Workers, Capitalists, and the Government: Fiscal Policy and Income (Re)Distribution*

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Abstract

This paper presents a capitalist-worker New Keynesian model for fiscal policy analysis that incorporates insights from the recent heterogeneous agent, incomplete markets literature while preserving the tractability of a two-agent framework. In the model, capitalists earn income from firm profits and investing in physical capital, while workers only receive labor income. Portfolio adjustment costs deliver realistic intertemporal marginal propensities to consume, and the concentration of profit income among wealthy capitalists avoids implausible income effects on labor supply. The embedded fiscal transmission mechanism implies that deficit-financing is expansionary due to redistributive effects. We estimate a medium-scale version of the model by Bayesian impulse response matching, drawing on a novel stylized fact: the response of the labor share of income to an unanticipated increase in government purchases is positive, persistent and hump-shaped. The model is able to replicate this characteristic pattern and the dynamics of other key macroeconomic variables under a plausible parameterization, suggesting that not only the presumed transmission mechanism is better in line with micro evidence but also that the implied aggregate dynamics fit macro data well.

Keywords: Fiscal Policy, DSGE, TANK, Labor Share.
JEL Classification: E32, E62, C52.

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1 Introduction

An important strand of the recent macroeconomic literature analyzes macroeconomic dynamics and policy in a framework that combines nominal rigidities with a Bewley-Imrohoroglu-Huggett-Aiyagari type heterogeneous-agent, incomplete markets environment and aggregate uncertainty. Following Kaplan *et al.* (2018), we refer to such environments as heterogenous-agent New Keynesian (HANK) models. Settings of this type – with rich heterogeneity on the household side – are required to address certain important macroeconomic questions that are not even well-defined in a representative-agent setting (e.g., the varied impact of aggregate shocks across the entire income distribution). Yet HANK models also deliver aggregate dynamics that potentially diverge from those implied by their representative-agent counterparts (see, for instance, Kaplan and Violante (2018), Auclert *et al.* (2018) and Mitman *et al.* (2019)). With this potential significance of inequality for macro in mind, alongside the flourishing HANK literature there has been a renewed interest in the ability of two-agent New Keynesian (TANK) models to capture some of the properties of heterogeneous-agent models with respect to aggregate dynamics (see, e.g., Debortoli and Galí (2017); Bilbiie (2019b)).

The prototypical TANK model (Galí *et al.*, 2004, 2007) features a share of the population that are *optimizers* – meaning they follow the permanent income hypothesis – and a set of *rule-of-thumb* agents who do not have any access to financial markets. We will accordingly refer to this framework as the OR-TANK model (where "O" stands for optimizers and "R" denotes rule-of-thumb people). It was originally developed primarily to remedy the low aggregate marginal propensity to consume (MPC) characteristic of representative agent NK models (RANK) and, more specifically, to capture the crowding-in of private consumption in response to an increase in government spending documented in numerous empirical studies.

In this paper, we contribute to the development of the TANK-literature by addressing two limitations of the OR-TANK model that the recent HANK literature has uncovered. First, in independent work Auclert *et al.* (2018) and Mitman *et al.* (2019) show that heterogeneous-agent models are capable of matching dynamic consumption responses to idiosyncratic shocks and macroeconomic policies that are in line with the data in a way that neither RANK nor OR-TANK can. Using Norwegian administrative data and the Italian Survey of Household Income and Wealth, Auclert *et al.* (2018) show that, in response to an unanticipated increase in income, the intertemporal marginal propensities to consume (iMPCs) in the year following the transfer is still fairly large and display a pattern of gradual decay thereafter.[1] The RANK model largely fails to match the data, as agents' consumption behavior is entirely determined by permanent income considerations and, consequently, iMPCs are flat at a low level. While the OR-TANK model succeeds, almost by construction, in matching the high impact-MPC,

[1] Auclert *et al.* (2018) define, for given dates t and s, the intertemporal marginal propensity to consume (iMPC), $M_{t,s} = \partial C_t / \partial Y_s$ as the response of consumption at date t to an aggregate income shock at date s.

the extreme specification of limited asset market participation it presumes makes iMPCs drop sharply thereafter – in contrast to what the evidence suggests.

