t, are assumed to follow exogenous log linear AR(1) processes in real terms as for L_t^g, with i.i.d. innovations ε_t^{cg} and ε_t^{tr}.

As for steady state values, based on sample averages we set purchases of goods and services at 10% of output, debt at 60% (on a yearly basis) and L^g equal to 20% of total employment. Steady state values for tax rates are assumed to be simply

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[12] As we use average effective tax rates, instead of marginal tax rates, we might have a potential misspecification problem for labor income taxes, as these are generally progressive (capital income and consumption taxes, instead, tend to be proportional). However, estimated elasticities of the labor income tax revenues are not very far from 1 in the Euro area (1.3 for Germany, 0.6 for France, 0.8 for Italy and 1.1 for Spain, which on a weighted average basis is close to 1; see for these numbers van den Noord, P., 2000). This implies that average effective and average marginal tax rate tend to comove and that the mild pro-cyclicality in tax rates that we find (see Section 3.2.4) is not due to the way we estimate average tax rates. Also results in Mendoza, Razin and Tesar (1994) support the view that the dynamics of average and marginal tax rates are not very different. As we demean the variables, we are mainly concerned with the dynamics.

the averages over the sample period of our estimates of average effective tax rates (approximately equal to 16% for consumption taxes, 19% for capital income taxes, 45% for labor income taxes). Given these figures, the steady state value for transfers is set residually so as to satisfy the government budget constraint (it turns out to be equal to 16.5% of output).

Some remarks on the fiscal policy rules

In our benchmark specification we assume that taxes are set in order to keep real debt dynamics (as a share of GDP) under control. This is consistent with the idea that debt stabilization is an important motive in the conduct of fiscal policy. Moreover, as Schmitt-Grohé and Uribe (2006) show in a model very similar to ours, such linear tax rules, where tax rates depend on the debt to GDP ratio and output gap, can in fact approximate optimal rules.

To explore the issue of the cyclical stabilization role of tax rates, we added to our policy rules the growth rate of detrended output (i.e., the gap between GDP growth and trend growth). The estimates show that the coefficients relating tax rates to this measure of gap are in general positive (suggesting pro-cyclical changes in tax rates) but too small to significantly affect the results.[13] We have also experimented adding measures of expenditures (transfers, government purchases of good and services, government wage bill) in the tax rules and found that the corresponding coefficients are not well-identified and in general not sizeable.

As for expenditures, we are assuming they are all exogenous AR(1) processes. The inclusion of measures of economic activity in the process describing expenditures is potentially important, as an expansionary fiscal shock could bring about an increase in activity and employment and therefore a reduction in automatic stabilizers (as unemployment expenditures, which are included in transfers to households). The latter could in turn offset the increase in disposable income of non-Ricardian households coming from the increase in labor income.

We have therefore experimented with introducing fiscal rules on expenditures while at the same time assuming exogenous processes for the tax rates. In general, the

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[13] There is some evidence on the response of the overall budget deficit to the cycle (as measured for example by the output gap) on a yearly basis, although Galí and Perotti (2003) document that the response is at best weak. The evidence is more supportive of the stabilization role of fiscal policy when estimates are conducted using real time data; see on this Forni and Momigliano (2004).

parameters relating expenditure items with the debt ratio and the output growth are estimated to be negative and very small (and, with the exception of the response of transfers to debt, also not very well-identified). We have used these estimated rules on expenditure items to assess the responses to tax rates and expenditure shocks and found results that are not qualitatively different from the ones obtained under our baseline specification (where we define fiscal rules on tax rates). In particular, the estimated response of transfers to output growth is relatively mild and not able to change in any significant way our estimated response of private consumption to government expenditure shocks.

Finally, another relevant issue is whether we are able to properly identify fiscal policy innovations, in particular tax rates innovations. In this respect, we follow the approach that is standard in the literature on monetary policy, that is to augment the tax rules with an i.i.d. error term and to assume that this error represents an unexpected change in policy. However, it might be argued that fiscal policy is different, as it suffers more than monetary policy from announcement effects and implementation lags. Although this criticism cannot be entirely disregarded, it is difficult to believe that changes in effective tax rates on a quarterly basis could be fully anticipated. Moreover, we assume that a share of agents consume their current disposable income. For these agents, even changes that are announced in advance will not have any effect prior to their realization.

3.2.5 Monetary policy

The monetary policy specification is in line with SW and assumes that the central bank follows an augmented Taylor interest rate feedback rule characterized by a response of the nominal rate R_t to its lagged value, to the gap between lagged inflation π_{t-1} and steady state inflation π, to the gap between contemporaneous (detrended) output y_t and its steady state value, to changes in inflation $\Delta\pi_t = \pi_t - \pi_{t-1}$ and to output growth $\Delta y_t = y_t - y_{t-1}$.[14]

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[14] We follow SW and others and assume that the Taylor rule is a good description of the conduct of monetary policy also before the Euro, during the period characterized by the European Monetary System (that provided, anyway, some coordination in monetary policy across European countries). Also, as discussed in Section 3.3.1, we de-trended the inflation rate data with a linear spline. This is equivalent to assuming a varying target inflation rate for the monetary authority, and should take care of the transition period from the EMS to the single monetary policy.

In log-linearized form we have:

$$\widehat{R}_t = \rho_R \widehat{R}_{t-1} + (1 - \rho_R)(\rho_\pi \widehat{\pi}_{t-1} + \rho_y \widehat{y}_t) + \rho_{\Delta\pi} \widehat{\Delta\pi}_t + \rho_{\Delta y} \widehat{\Delta y}_t + \widehat{\varepsilon}_t^m \qquad (3.20)$$

The monetary policy shock ε_t^m is assumed to be i.i.d.[15,16]

3.2.6   Aggregations and market clearing

The aggregate per-capita level of any household quantity variable $x_t(i)$ is given by

$$x_t = \int_0^1 x_t(i)di = (1 - \gamma)x_t^R + \gamma x_t^{NR}$$

as households within each of the two groups are identical. Therefore, as an example, aggregate consumption is given by $c_t = (1 - \gamma)c_t^R + \gamma c_t^{NR}$, while aggregate capital, as any variable which relates only to Ricardians, by $\overline{k}_t = (1 - \gamma)\overline{k}_t^R$. Equilibrium in the goods market requires:

$$y_t = A_t \left(\frac{k_t}{\nu_t}\right)^\alpha (L_t^p)^{1-\alpha} = c_t + i_t + c_t^g + adj_t \qquad (3.21)$$

where adj_t stands for (detrended) adjustment costs in real terms,

$$adj_t = \frac{\phi}{2}(\pi_t^w \nu_t - \pi)^2 \frac{w_t}{P_t} + \psi(u_t)\frac{\overline{k}_t}{\nu_t} + \frac{\kappa}{2}(\widetilde{\pi}_t - \pi)^2 \frac{y_t}{1 + \tau_t^c}$$

with $\pi_t^w \equiv w_t/w_{t-1}$ and $\widetilde{\pi}_t \equiv \widetilde{P}_t/\widetilde{P}_{t-1}$. Market clearing conditions in capital and private labor markets are obtained by setting firms' demands (3.2) and (3.3) equal to households' supplies.

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[15] In new-Keynesian models with non-Ricardian agents the *Taylor principle* (that states $\rho_\pi > 1$ as a sufficient condition for local determinacy) might not hold. For example, Bilbiie (2006) argues, in a model without capital, that determinacy requires a muted (less than one for one) response of nominal rate to inflation (the so called *inverted Taylor principle*). On the other hand, Galí *et al.* (2004, 2007) show that, when both price stickiness and the share of non-Ricardians are high, the Taylor principle should be reinforced (*reinforced Taylor principle*), that is determinacy requires a response of nominal rate to inflation much greater than one. In our model, however, the Taylor principle holds. The reason is that both Bilbiie (2006) and Galí *et al.* (2004, 2007) assume flexible wages, while we assume sticky wages. As Colciago (2006) has shown, with (reasonable amounts of) wage stickiness the Taylor principle is restored.

[16] We have experimented with different specifications of the Taylor rule and different priors on its coefficients (for details refer to the working paper version, Forni *et al.* 2007) and found that the estimated effects of fiscal shocks are not substantially affected. This suggests that controlling for monetary policy is not crucial when estimating the effects of fiscal policy shocks, a result in line with Perotti (2005).

3.3 Solution and estimation

Ricardian households maximize (3.8) subject to (3.9) and (3.10) with respect to c_t^R, b_{t+1}^R, w_t, i_t^R, $\overline{k}_{t+1}^R$, u_t, and the two Lagrangian multipliers, λ_t and μ_t respectively. In the symmetric equilibrium, the corresponding first order conditions are

$$\frac{\varepsilon_t^b}{(c_t^R - hc_{t-1}^R/\nu_t)} = \lambda_t P_t \tag{3.22}$$

$$\lambda_t = \beta R_t E_t \left[\frac{\lambda_{t+1}}{\nu_{t+1}} \right] \tag{3.23}$$

$$\theta_L \, \varepsilon_t^b \, \varepsilon_t^L \, L_t^{R\,\sigma_L} \frac{L_t^{p,R}}{w_t} + \beta \, \phi \, E_t \Big[\lambda_{t+1}\nu_{t+1} \left(\pi_{t+1}^w \nu_{t+1} - \pi \right) \pi_{t+1}^w{}^2 \Big] \tag{3.24}$$
$$= \lambda_t \left[\phi \, \nu_t \left(\pi_t^w \nu_t - \pi \right) \pi_t^w + (1 - \tau_t^w)(\theta_L L_t^{p,R} - L_t^R) \right]$$

$$\lambda_t \frac{P_t}{(1 + \tau_t^c)} = \mu_t \left\{ [1 - s_t(.)] - s_t'(.) \frac{\varepsilon_t^i I_t}{I_{t-1}} \nu_t \right\} + \beta E_t \left[\mu_{t+1} s_{t+1}'(.)\varepsilon_{t+1}^i \left(\frac{I_{t+1}}{I_t} \right)^2 \nu_{t+1} \right] \tag{3.25}$$

$$\mu_t = \beta E_t \left\{ \frac{\lambda_{t+1}}{\nu_{t+1}} \left[(1 - \tau_{t+1}^k)R_{t+1}^k u_{t+1} - \psi(u_{t+1})P_{t+1} \right] + \frac{\mu_{t+1}}{\nu_{t+1}}(1 - \delta) \right\} \tag{3.26}$$

$$\psi'(u_t)P_t = R_t^k(1 - \tau_t^k) \tag{3.27}$$

plus constraints (3.9) and (3.10). Defining $mc_t \equiv MC_t/Z_t P_t$ and $\chi_t \equiv \lambda_t/P_t$, firms' price choice f.o.c. is:

$$\kappa(\widetilde{\pi}_t - \pi)\widetilde{\pi}_t = \beta E_t \left[\frac{\chi_{t+1}}{\chi_t}\nu_{t+1}\kappa(\widetilde{\pi}_{t+1} - \pi)\frac{1 + \tau_t^c}{1 + \tau_{t+1}^c}\widetilde{\pi}_{t+1}\frac{y_{t+1}}{y_t} \right] + \theta_c mc_t(1 + \tau_t^c) + 1 - \theta_c \tag{3.28}$$

First order conditions are then log-linearized around the deterministic steady state and the model is solved using linear techniques.[17] We map the solution with a matrix of observables (described in the next section) and estimate the model using Bayesian inference methods, following Schorfheide (2000) and SW.

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[17] In the working paper version of this chapter we reported all the steps to compute the closed form steady state and the log-linearization of the model. The current version differs only in that it assumes a unit root technology process (we did not have steady state growth in the previous version).

3.3.1   Data and prior distributions

We use data on private consumption, investment, real wages, inflation and nominal interest rate. As for public sector variables, we use government purchases of goods and services, transfers to households, public employment, tax rates on labor income, on capital income, on consumption and total tax revenues. In Appendix B we report sources and description of each series, we describe in detail the methodology that we have employed to compute average effective tax rates and to obtain quarterly variables from annual ones. We provide also some comparisons with alternative sources.

Real variables, except for prices and employment levels, display in the model a unit root. The corresponding observables are used in estimation in growth rates.[18] Therefore the vector of observable variables O_t is given by:

$$O_t = \left[\begin{array}{c} \Delta \log C_t, \Delta \log I_t, \Delta \log C_t^g, \Delta \log Tr_t, \\ \Delta \log T_t, \Delta \log W_t/P_t, L_t^g, R_t, \pi_t, \tau_t^w, \tau_t^k, \tau_t^c \end{array} \right]$$

For each non stationary variable X_t we assume an observation equation of the type:

$$\Delta \log X_t = \log x_t - \log x_{t-1} + \log \nu_t$$

where X_t is the real level of the observable while x_t is the corresponding detrended variable in the model. For tax rates, we simply subtract sample means from the variables in logarithm. As for the inflation trend, we fit a linear spline until 1999:Q1 and assume a 2% target for annual inflation thereafter. The trend for the interest rate is assumed to be equal to that of the inflation rate time the steady state growth rate ν and divided by the discount factor β, consistently with the steady state of the model.

We calibrate four parameters: $\beta = 0.9926$ (so that the annual steady state real interest rate is 3%), $\delta = 0.025$ (so to imply a 10% annual depreciation rate of capital), $\alpha = 0.3$ (which makes the steady state labor share in income approximately equal to 70%), $\theta_c = 6.5$ (which implies a steady state price mark-up approximately equal to 18%). We calibrate θ_c as it is difficult to jointly identify it and the adjustment cost parameter on prices κ.

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[18] We tried also to estimate the model by linearly detrending the data for government purchases and transfers (instead of using growth rates), as these variables are exogenous and modeled as autoregressive processes. Results in terms of estimated parameters are substantially unchanged.

Table 3.1 shows the main prior distributions for the remaining parameters. Prior distributions are also reported, together with posteriors, in Figure 3.1. As for the preference parameters, a Gamma distribution is assumed for the coefficient of Frisch elasticity σ_l, with a mean of 3 and a standard deviation equal to 0.5. The fraction of non-Ricardian consumers γ, whose mean is set at 0.5 as in the baseline setting in GLSV, and the habit coefficient h, whose mean is set at 0.7 as in SW, are distributed according to a Beta distribution with standard deviations of 0.1. The labor wage elasticity θ_L is assumed to follow a Gamma distribution centered on a value of 6.5, which yields the steady state wage mark-up equal to the one for prices; a prior variance of 1 is assumed, so that - based on the priors - the markup ranges from 10% to 50% approximately.

A Gamma distribution is chosen for the four friction parameters. Since there is some uncertainty on whether prices or wages are more rigid (for example, SW claim that, despite common belief, a very robust result of their estimated model for the Euro area is the greater stickiness in prices relative to wages), we set the mean of both adjustment cost coefficients on prices and wages, κ and ϕ, at 100. Given mean values for the other parameters, this assumption corresponds approximately to an adjustment frequency for prices of five quarters[19] (approximately the frequency at which the median firm changes its prices in the Euro area according to the evidence presented in Fabiani *et al.,* 2006). The range covered by the prior distributions of both parameters is chosen so as to span approximately from less than one fifth to more than double the mean frequency of adjustment, therefore including very low degrees of nominal rigidity. Investment and capital utilization adjustment coefficients, s'' and ψ''/ψ', have a mean, respectively, of 5 and 0.2 and a standard deviation equal to 0.25 and 0.1, in line with the priors of SW.

All non policy shocks (except for ν_t) are assumed to be characterized by an AR(1) process of the type

$$\log \varepsilon_t = \rho_\varepsilon \log \varepsilon_{t-1} + \eta_t \tag{3.29}$$

with η_t i.i.d. A Beta distribution is chosen for the autoregressive coefficients ρ, with mean and standard deviation set at 0.85 and 0.1, respectively, as in SW. For these shocks, the standard deviations of the innovations are assumed to be distributed as

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[19] The mapping between cost of adjustment parameters and adjustment frequency can be obtained comparing coefficients in the respective expectational Phillips curves.

Table 3.1 - Selected prior and posterior distributions

Parameter		Prior distrib.			Posterior distrib.			
					Baseline		*Unions*	
		type	*mean*	*st.dev.*	*mean*	*st.dev.*	*mean*	*st.dev.*
Preferences and technology								
inv. lab. supply wage elast.	σ_L	Γ	3	0.5	2.00	0.25	1.94	0.23
fraction of non-Ricardians	γ	β	0.5	0.1	0.34	0.03	0.37	0.02
habit parameter	h	β	0.7	0.1	0.73	0.03	0.72	0.02
labor demand wage elast.	θ_L	Γ	6.5	1	6.20	0.73	5.84	0.66
Frictions								
investment adj. cost	s''	Γ	5	0.25	5.30	0.25	5.27	0.25
wage adjustment cost	ϕ	Γ	100	$1000^{\frac{1}{2}}$	109.45	28.08	80.41	20.55
price adjustment cost	κ	Γ	100	$1000^{\frac{1}{2}}$	214.60	21.53	204.86	29.78
capital utilization cost	ψ''/ψ'	Γ	0.2	0.1	0.22	0.03	0.28	0.06
Monetary policy								
interest rate AR coeff.	ρ_R	β	0.8	0.1	0.92	0.01	0.91	0.01
inflation coefficient	ρ_π	Γ	1.7	0.1	1.72	0.10	1.73	0.10
output coefficient	ρ_y	N	0.125	0.05	0.13	0.03	0.08	0.02
inflation change coeff.	$\rho_{\Delta\pi}$	N	0.3	0.1	0.23	0.09	0.25	0.09
output growth coeff.	$\rho_{\Delta y}$	N	0.25^2	0.05	0.07	0.01	0.05	0.01
Fiscal policy								
labor tax rate AR coeff.	ρ_{τ^w}	β	0.8	0.1	0.91	0.01	0.89	0.01
labor tax rate debt coeff.	η_{τ^w}	Γ	0.5	0.1	0.28	0.03	0.27	0.03
cons. tax rate AR coeff.	ρ_{τ^c}	β	0.8	0.1	0.96	0.00	0.95	0.01
cons. tax rate debt coeff.	η_{τ^c}	Γ	0.5	0.1	0.50	0.06	0.47	0.05
capital tax rate AR coeff.	ρ_{τ^k}	β	0.8	0.1	0.97	0.00	0.96	0.01
capital tax rate debt coeff.	η_{τ^k}	Γ	0.5	0.1	0.57	0.06	0.46	0.06
Loglikelihood					-4750.2		-4753.3	

Gamma with a 0.01 mean and 0.02 standard deviation.

Monetary policy parameters are assumed to have the same distribution type, mean and standard deviation as in SW, the only exception being that ρ_π, the coefficient measuring the response of the nominal rate to lagged inflation, is assumed to be Gamma rather than Normal-distributed. Innovations to monetary policy are assumed to be white noise with standard deviation distributed as Gamma with mean 0.01 and standard deviation equal to 0.02.

Tax policies are a priori taken to be quite persistent, with autoregressive coefficients distributed as a Beta with mean 0.8 and standard deviation equal to 0.1. Tax rate elasticities with respect to debt are all assumed to be distributed as a Gamma with mean 0.5 and standard deviation equal to 0.1 (so that they range approximately between 0.2 and 0.8). Innovations in tax rates are assumed to be white noise with standard deviation distributed as Gamma with mean 0.01 and standard deviation equal to 0.02.

As we use data on tax rates and total tax revenues, it is unlikely that the accounting identity (3.16) be satisfied. We therefore added in estimation a measurement error to total revenues, ε_t^t, with standard deviation calibrated at 0.1%. This error should capture all the other sources of revenue not covered by the three taxes considered in the model. Although in the baseline we assume this error to be i.i.d., estimation results are not substantially different if we assume that it is autocorrelated. Moreover, minor differences in results are obtained if we model ε_t^t as a structural shock, instead of as a measurement error.

3.4   Estimation results

Given priors, we estimate the posterior distributions of the parameters using the Metropolis-Hastings algorithm with one million iterations, a number which seems to be sufficient to achieve convergence (as measured by the cumulated means and standard deviations of the parameters). Figure 3.1 plots prior and posterior distributions for a selection of parameters.[20]

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[20] The percentage of accepted draws is 31%. Since we initialize the MH with the estimated mode and Hessian, the latter evaluated at the mode, of the posterior distribution, we have carried out several diagnostic checks on the properties of the mode. In particular, we have checked the gradient at the mode, the conditioning number of the Hessian, the covariance among parameters implicit in
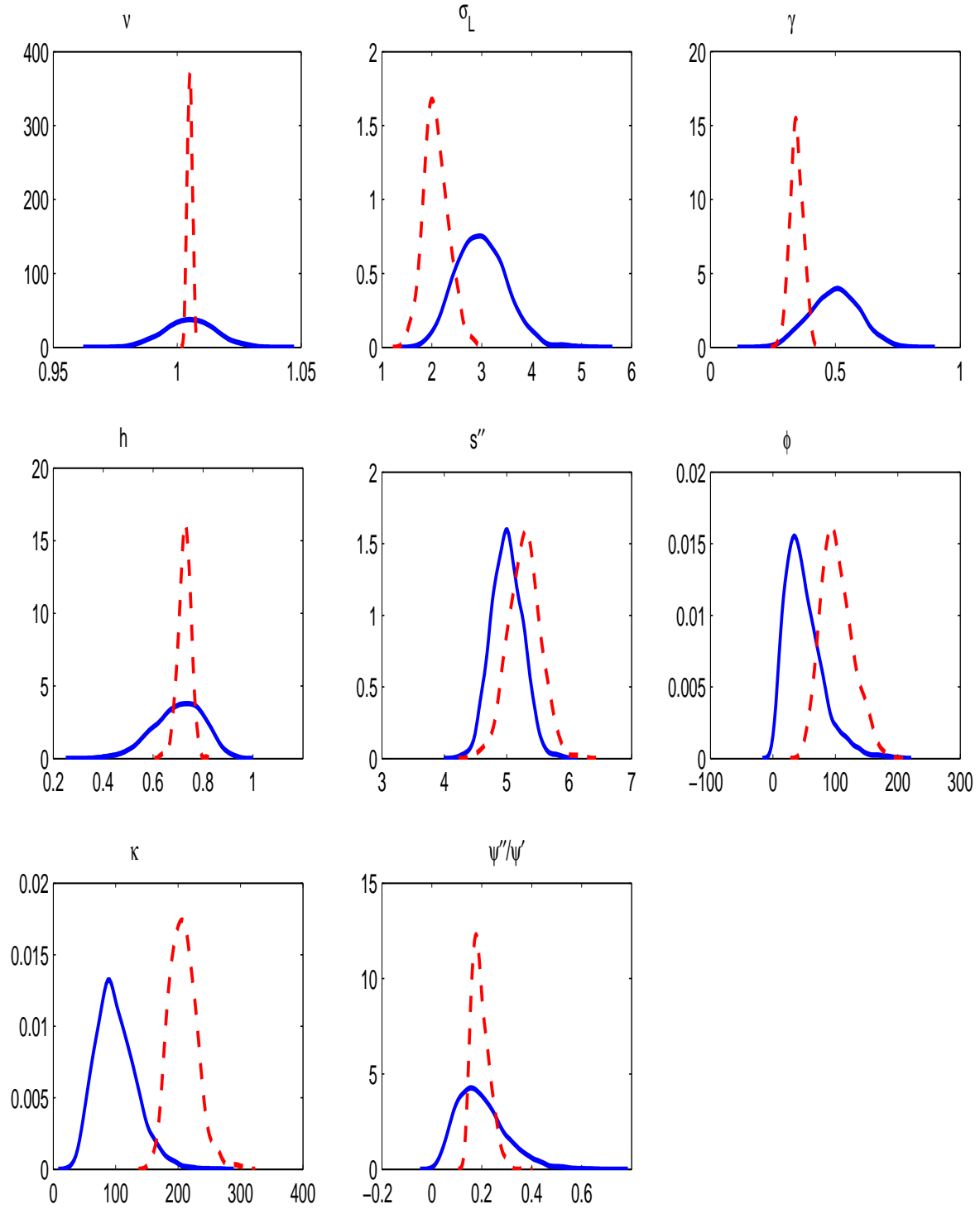
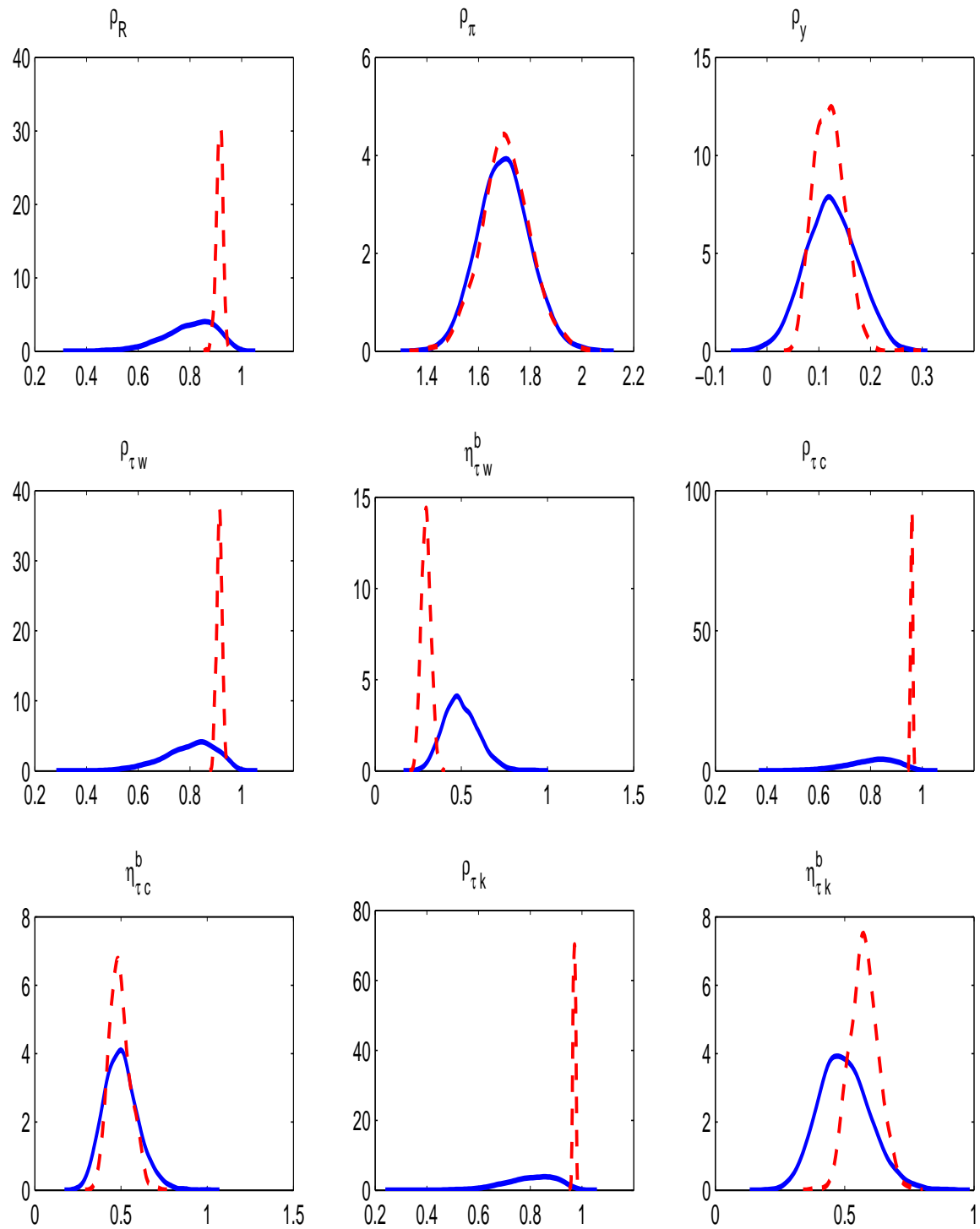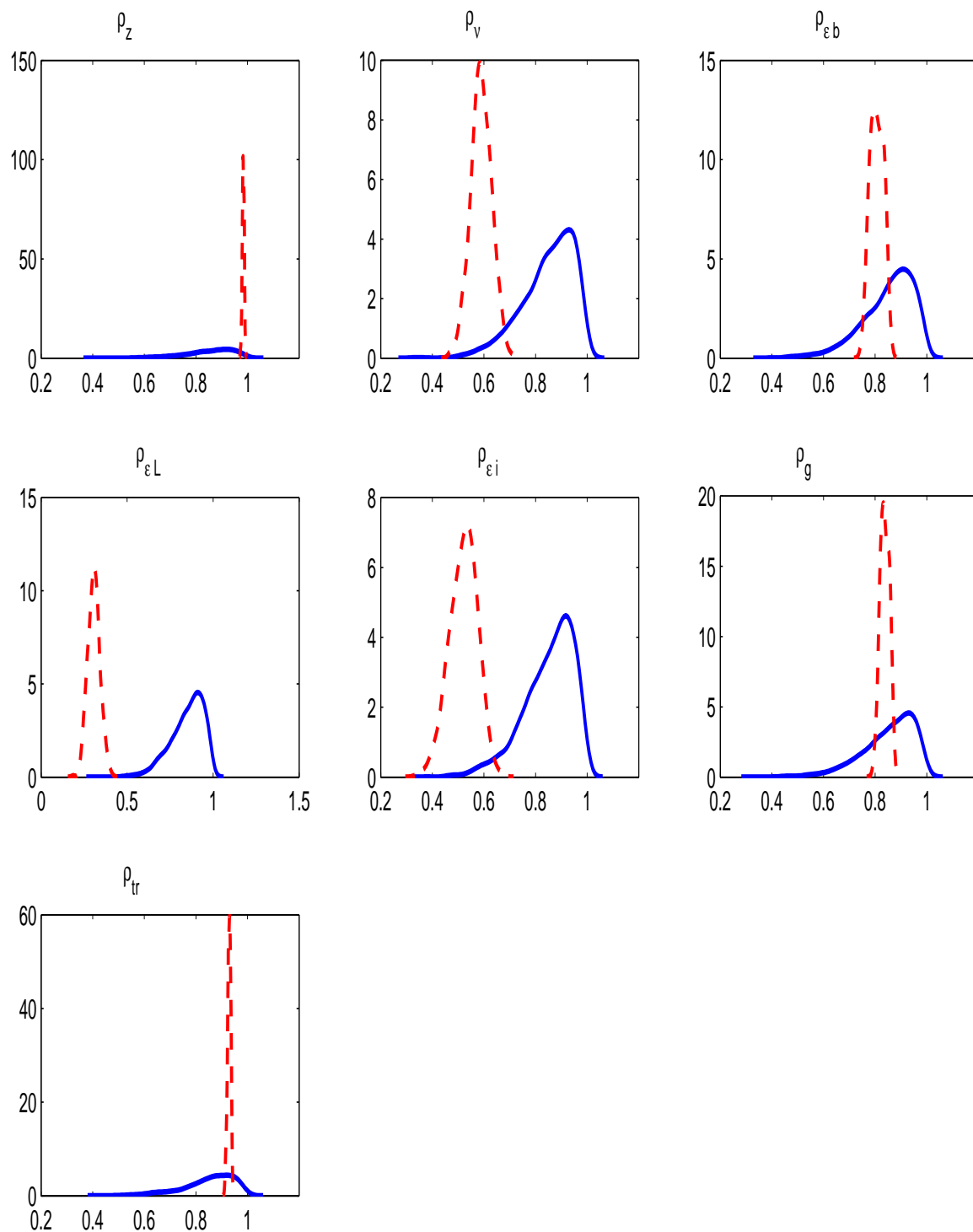**Figure 3.1.a** - Prior (solid/blue) vs. posterior (dashed/red) distributions

Figure 3.1.b - Prior (solid/blue) vs. posterior (dashed/red) distributions

Figure 3.1.c - Prior (solid/blue) vs. posterior (dashed/red) distributions

Overall, most parameters seem to be well-identified, as shown by the fact that either the posterior distribution is not centered on the prior or it is centered but with a smaller dispersion. Some parameters however are not: this is the case for those related to investment adjustment cost, s'', the monetary response to inflation, ρ_π, and to a certain degree the parameters capturing the response of the consumption and capital income tax rates to the debt level. The fact that the labor income tax rate coefficient on debt is well-identified is not surprising. Labor income tax rates include social security contributions that have been increasing in the last twenty years in order to keep social security deficits under control (these deficits have been an important determinant of public debt growth in most European countries).

Right columns of Table 3.1 summarize estimated means and standard deviations for a selection of the parameters for both the baseline specification and the model with unions representing also non-Ricardian agents. The top panel reports estimates for preference and technology parameters. The estimated fraction of non-Ricardian households (mean of the posterior) turns out to be 0.34 (0.37 with unions), which is in line with CS and below the level originally estimated by Campbell-Mankiw (1989) for the US (roughly half of the population).[21]

Among preference parameters, habit, h, and the elasticity of labor supply with respect to real wage, $1/\sigma_l$, are estimated to be higher with respect to both SW and CS. Also the wage elasticity of labor demand, θ_L, is estimated to be higher than the calibrated value of SW and CS, implying a lower steady state wage markup, at about 20%.

With respect to both SW and CS, the estimate for price stickiness confirms the result that it exceeds that of wages by a factor of two. Based on a Rotemberg-Calvo equivalence, price duration equals almost 7 quarters, i.e. lower than in the two above papers, though comparable with the estimate in Galí, Gertler and López-

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the estimated Hessian. We also plotted slices of the likelihood around the mode. The Hessian is in general well conditioned and does not imply any correlation among parameters higher that 0.8, and the likelihood at the mode shows a significant curvature for almost all parameters. This latter result, in particular, is evidence of the fact that the data contain useful information to identify the parameters.

[21] non-Ricardian agents can be thought of as a proxy for liquidity constrained households, whose share might have been decreasing in recent years along with the development of financial markets. We did not, however, attempt to estimate our DSGE with time varying parameters, as techniques "are still at an infant stage when it comes to structurally estimating time variations in the parameters of stochastic general equilibrium models" (Canova, 2008, pg. 4).

Salído (2001).

Estimated policy coefficients feature, on the monetary side, a lower smoothing and a higher weight on inflation (particularly on inflation change) with respect to both SW and CS. On the fiscal side, tax rate processes appear to be highly persistent, although the reaction to debt level is quite sizeable and large enough to be stabilizing. The autoregressive parameter for government purchases, public employment and transfers to households are estimated at respectively 0.86, 0.92 and 0.97 (levels similar to the one estimated for government consumption G by both SW and CS), pointing to a high persistence of fiscal policy innovations.

As for the capacity of the model to fit the data, in Figure 3.2 we report the cross-covariance functions of the model variables against the data. We consider four lags and four leads. We plot the 90% confidence bands of the cross-covariance functions obtained on 10,000 random samples generated by the DSGE model. The samples are obtained by randomly drawing 100 times from the parameter posterior distribution and running the model 100 times for each parameter draw. For comparability with our data set (which is 100 period long), for each draw we run the model for 200 periods and use the first 100 as burning sample. Almost all data covariances, and in particular all those involving fiscal policy variables, fall within the confidence intervals suggesting that the model is able to mimic the cross-covariance in the data within a one year horizon.

Figure 3.2 - Cross-correlations at +/- 4 periods: data (solid/red) vs. model (dashed/blue 90% confidence bands)
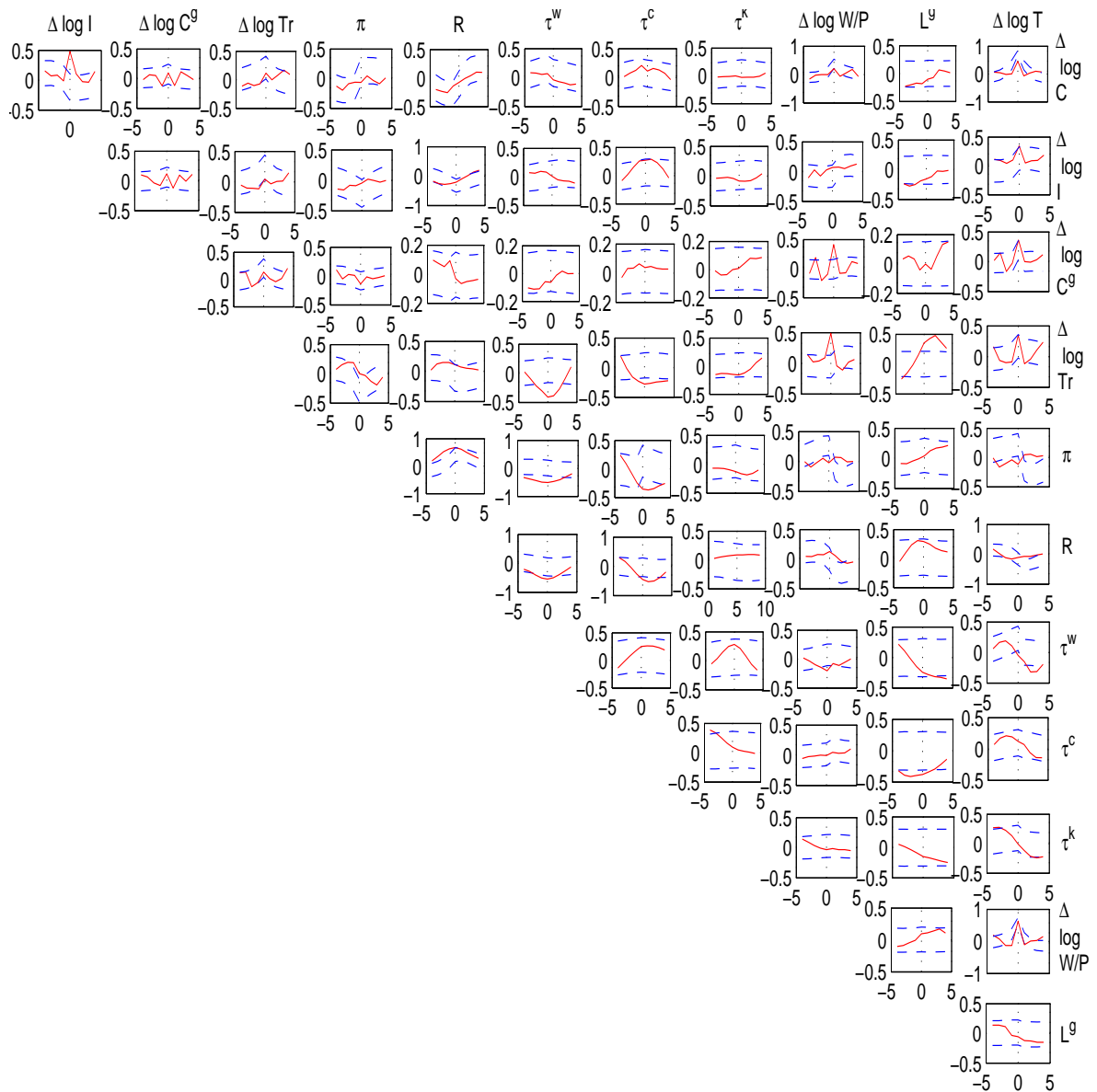
3.5   General equilibrium effects of fiscal policy

3.5.1   Government spending shocks

We now discuss the implications of our estimates for the effects of government spending shocks on the economy. Figure 3.3 shows impulse responses with respect to a shock to real detrended government purchases of goods and services, Figure 3.4 with respect to a shock to government employment, while Figure 3.5 with respect to real detrended transfers. The solid line shows median values, while the dotted ones the 5th and 95th percentile based on posterior distributions. The magnitude of the shocks is set in order to have an increase in expenditures equal to one percent of steady state private output (i.e. excluding the government wage bill).[22] Impulse responses are for each variable the deviation from steady state values expressed in percentage points. The deviations of the real interest rate and inflation (gross of consumption taxes) are reported in annualized percentage points. For the different components of revenues (from labor income, capital income and consumption taxes), total revenues and debt we report their change as a percentage of output. The bottom right panel of each figure shows the path of the shock.

We can immediately observe that on impact all three shocks increase employment and aggregate private consumption. The shock to purchases does that by increasing the demand for goods and services which, in turn, brings about an increase in employment and labor income. This sustains consumption of non-Ricardians, to an extent sufficient (also in view of their share) to compensate for the decrease in Ricardian consumption due to the negative wealth effect of debt-financed spending. Adjustments occur mainly in quantities: real wages, marginal costs, inflation and the nominal interest rate all increase mildly. The rise in employment makes the use of capital more profitable and leads to a more intensive use of capacity, while investment drops due to the increase in the rental rate of capital.[23]

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[22] In particular, the shock to L_g is calibrated in order to have an increase in the public wage bill, using the steady state level of wages, equal to 1% of steady state output.

[23] Despite a similar estimate of the mean share of non-Ricardians in their specification with (fixed) distortionary taxes, CS obtain a slightly negative response of private consumption to a government consumption (G) shock. Most of the differences between our and CS results relate to the fiscal variables used in estimation and to the specification of the fiscal rules. First, as shown also by López-Salído and Rabanal (2008) for the US, the use of data on public transfers - that translate one to one into consumption of non-Ricardians, while don't have any effect on Ricardians - is very
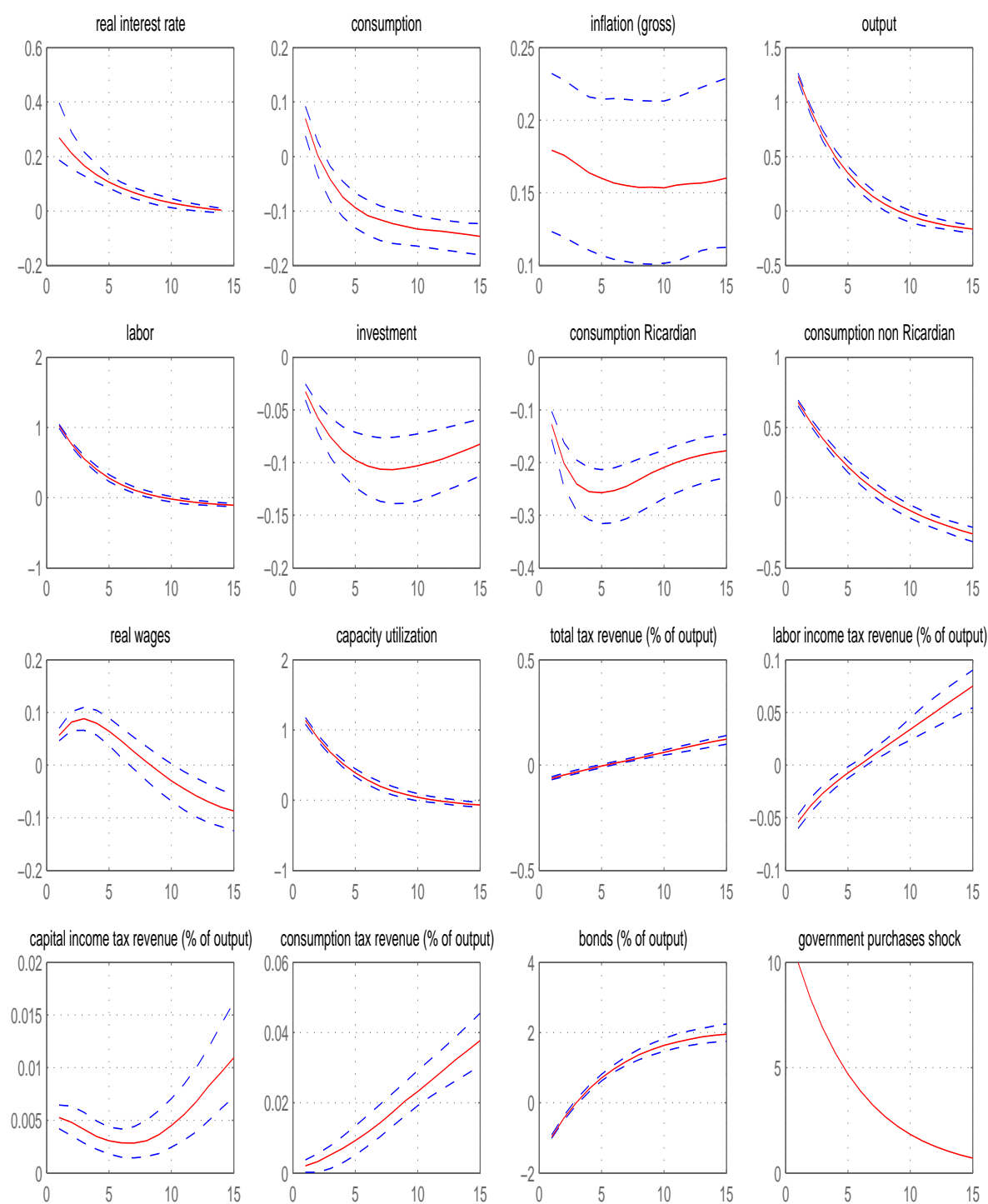
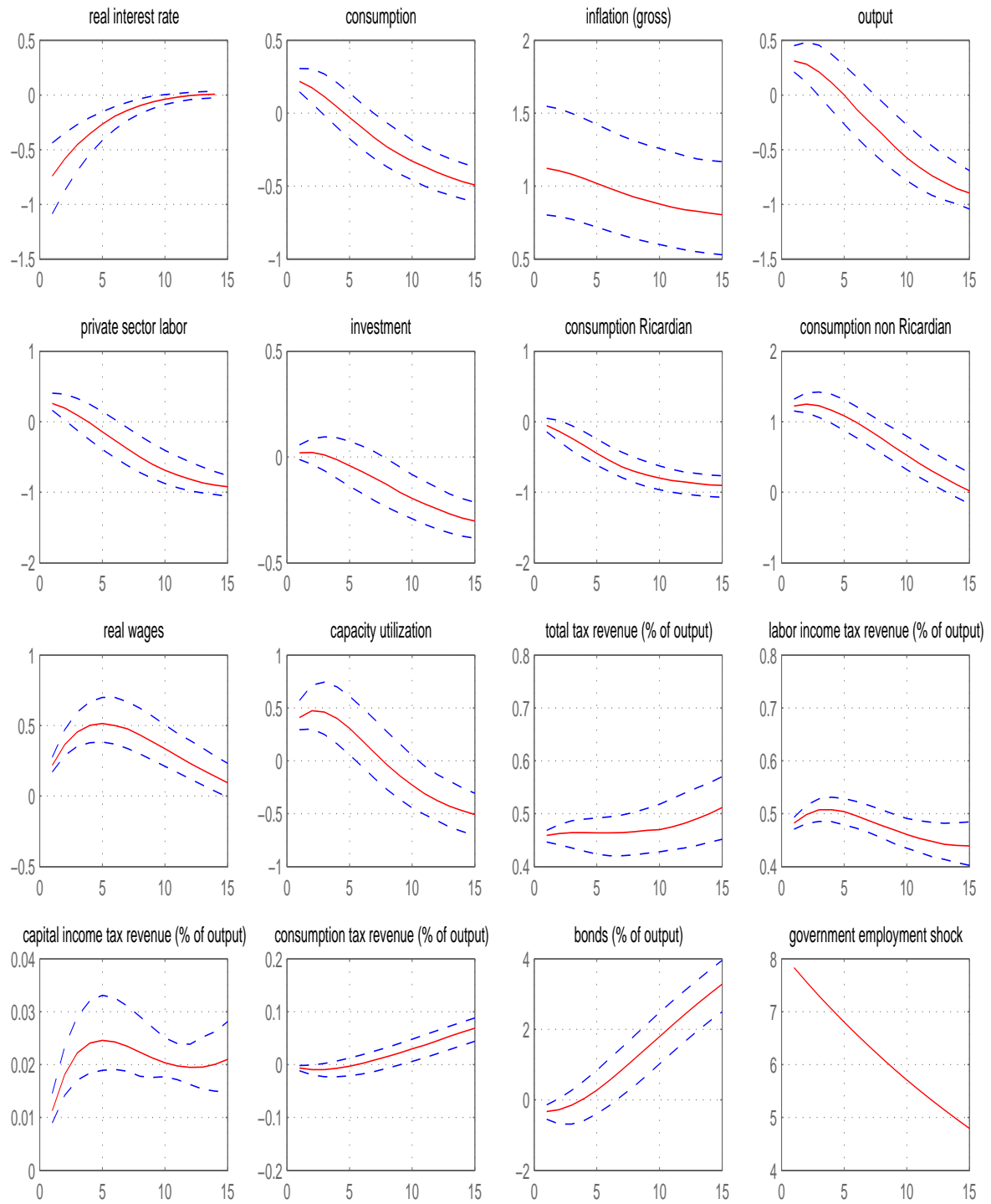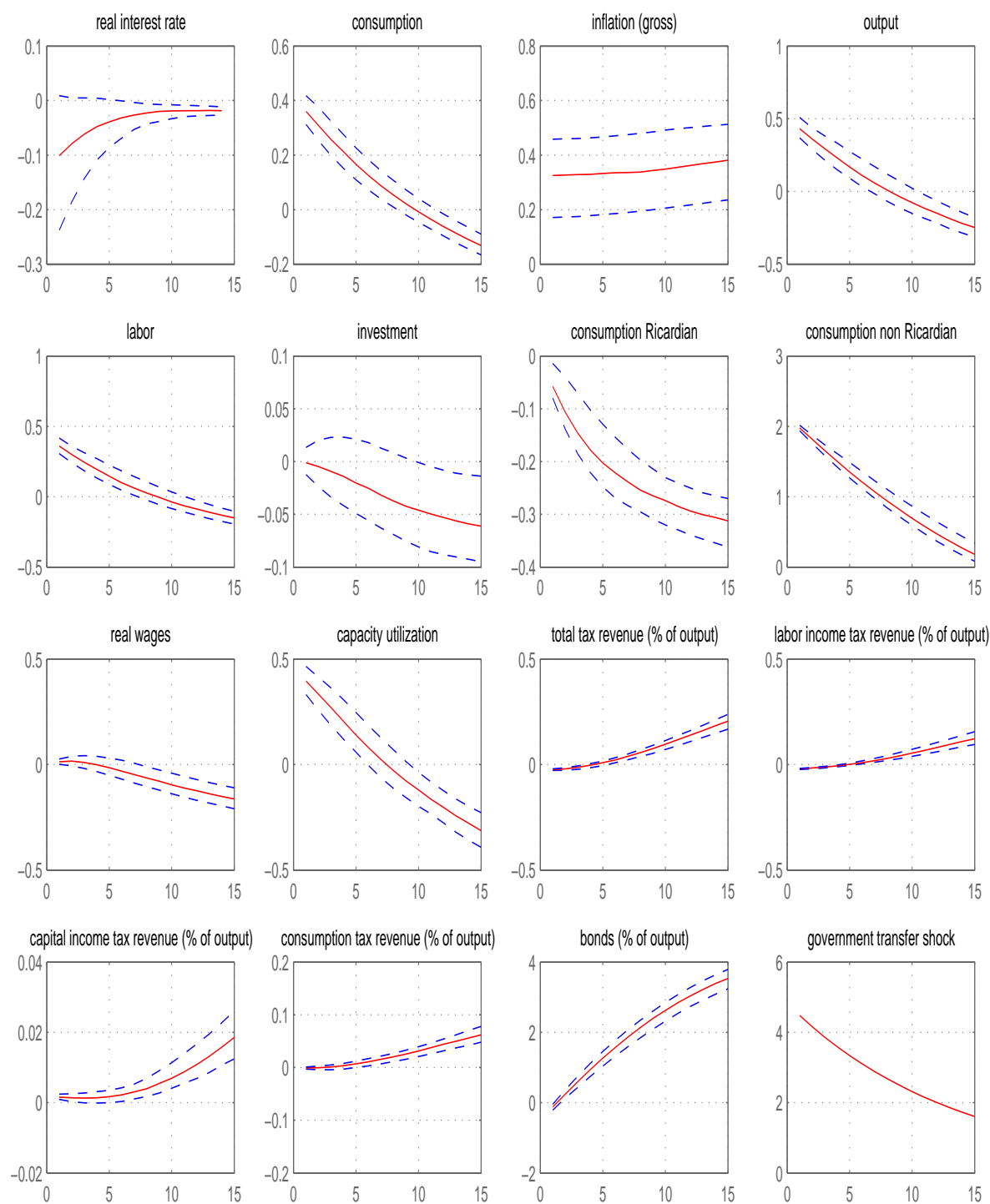**Figure 3.3** - Responses after a government purchases shock

Figure 3.4 - Responses after a government employment shock

Figure 3.5 - Responses after a transfers shock

The shock to government employment increases total labor demand and determines an increase in both total employment and labor income. However, the increase in government employment reduces the supply of labor available for private production (for any given wage) despite the increase induced by the negative wealth effect of debt-financed government hiring. Private sector labor demand expands following the higher demand for goods by non-Ricardians, which firms mostly accommodate by decreasing unitary markups on their prices. Overall, real wages and private employment increase (the latter only on impact). Labor income is higher for all households, but Ricardian consumption is depressed by the negative wealth effect. With respect to a c_t^g shock, the l_t^g shock has a slightly greater positive impact on private aggregate consumption, as non-Ricardian consumption hikes (after the boost in labor income), but lower on private output, as the hiring from the government tends to crowd out employment in the private sector.

Finally, the shock to transfers to households has the biggest and more persistent impact on consumption as it translates one to one into an increase in disposable income of non-Ricardians. Demand-driven output and employment also increase, while real wages are initially unchanged.

These estimated responses are consistent with a new-Keynesian framework but not with an RBC-style model. Inconsistencies with the latter lie not only in the non-negative response of private consumption following a government expenditure shock, but also in the (mild) increase of real wages after a shock to c_t^g, as the wealth effect brings about an increase in labor supply that in turn should imply, in a RBC model, a decrease in the marginal productivity of labor and thus in real wages too. The increase in real wages that we find is therefore possible only if there is an outward shift in labor demand. Moreover, after a government employment shock, private employment increases on impact, although mildly, reflecting the Keynesian effect

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important to identify two key parameters for the response of aggregate consumption, i.e. the share of non-Ricardian agents and the habit coefficient. CS, that do not use fiscal data other than G, estimate an extremely low consumption habit of Ricardians (0.41; SW have 0.6), which brings about a significant fall in Ricardian consumption after the expenditure shock. Second, in order to properly identify the coefficient of the fiscal rules it is very important to use data on revenues. CS estimate an elasticity of total (lump sum) taxes to the real debt level equal to 1.5%, a very high number compared to our estimate of about 0.5%. Therefore, in their work total taxes increase more sharply than in our case after a deficit financed government expenditure shock, reducing on impact the disposable income of non-Ricardian households.

on labor demand via an increase in consumption and output. In fact, in an RBC-style model, for reasonable calibrations of the parameters, the increase in labor supply due to the standard wealth effect cannot compensate for the increased labor demand from the government, so that private sector employment would decrease on impact. The increase in private sector employment that we find is therefore due to the contemporaneous shift in labor demand. This Keynesian effect, however, does not last long and after roughly four quarters employment in the private sector starts reducing.

3.5.2 Shocks to tax rates

Next we look at the effects of tax rates innovations. Figures 3.6-3.8 plot the impulse responses of a shock to, respectively, the tax rate on labor income, capital income and consumption, all calibrated in order to achieve a decrease in revenues equal to 1% of steady state private output (that is excluding wL^g).

The reduction in labor income tax rate (approximately 1.6 percentage points) leads, on the one hand, to an outward shift of labor supply and, on the other hand, to an increase in non-Ricardian disposable income and consumption. Aggregate demand increases, and therefore output and employment also do, further reinforcing the increase in disposable income. Real wages and inflation fall. It is interesting to note that the effect of the tax cut does in fact produce on impact a revenue loss close to 1% of output: the additional revenues from the increased labor income tax base are matched by the increase in output.

The decrease in capital income tax rate (slightly less than 3 percentage points) leads on impact to a reallocation from labor to capital, whose utilization spikes up. Ricardian intertemporal choice starts favoring investment rather than consumption. The decrease in employment reduces non-Ricardian labor income. Therefore, aggregate consumption falls, and inflation do as well. Over time, however, physical capital builds up, leading employment back towards its steady state value. In the case of changes in capital income taxes, therefore, the presence of non-Ricardian consumers has a stabilizing effect on output. In fact, the expansionary effect (via an increase in capacity utilization and investment) of a reduction in τ_t^k is partially compensated by a reduction in employment and disposable income of non-Ricardians. The actual revenue loss on impact after the tax cut is higher than 1%, as the reduction in the
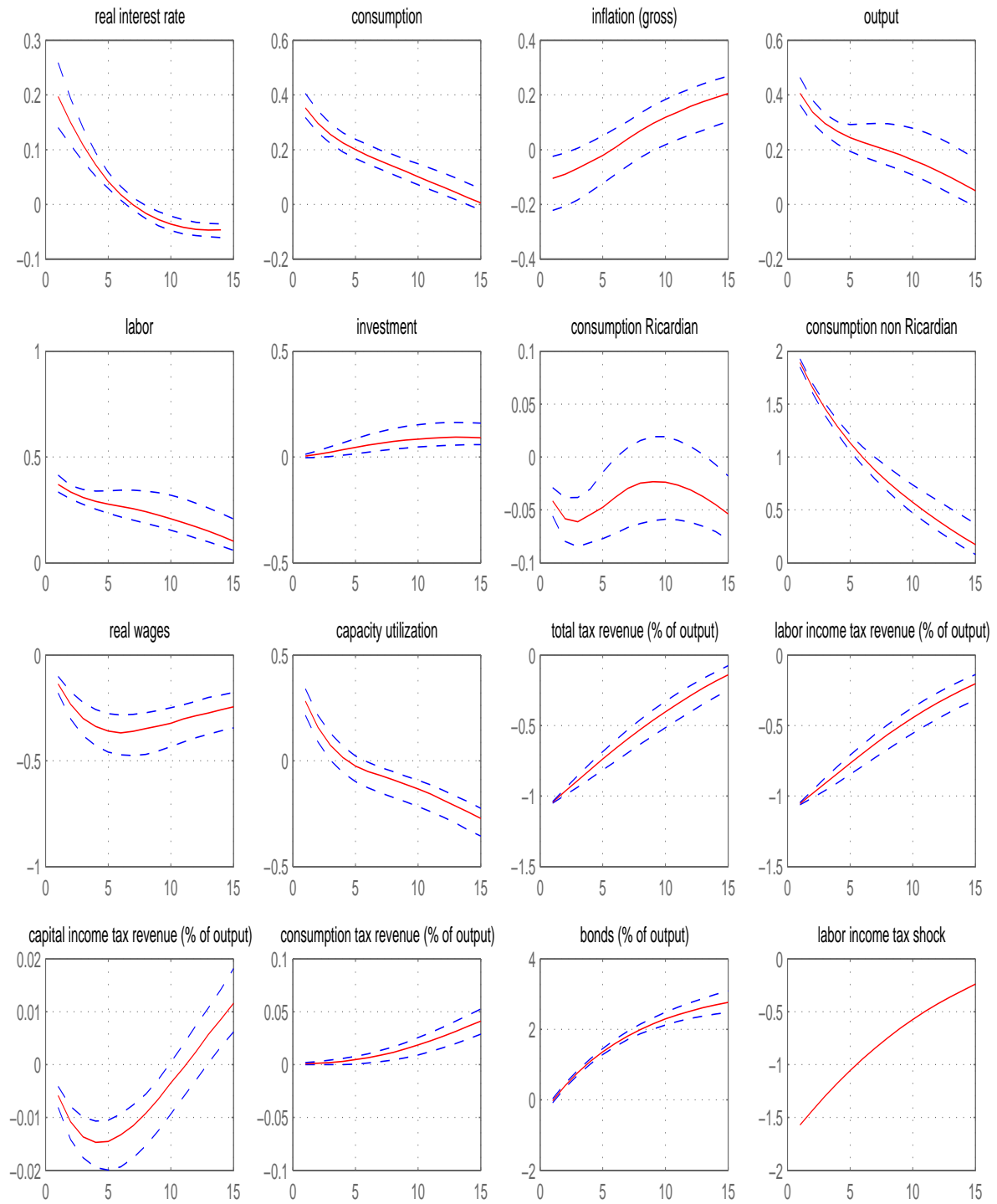
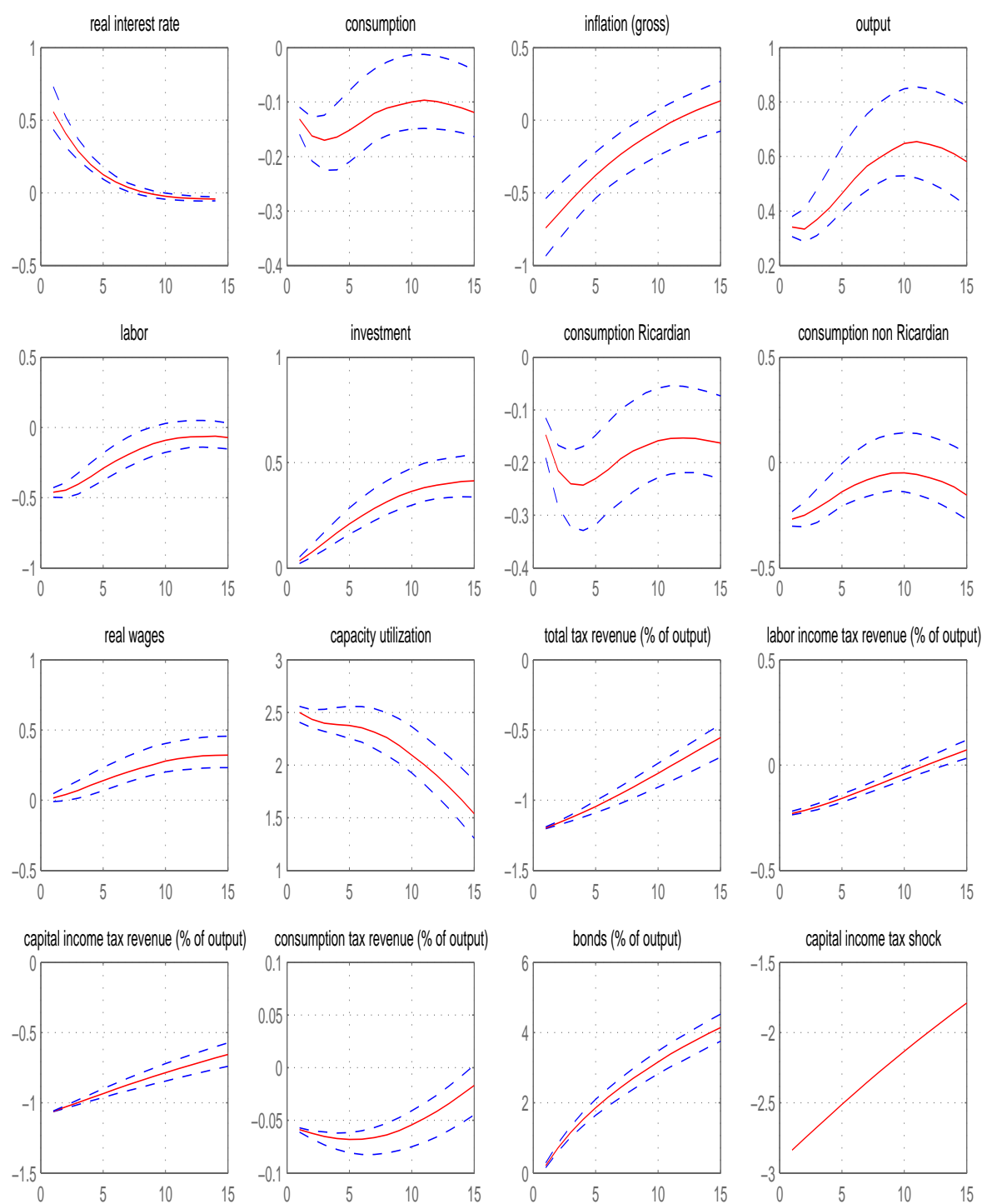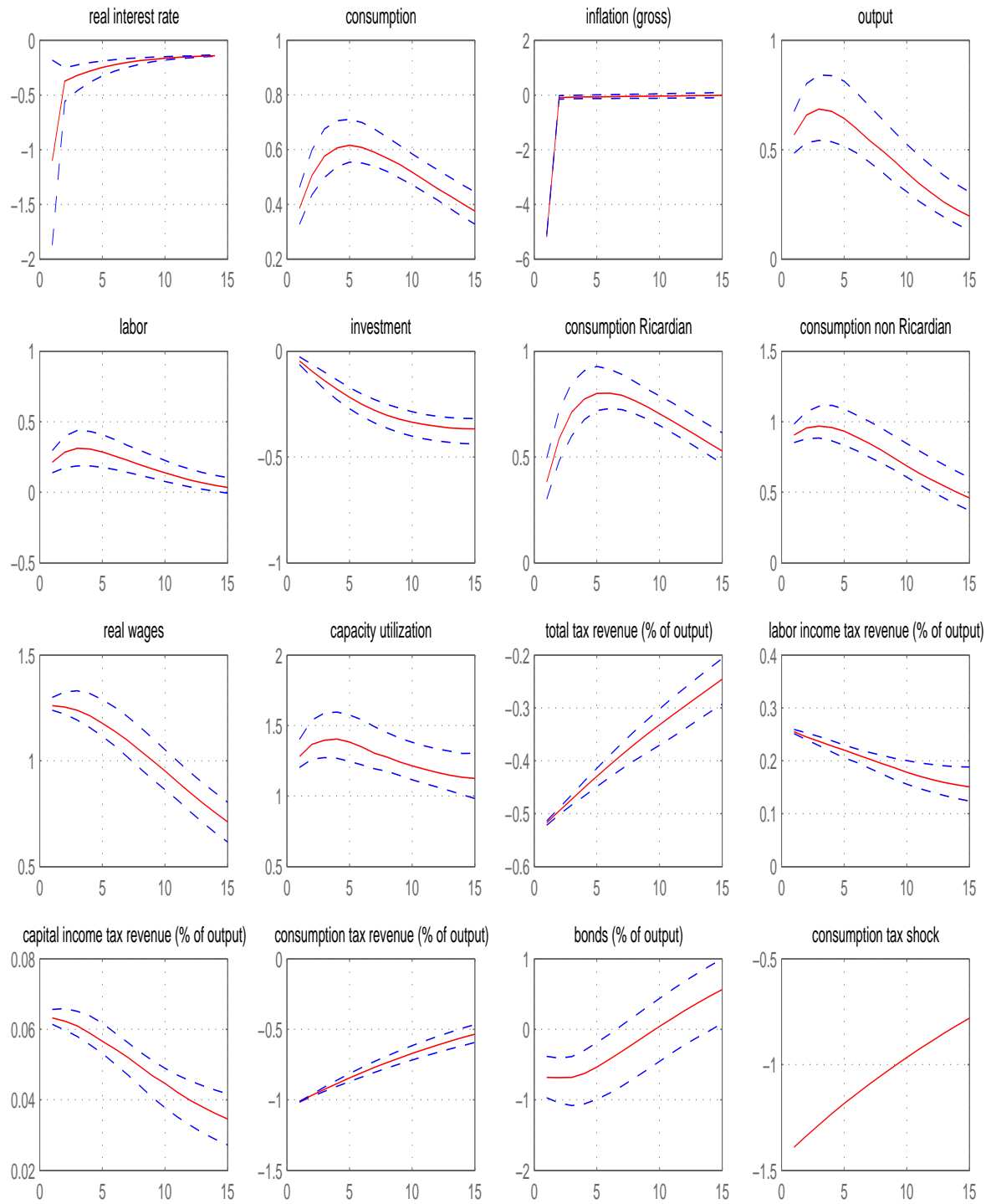**Figure 3.6** - Responses after a labor income tax shock

Figure 3.7 - Responses after a capital income tax shock

Figure 3.8 - Responses after a consumption tax shock

labor income tax base adds on to the reduction in capital income tax rate.

The main effect of a decrease in consumption tax rate (around 1.4 percentage points) is a one time decrease in inflation (around 5% on annual terms) that induces a decrease in the policy and, hence, in the real interest rate. Consumption of the cheaper goods basket substantially increases, more and faster for non-Ricardians than for Ricardians. Firms increase output to meet the additional demand and they do so by increasing employment and capital utilization (investment has not become cheaper as it is not subject to consumption taxes). The smoother increase in Ricardian consumption gradually shifts resources away from investment. The actual tax revenue loss is significantly smaller than 1%: the cut in consumption taxes induces a substantial increase in labor income tax base and revenues.

Overall, the short run expansionary effect of cutting consumption taxes is greatest, while at the same time inducing a revenue loss equal to half of that measured on steady state values. Also cuts to labor income taxes have substantial positive effects on consumption and output. Capital income tax cuts, on the other hand, incur in significant revenue losses as they induce a reduction in labor income; however, as expected, the effect on output at medium term horizons is greatest.[24]

3.5.3 Fiscal multipliers

To summarize the quantitative effects of our six fiscal shocks we report in Table 3.2 the fiscal multipliers on private output, consumption, investment and inflation implied by our estimates. We report the average effects in the first 1, 4, 8 and 12 quarters respectively, expressed in percentage points (annualized in the case of inflation).

Fiscal multipliers on consumption and output are quite sizeable, although generally smaller than one. The average effect on output in the first year is, as expected, greatest for a shock to purchases of good and services (these being part of aggregate

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[24] Our estimated model can be used to perform *dynamic scoring*; see on this, among others, Mankiw and Weinzierl (2006). Although we did not analyze the issue in this chapter, the evidence reported can nonetheless provide some useful information. For example, we have discussed the revenue losses of different tax cuts. Since the model is log-linear, these losses can be easily rescaled. Therefore, a cut of 1 percentage point of: i) the labor income tax rate, would lead to a revenue loss on impact of about 0.6% of GDP; ii) the capital income tax rate, of about 0.4%; iii) the consumption tax rate, of about 0.35%.

demand): the other shocks all have multipliers between 0.3 and 0.6. The effect on private consumption is higher for innovations to consumption taxes, labor taxes and transfers.

The impact effect on consumption and output of a reduction in labor income or consumption tax rates is similar to an increase in transfers or in public employment. The effect, in all cases, works through an increase in household (in particular non-Ricardian) real labor income, which drives the increase in consumption and output. However, the innovation in public employment tends to crowd out private employment and therefore output and consumption: after 12 quarters the average effect on output and consumption becomes negative.

The effects on prices (expressed in annualized terms) are generally mild, the notable exception being innovations in consumption taxes (as they translate one to one to prices). Also increases in public employment tend to have a significant effect on nominal wages and therefore on inflation.

These results are broadly in line with available empirical evidence, coming from both VAR analyses and large-scale macroeconomic models, i.e. models which are either not microfounded at all or not in the same way as DSGEs. Analyses with VAR, though, have usually focused on a smaller set of variables than our work.

Our result of small and short-lived expansionary effects on private consumption and output following an expenditure shock is in line with the responses obtained by Mountford and Uhlig (2005) for the US and Perotti (2005) for West Germany (the only Euro area country that he considered).[25] We also share with most of the VAR literature the reduction of private investment in response to public consumption shock.[26]

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[25] Both Perotti (2005) and Mountford and Uhlig (2005) consider innovations to two variables: government spending (including purchases of good and services, the public wage bill and government investment) and net taxes (i.e., taxes net of transfers to households). These definitions are different from ours and therefore any quantitative comparison with our work should take these differences into account.

[26] We could make a direct comparison with our estimates by running a VAR on our data. However, there are a number of difficulties in comparing DSGE and VAR. First, there is a variety of identification strategies in VARs and it is not clear which one should we compare the DSGE results with. Second and relatedly, it is very difficult to impose to the VAR the same restrictions that come from a DSGE model: there are issues of invertibility of the DSGE to obtain a VAR representation (on this see Fernandez-Villaverde, Rubio-Ramirez, Sargent and Watson, 2007), as well as problems related to the bias coming from the approximation of the VAR when working with small sample data (as discussed in Chari, Kehoe and McGrattan, 2005, Christiano, Eichenbaum and Vigfusson,

Table 3.2 - Fiscal multipliers

		Quarters	$\frac{\Delta y}{y}$	$\frac{\Delta c}{c}$	$\frac{\Delta I}{I}$	$\Delta\pi$
Increase in	c^g	1	1.21	0.05	-0.04	0.21
		4	0.85	-0.03	-0.07	0.20
		8	0.54	-0.09	-0.10	0.20
		12	0.35	-0.11	-0.11	0.19
	L^g	1	0.33	0.22	0.03	1.14
		4	0.27	0.15	0.02	1.11
		8	0.07	0.01	-0.02	1.04
		12	-0.14	-0.11	-0.07	0.99
	tr	1	0.42	0.35	0.00	0.30
		4	0.31	0.27	0.00	0.30
		8	0.21	0.19	-0.01	0.30
		12	0.12	0.12	-0.02	0.30
Reduction of	τ^w	1	0.39	0.34	0.00	-0.11
		4	0.31	0.28	0.02	-0.08
		8	0.26	0.22	0.04	-0.03
		12	0.23	0.18	0.06	0.02
	τ^k	1	0.33	-0.14	0.04	-0.72
		4	0.35	-0.17	0.11	-0.58
		8	0.45	-0.16	0.20	-0.41
		12	0.52	-0.14	0.26	-0.29
	τ^c	1	0.53	0.36	-0.05	-5.01
		4	0.60	0.49	-0.11	-1.33
		8	0.58	0.53	-0.19	-0.68
		12	0.51	0.52	-0.24	-0.46

Note: Fiscal multipliers are computed as averages of the percent responses over the specified number of quarters. Expenditure innovations are set equal to 1% of steady state output. Tax rates innovations are such that the reduction of revenues is equal to 1% of steady state output. The change in inflation is expressed in annualized percentage points.

2006 and Ravenna, 2007). Third, given the number of series (12) that we use in estimation and the relatively short sample period, the large number of parameters to estimate in a VAR would reduce heavily the degrees of freedom and the precision of the estimates.

As for simulation exercises run with large-scale models, they usually assume as exogenous the path of certain variables, as the interest rates or the fiscal variables themselves. This obviously complicates the comparison. Henry *et al.* (2004), for example, compare output and inflation responses from a selection of large-scale macro models of Euro area countries institutions with respect to four fiscal shocks: purchases of good and services, personal income tax, indirect taxes and social security contributions. The first year effect on output of a 1% of GDP increase in purchases of goods and services ranges between 1.18 for the Deutsche Bundesbank model to 0.87 for the model of the National Bank of Belgium. The average of the models considered is 0.97, slightly higher than our number (0.85). However, the results for the second year after the shock - on the average of the countries considered - is 1.19, higher than what we find. As for the other shocks considered, we can make reasonable comparisons only with the one to indirect tax rates.[27] Henry *et al.* (2004) report an average effect in the first year of 0.35 on GDP, not far from our estimates (0.60).

Finally, we briefly comment on the contribution of each of the structural fiscal shock to the variance of the endogenous variables (see Table 3.3). Focusing on the long term horizon, we see that innovations to government variables have almost no explanatory power for the variance of any of the macro variables considered (except for the fiscal variables themselves). As for the tax rates, the prominent role of technology shocks should not come as a surprise: the fiscal rules relate the tax rates to the level of debt as a share of GDP; the latter is heavily affected by technology shocks.

3.5.4   Some robustness with respect to the share of non-Ricardian agents

In Figure 3.9 we plot the average first year response of output, consumption and investment to each of our six fiscal shocks, allowing the parameter γ to move between

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[27] As a matter of fact, personal income taxes include taxes on both labor and capital income, while we consider them separately. Social security contributions are, in our framework, included in τ^w as we assume that in the bargaining process firms care for the total cost of labor (w, that includes all social security contributions) while workers do for the take-home pay ($w(1-\tau^w)$, that is net of all social security contributions and personal income taxes on labor).

Table 3.3 - Variance decomposition

after 1 period

	ε^z	ε^ν	ε^b	ε^L	ε^m	ε^{cg}	ε^{tr}	$\varepsilon^{\tau w}$	$\varepsilon^{\tau c}$	$\varepsilon^{\tau k}$	ε^i	ε^{lg}	ε^t	Tot
$\Delta \log C$	0.5	6.5	82.4	2.4	6.7	0.0	0.1	1.1	0.2	0.0	0.0	0.0	0.0	100
$\Delta \log I$	0.1	10.9	9.1	0.5	4.7	0.0	0.0	0.0	0.0	0.0	74.7	0.0	0.0	100
π	34.6	17.3	7.8	21.4	1.8	0.1	0.0	0.0	16.3	0.3	0.0	0.2	0.0	100
R	6.4	4.0	13.6	6.4	65.0	0.9	0.0	0.1	1.2	0.0	2.4	0.0	0.0	100
τ^w	0.0	0.0	0.1	0.0	0.0	0.0	0.0	99.9	0.0	0.0	0.0	0.0	0.0	100
τ^c	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.9	0.0	0.0	0.0	0.0	100
τ^k	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	0.0	0.0	0.0	100
$\Delta \log \frac{W}{P}$	0.0	0.9	4.1	93.2	0.8	0.0	0.0	0.1	0.9	0.0	0.0	0.0	0.0	100
$\Delta \log T$	3.8	3.6	31.3	21.2	5.6	2.3	0.0	10.0	0.2	2.1	3.4	0.3	16.3	100

after 4 periods

	ε^z	ε^ν	ε^b	ε^L	ε^m	ε^{cg}	ε^{tr}	$\varepsilon^{\tau w}$	$\varepsilon^{\tau c}$	$\varepsilon^{\tau k}$	ε^i	ε^{lg}	ε^t	Tot
$\Delta \log C$	1.2	9.4	79.3	2.7	6.1	0.0	0.1	1.0	0.2	0.0	0.0	0.0	0.0	100
$\Delta \log I$	0.7	11.0	11.7	0.9	4.5	0.0	0.0	0.0	0.0	0.1	71.1	0.0	0.0	100
π	51.1	16.9	7.1	14.4	1.4	0.2	0.1	0.0	8.1	0.2	0.0	0.5	0.0	100
R	22.3	7.6	33.0	6.5	25.7	0.6	0.1	0.1	0.4	0.0	3.5	0.2	0.0	100
τ^w	0.3	1.6	4.7	0.1	5.8	0.0	0.0	86.8	0.0	0.0	0.6	0.0	0.0	100
τ^c	0.1	0.7	2.3	0.1	2.7	0.0	0.0	0.0	93.7	0.0	0.3	0.0	0.0	100
τ^k	0.0	0.2	0.6	0.0	0.7	0.0	0.0	0.0	0.0	98.4	0.1	0.0	0.0	100
$\Delta \log \frac{W}{P}$	0.3	6.1	4.0	87.9	0.8	0.0	0.0	0.1	0.8	0.0	0.0	0.0	0.0	100
$\Delta \log T$	4.3	6.1	32.4	21.1	5.3	2.0	0.0	8.9	0.1	1.9	3.3	0.2	14.2	100

asymptotic

	ε^z	ε^ν	ε^b	ε^L	ε^m	ε^{cg}	ε^{tr}	$\varepsilon^{\tau w}$	$\varepsilon^{\tau c}$	$\varepsilon^{\tau k}$	ε^i	ε^{lg}	ε^t	Tot
$\Delta \log C$	1.5	12.9	75.8	2.4	6.2	0.0	0.1	0.7	0.2	0.0	0.1	0.0	0.0	100
$\Delta \log I$	1.1	12.5	19.6	1.6	5.9	0.1	0.0	0.0	0.1	0.1	59.2	0.0	0.0	100
π	70.6	9.3	3.5	6.0	5.6	0.5	0.2	0.9	1.8	0.7	0.0	0.9	0.0	100
R	60.1	4.7	13.5	3.0	14.0	0.6	0.2	0.8	0.2	0.6	1.4	0.8	0.0	100
τ^w	33.3	13.9	2.6	1.3	27.4	1.5	0.7	13.3	0.4	4.0	0.3	1.3	0.0	100
τ^c	36.2	12.2	1.8	1.1	24.9	1.4	0.7	4.0	12.2	4.1	0.1	1.4	0.0	100
τ^k	32.3	9.6	1.3	0.9	20.1	1.1	0.5	3.2	0.3	29.3	0.1	1.2	0.0	100
$\Delta \log \frac{W}{P}$	0.7	9.0	6.2	81.9	1.4	0.0	0.0	0.1	0.7	0.0	0.1	0.0	0.0	100
$\Delta \log T$	4.6	8.4	34.5	19.1	7.3	1.8	0.0	7.6	0.1	1.6	3.1	0.2	11.6	100

0 and 1, while leaving the other parameters set at their estimated values.[28] We focus on the share of non-Ricardians as this parameter has attracted considerable attention and it is key in determining whether the response to fiscal shocks of certain variables is positive or negative.[29]

Focusing on the response of private consumption to expenditures shocks, it is interesting to note that it crosses the zero line for values of γ around 0.4 in case of innovations to purchases (note that we are here considering the average first year response, which for private consumption is lower than the impact response), while around 0.25 for innovations to public employment; it is always positive for innovation to transfers. Previous work has focused on the response of private consumption to shocks to government consumption G, which - based on national accounts - satisfies the identity $G = WL^g + C^g$. On average, in our sample period, the public sector wage bill has been roughly 60% of G. Therefore our results suggest a threshold value of γ for a G shock at about 0.3-0.35. Another interesting result is that the response of investment does not vary significantly as γ changes (and it remains close to zero).

On the revenue side, the share of non-Ricardians has a small impact in the case of capital income and consumption tax cuts. For labor income tax shocks, the shape of the first year average responses is very similar to the one following a transfer shock and, although at a different level, that following a government employment shock. In all those cases the effects are mainly played by higher current disposable labor income and are therefore magnified by a higher γ. Output and private consumption tend to grow with the increase in the share of non-Ricardians following cuts to labor income and consumption tax, although in a much steeper way for labor income tax cuts.

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[28] Note that, consistently with note 17 and differently from GLSV, the equilibrium is determined over the whole range of γ.

[29] In the working paper version we presented an analysis with respect to a wider set of parameters. Regarding spending shocks, we noted that results are most sensitive to γ and to the autoregressive coefficients of the expenditure processes. The effect of a greater persistence in expenditure shocks is of no surprise: as it becomes higher, the negative wealth effect on Ricardian consumption is exacerbated, and the impact response of total private consumption is diminished. Most of the other parameters have more limited effects on the results.

Figure 3.9 - Robustness - First year average responses of output, consumption and investment to fiscal shocks for different shares of non-Ricardian agents
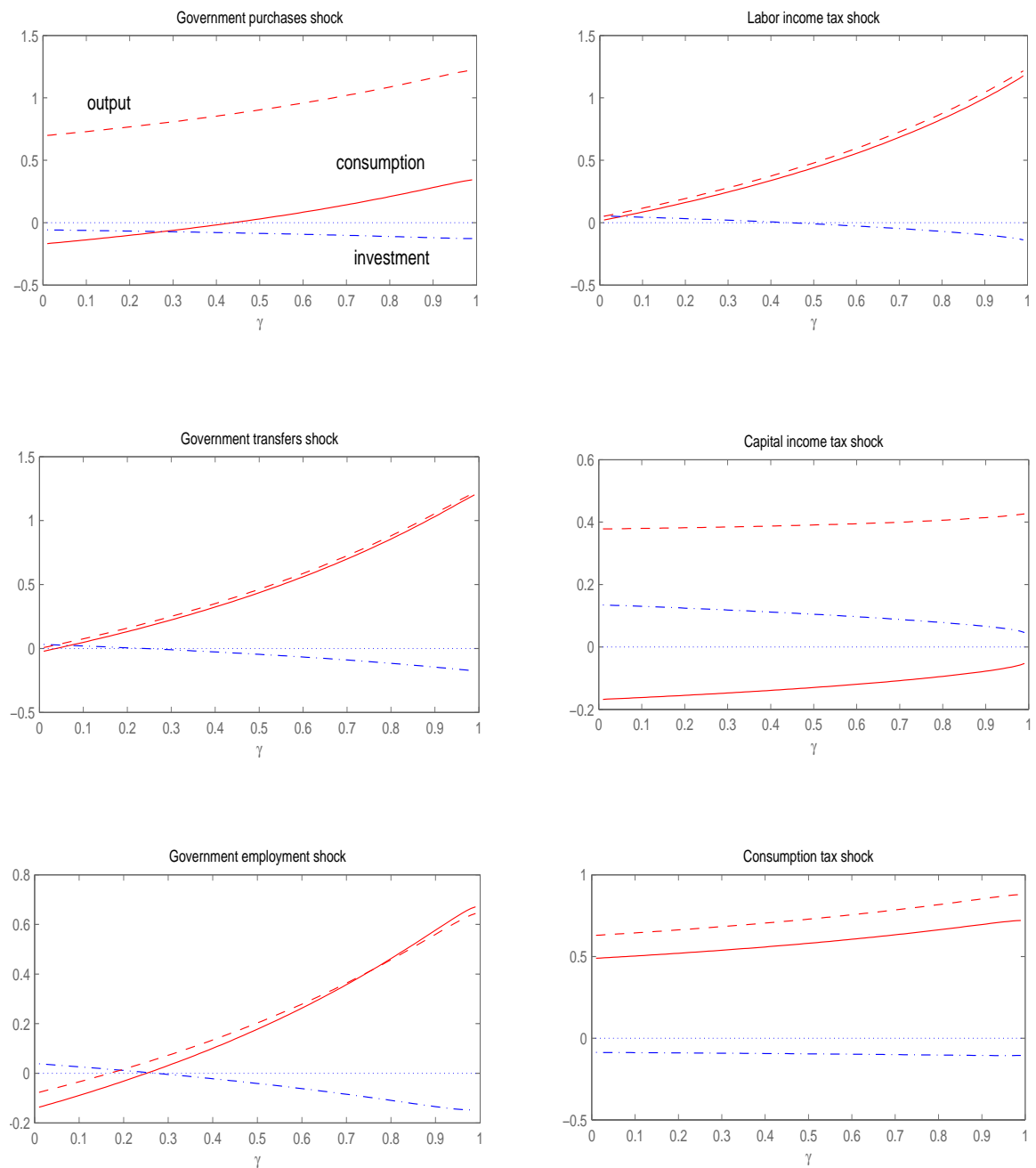
3.6   Concluding remarks

In this chapter we have presented new evidence regarding the macroeconomic effects of fiscal policy in the Euro area. To this end, we have developed a general equilibrium model and estimated its structural parameters through Bayesian techniques. As most of the Euro area official data on government accounts are available only at an annual frequency and given the importance for our purposes of including detailed information on government variables, we have also computed quarterly data for important fiscal policy series.

Our results point to a significant share of non-Ricardian agents and to the prevalence of mild Keynesian effects of fiscal policy. In particular, although innovations in fiscal policy variables tend to be rather persistent, government purchases of goods and services and compensations for public employees have small and short lived expansionary effects on private consumption, while innovations to transfers to households show a slightly more sizeable and lasting effect. The effects are more significant on the revenue side: decreases in labor income and consumption tax rates have sizeable effects on consumption and output, while a reduction in capital income tax favors investment and output in the medium run. Moreover, our results suggest that fiscal policy variables contribute little to the cyclical variability of the main macro variables.

The reported evidence seems to favor the new-Keynesian framework. The estimated impact increases in private aggregate consumption and real wages after shocks to government spending items, and in private sector employment after a government employment shock, are not consistent with standard RBC models.

While our model is rather general, we have restricted our focus to a closed economy setup. Although we believe this is a good approximation for an economic area as the Euro area, as SW have shown, we might still be missing some effects coming from the external channel. This, however, is a topic for future research.

Appendix to Chapter 3

3.A   An alternative specification for the labor market

The way labor supply of non-Ricardian agents reacts to fiscal shocks is key to the dynamic responses in our model. In fact, as we assume that non-Ricardian behavior in the labor market fully mirrors Ricardian behavior, the labor supply increase of the latter due to negative wealth effects is entirely transmitted to non-Ricardian agents. Following a government spending shock, such spillover could induce an upward bias in the responses of aggregate labor supply, labor income (given sticky wages) and, ultimately, both non-Ricardian and aggregate consumption. In order to control this potential bias we consider an alternative labor market structure which tries to give an explicit role to non-Ricardian agents in labor choices. In this alternative structure each worker delegates the intertemporal wage choice to a union whose preferences equally represent those of all agents in the economy. Our modeling extends the union setup proposed by GLSV to include the presence of (intertemporal) wage adjustment costs.

We consider a continuum of labor types, which are employed both in the private and in the public sector, and one union for each labor type m. Each union represents $1 - \gamma$ Ricardians and γ non-Ricardians (all indexed by i, perfectly substitutable in work effort within their own labor type m). The typical union m sets nominal wages $\{w_t(m)\}_{t=0}^{\infty}$ for workers of its labor type subject to quadratic adjustment costs and to demand schedules in the private and the public sector (the latter following the exogenous process specified in the main text). The union equally charges each member household with lump-sum fees to cover wage adjustment costs. It trades off the utility value of intertemporal labor income gains from working in either sector (net of both wage adjustment costs and taxes) versus the disutility of the work effort. That is, it maximizes:

$$E_0 \sum_{t=0}^{\infty} \beta^t \Bigg\{ \gamma \left[U_{c_t^{NR}(im)} \left((1-\tau_t^w) \frac{w_t(m)}{P_t} L_t^{NR}(i,m) - \frac{\phi}{2} \left(\frac{w_t(m)}{w_{t-1}(m)} \nu_t - \pi \right)^2 \frac{w_t}{P_t} \right) - \frac{\varepsilon^b \varepsilon^L L_t^{NR}(i,m)^{1+\sigma_L}}{1+\sigma_L} \right]$$

$$+ (1-\gamma) \left[U_{c_t^R(im)} \left((1-\tau_t^w) \frac{w_t(m)}{P_t} L_t^R(i,m) - \frac{\phi}{2} \left(\frac{w_t(m)}{w_{t-1}(m)} \nu_t - \pi \right)^2 \frac{w_t}{P_t} \right) - \frac{\varepsilon^b \varepsilon^L L_t^R(i,m)^{1+\sigma_L}}{1+\sigma_L} \right]$$

subject to (for $T = \{R, NR\}$)

$$L_t^T(i, m) = L_t^{p,T}(i, m) + L_t^{g,T}(i, m)$$

$$L_t^{g,T}(i,m) = L_t^g(i,m) = L_t^g(m)$$

$$L_t^{p,T}(i,m) = L_t^p(i,m) = L_t^p(m) = \left(\frac{w_t(m)}{w_t}\right)^{-\theta_L} L_t^p$$

where constraints recognize that the union takes into account that firms and the public sector allocate labor demand uniformly across different workers of type m, independently of them being Ricardian or non-Ricardian.

Assuming that all households have external habits which are group-specific, with a common habit parameter h, in a symmetric equilibrium the first order condition reads

$$\left[\frac{\gamma \varepsilon_t^b}{\left(c_t^{NR} - h\frac{c_{t-1}^{NR}}{\nu_t}\right)} + \frac{(1-\gamma)\varepsilon_t^b}{\left(c_t^R - h\frac{c_{t-1}^R}{\nu_t}\right)}\right] \left[\phi_w(\pi_t^w \nu_t - \pi)\pi_t^w \nu_t + (1-\tau_t^w)(\theta_L L_t^p - L_t)\right]$$

$$= \theta_L \varepsilon_t^b \varepsilon_t^L \frac{L_t^p}{\omega_t} L_t^{\sigma_L} + \phi\beta E_t \left\{\left[\frac{\gamma \varepsilon_{t+1}^b}{\left(c_{t+1}^{NR} - h\frac{c_t^{NR}}{\nu_{t+1}}\right)} + \frac{(1-\gamma)\varepsilon_{t+1}^b}{\left(c_{t+1}^R - h\frac{c_t^R}{\nu_{t+1}}\right)}\right](\pi_{t+1}^w \nu_{t+1} - \pi)\frac{\pi_{t+1}^{w2}}{\pi_{t+1}}\nu_{t+1}\right\}$$

which for $\gamma = 0$ reduces to the analogous equation of the baseline specification, where it is only Ricardian households who choose the wage. For $\gamma \neq 0$, discounting is done through a weighted average of the marginal utilities of the two types of agents in the economy.

The last two columns of Table 3.1 report the posterior parameter distributions obtained estimating the model with this version of the labor market, while leaving all other aspects unchanged. Most parameters values are only marginally changed. In particular the share of non-Ricardian agents, γ, is now estimated (mean of the posterior) at 0.37, instead of 0.34 as in the baseline. Therefore, including non-Ricardian agents in the wage optimization problem, weighted by their share, increases only marginally the estimated share of non-Ricardians. The other parameter that is affected by the different assumptions regarding the labor market is the wage elasticity of the labor demand, θ_L, now estimated at 5.8 instead of 6.2. That implies that the steady state wage markup increases slightly, from 19 to 20%. The dynamic behavior of the model is in every respect very similar to the baseline case.

3.B   Data sources and description

General description

The model is estimated using quarterly data over the period from 1980:1 to 2005:4. The National Accounts (NA) and the government sector series are seasonally adjusted and, when available, working day adjusted.

Data for quarterly NA variables (household consumption, capital accumulation, private compensations and public employment) are taken from the Eurostat ESA95 data base. Euro area NA data have a break in 1991 because of the German unification: for previous years, we use the series reconstructed by the ECB for the Area Wide Model (AWM-ECB).[30]

A large part of the Euro area information for the government sector is available only on annual basis.[31] Annual fiscal data for C^g, T and Tr are mainly obtained from the AMECO data base of the European Commission.[32] Considering breaks in accounting standards as well as German unification, we had to join ESA79 (excluding East Germany) with ESA95 series in order to obtain series starting from 1980. In each of these joins, we removed level discontinuities by applying the growth rates of the old series to the levels of the new series, as done by most data providers. We then obtained quarterly series from annual ones, applying standard techniques commonly adopted by national statistical offices to estimate high frequency series using proxy indicators. In particular, we followed the Chow and Lin (1971) method, as modified by Barbone *et al.* (1981). We used a particular care in the choice of the quarterly NA indicators for each series.

Concerning implicit tax rates we computed annual series starting from 1980 following the original contribution by Mendoza *et al.* (1994, henceforth MRT). In their original paper, the series were computed for the period 1965-1988 and, among Euro area countries, only for Germany, France and Italy. We obtained our annual rates applying the same formulas as MRT to Euro area data. To compute the quar-

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[30] In particular we refer to the release of the AWM-ECB updated to the 2005:4, available on the web site of the Euro Area Business Cycle Network-EABCN.

[31] Recently Eurostat has released a number of quarterly series for the principal items of the government accounts, but only for a short time span (from 1999:1) and not adjusted either for seasonality or for working days.

[32] In alternative to AMECO some variables, as documented in the following section, are extracted from ECOUT, the data base of the OECD Economic Outlook.

terly rates, we had to pick quarterly NA indicators for each variable entering in the computation of the rate, as detailed in the next section.

Data sources and methodology for the individual data series

In the following we document, series by series, the sources and the data processing that we have done.

Households' consumption (C) = real private consumption; source: AWM-ECB data set up to 1990:4 and NA-ESA95 thereafter.

Investment (I) = real investments; source: AWM-ECB up to 1990:4 and NA-ESA95 thereafter.

Interest rate (R) = three-months nominal interest rate; source: AWM-ECB.

Inflation rate (π) = annual percentage changes of the Harmonized Index of Consumer Price (HICP); source: AWM-ECB.

Private per-capita real compensations (W/P) = private sector per-capita real compensations, computed as the ratio between private compensations and private employees (private variables are computed as difference between whole economy and public sector values); source: AWM-ECB up to 1990:4 and NA-ESA95 thereafter.

Government consumption less compensations (C^g) = real government purchases of good and services (does not include any type of transfers); source for annual series: ECOUT. The quarterly indicator is the difference between government consumption and non-market compensations; source for the quarterly indicator: AWM-ECB up to 1990:4 and NA-ESA95 thereafter.

Government transfers (Tr) = real government transfers to households; source for annual series: AMECO. The quarterly indicator is the unemployment rate.

Total revenues (T) = real government total revenues; source for annual nominal series: AMECO. The quarterly indicator is a sum of three components: 1) a series of direct taxes, with the annual data from AMECO and the quarterly data reconstructed using as indicator the NA data on value added in the market sector; 2) a series of indirect taxes, with the annual data from AMECO and the quarterly data reconstructed using as indicator the NA data on private and public consumption; 3) a series of social contributions, with the annual data from AMECO and the quarterly data reconstructed using as indicator the NA data for social contributions.

Government employment (L^g) = public employees; source: ECOUT.

Tax rate on labor income (τ^w) = the series is computed in two steps: 1) an average direct tax rate (thh) is computed as:

$$thh = \frac{TD_h}{(OSPUE + PEI + W)} \tag{C.30}$$

2) the labor tax rate is given by

$$\tau^w = \frac{(thh\ W + SC + T_w)}{(W + SC_e)} \tag{C.31}$$

where:

TD_h = households direct taxes

$OSPUE$ = operating surplus of private unincorporated firms

PEI = household property and entrepreneurial income

W = wages

SC = social contributions

T_w = taxes on payroll and workforce

SC_e = employers social contributions

τ^w is therefore a measure of the share of labor taxes and social contributions (the numerator) on the labor cost (the denominator). Sources for the annual series: OECD Revenue Statistics and AMECO. As quarterly indicators, we use for TD_h the NA data on value added in the market sector, while for $OSPUE + PEI$ the NA profit series. For wages and social contributions quarterly NA series are available.

Tax rate on consumption (τ^c) = the series is given by the ratio

$$\tau^c = \frac{TI_1 + TI_2}{(C + C^g - TI_1 - TI_2)} \tag{C.32}$$

where:

TI_1 = general taxes on goods and services

TI_2 = excise taxes

τ^c is therefore the tax rate on private and public consumption. Sources for the annual series: OECD Revenue Statistics, AMECO and ECOUT. As quarterly indicator for TI_1 and TI_2 we use the NA quarterly data on private and public consumption.

Tax rate on capital income (τ^k)= the series is computed as follows:

$$\tau^k = \frac{(thh\ (OSPUE + PEI) + TD_k + TP + TTR)}{NOS} \tag{C.33}$$

where thh is defined in (C.30) and:

TD_k = direct taxes on corporations

NOS = net operating surplus of the economy

TP = taxes on immovable property

TTR = taxes on financial and capital transactions

τ^k is therefore a measure of how taxes on all kind of businesses (the numerator) affect profits (the denominator). Sources for annual series: OECD Revenue Statistics and AMECO. As quarterly indicators, we use for TD_k the NA data on value added in the market sector, while for NOS the NA profit series. Given the lack of suitable quarterly indicators for both TP and TTR, these series are made quarterly by using a linear trend.

Comparison of our tax rates with alternative sources

Although coverage and definitions are slightly different, we can compare our tax rates series with those of three alternative data sets. Eurostat provides official yearly tax rate series starting from 1995, using a modified version of the MRT methodology. This latter is also at the basis of the OECD paper by Carey and Rabesona (2002, henceforth CR), where time series for OECD countries covering the years 1975-2000 are presented.

Our rates are an updated version for the Euro area of the rates computed by MRT. On an annual basis they can be compared with those provided by Eurostat as well as with those in MRT and in CR, all based on the MRT methodology: while CR introduce some modifications, Eurostat complements its calculations using country data not always in the public domain.

In terms of coverage, among Euro area countries MRT computed rates from 1965 to 1988 only for Germany, France and Italy. CR have longer series (from 1975 to 2002) for seven countries in the Euro area.[33] To compute figures for the Euro area, we aggregated these national rates using fixed GDP weights. Eurostat has computed tax rates for each European country since 1995 and provides GDP-weighted series. The top panel in Figure 3.A shows labor income tax rates. Our series is the highest but is comparable with MRT. The central panel of the figure shows that our tax rates on consumption closely track the MRT one in the first part of the eighties and

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[33]The countries are Germany, France, Italy, Austria, Belgium, Finland and Spain. The series in CR are from 1980 to 2000, but in this appendix we refer to an update version up to 2002, kindly provided by the authors.

almost overlaps with that of CR thereafter. The difference with the Eurostat series is mainly due to the fact that Eurostat does not include government purchases of goods and services in the tax base. Finally, in the bottom panel we report capital income tax rates.

Overall our estimates are higher than alternative figures for labor income tax rates, while lower than those for capital income. The difference relates mainly to the way direct taxes are split between labor and capital income revenues: in this we follow the MRT methodology (and in fact our series are close to theirs), while Eurostat uses additional information and CR introduce some modifications in the MRT methodology. However, as we use the demeaned series in estimation, we are mainly concerned with the profile of the rates (which is similar across different sources) more than with their levels.

Figure 3.A Annual implicit tax rates (in percentage points)

Tax rate on labor income

Tax rate on consumption

Tax rate on capital income
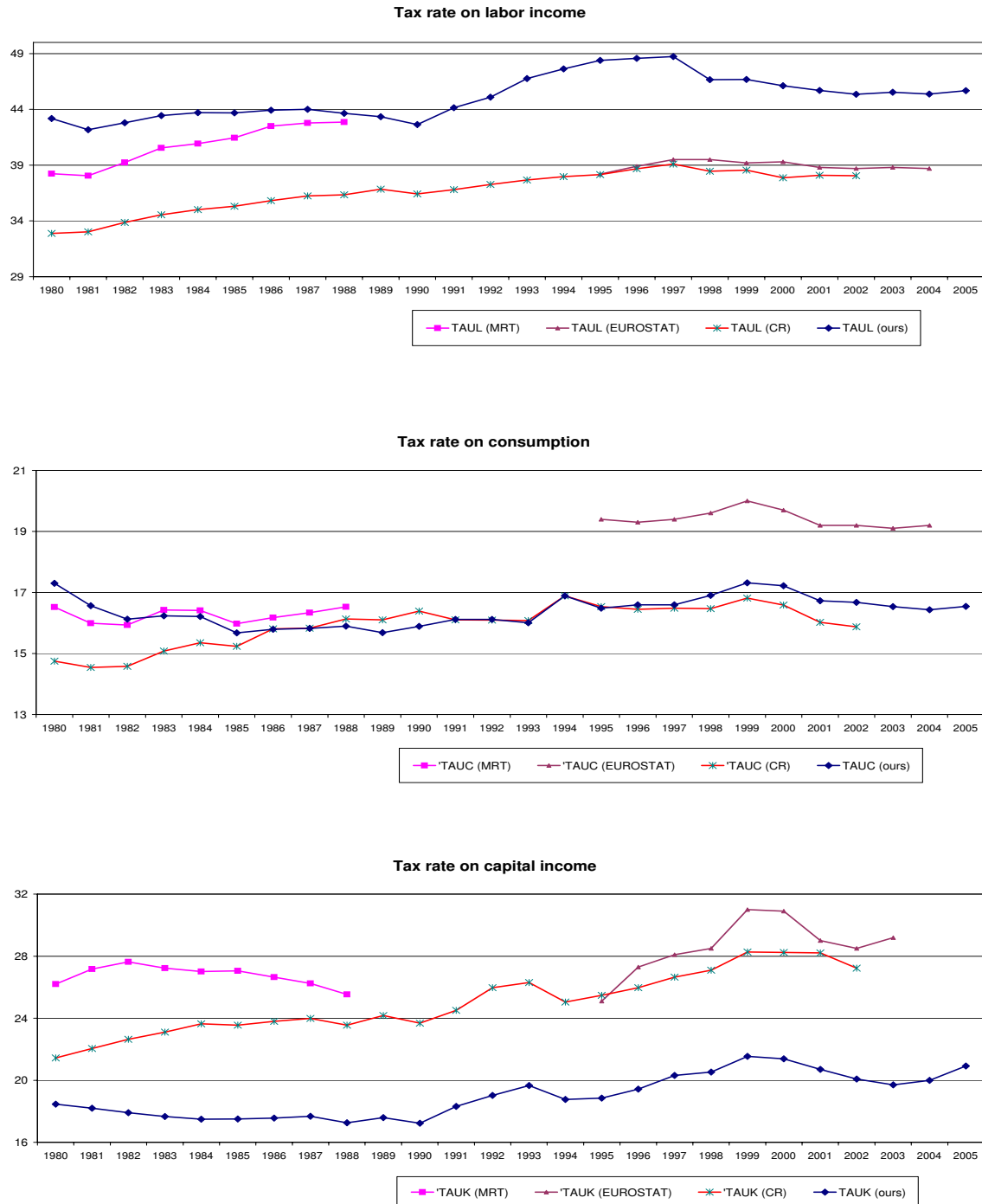
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