The second limitation we seek to remedy here concerns the undesirable labor supply dynamics due to income effects generated by profits dynamics in NK models. Broer *et al.* (2019), using a simple HANK framework, show that the textbook RANK monetary transmission mechanism relies on implausible income effects induced by profit variations: output falls in response to a monetary tightening because mark-ups and, hence, total profits rise; this increase in non-labor income triggers a rise in the household's demand for leisure or, equivalently, a fall in labor supply. This income effect of profits on labor supply is also present in OR-TANK models because optimizers are assumed to earn both profit and labor income. It furthermore operates not only following monetary policy shocks but also, for instance, in the case of fiscal policy, as Bilbiie (2008) has highlighted in a different context.

Against this backdrop, the objective of this paper is to bring the micro-structure of the OR-TANK model better in line with the empirical evidence and the theoretical HANK literature, and to see if the implied aggregate dynamics can be reconciled with time series macro data given reasonable parameter values. In the first part of the paper, we take inspiration from the data to motivate one among a number of alternative directions one might pursue with the goal of developing a "TANK 2.0." Specifically, we examine the effects of government spending shocks in a comprehensive VAR analysis, adopting the identification approach recently proposed by Forni and Gambetti (2016). Our focus on fiscal policy is in line with much work in the TANK tradition and further motivated by the observation of Kaplan and Violante (2018, p. 182) that fiscal policy is a case of "stark non-equivalence" between RANK and HANK models.[2] As such, fiscal policy lends itself to the study of RANK and TANK models. Our analysis uncovers previously undocumented redistributive consequences of fiscal stimulus measures: the response of the labor share of income to an unanticipated increase in government purchases is positive, persistent and hump-shaped. Indeed, we find evidence of redistribution from corporate profits to wages following what appears to have been mostly debt-financed discretionary government spending over the sample considered.[3] We interpret this finding as suggesting that such fiscal shocks do not only affect aggregate variables; they also shift the distribution of income from ' 'capital," broadly understood, towards "labor."

Motivated by the two theoretical limitations of OR-TANK stated above and guided by the empirical finding of a fiscal policy redistribution channel in the labor/profit dimension in the data, we next build a novel capitalist-worker two-agent New Keynesian model (which we call "CW-TANK"). The model

[2]That is to say, both impulse response functions and the underlying transmission mechanisms are different depending on whether or not household heterogeneity is accounted for.

[3]Our benchmark VAR is estimated from US data over the Great Moderation period. The resulting findings are shown to be robust to a series of checks that deviate from our baseline specification in a number of dimensions. We consider, amongst others, countries other than US; alternative sample periods; and the use of Jordà's (2005) local projection methods to compute impulse responses as in Ramey (2016) and Ramey and Zubairy (2018).

isolates different sources of income and allocates them to two distinct types of agents: capitalists, earning income from firms' profits and investing in physical capital; and workers, who only receive labor income. CW-TANK has several advantages relative to OR-TANK. In the first instance, from a theoretical standpoint, it incorporates and addresses the two insights from the recent HANK literature described above. We show this step-by-step, first replacing "Rs" with "Ws" and then substituting "Cs" for "Os." Workers represent a generalization of rule-of-thumb agents insofar as they can smooth consumption through borrowing and saving in government bonds to some extent: the degree of financial constraints is controlled by quadratic portfolio costs rather than simply being infinite (which would correspond to the rule-of-thumb case). This specification makes it possible to capture a realistic pattern of dynamic consumption responses. Avoiding the stark contrast between optimizers and rule-of-thumb directly matters for labor demand. Second, capitalists, different from optimizers, do not participate in the labor market and therefore do not receive labor income. This, as in Broer *et al.* (2019), breaks the link between profits and labor supply. In addition to its theoretical properties, the CW-TANK model also allows for a conceptually clean distinction between different income sources. And from an empirical standpoint, the model captures, albeit in a highly stylized fashion, the fact that wealth holdings are extremely concentrated in the data (see, e.g., Saez and Zucman (2016)).

We also contribute to discussions about the interplay between limited asset market participation and nominal wage rigidity. Studies including Colciago (2011), Furlanetto (2011) and Ascari *et al.* (2017) caution that including a fraction of rule-of-thumb households within the New Keynesian framework may not significantly alter the predictions of the simple RANK model once wage stickiness is accounted for. What is more, doing so potentially creates major difficulties in matching the empirical behavior of real wages as well as investment. Our analysis suggests that enriching the CW-TANK framework with nominal wage rigidity on top of price stickiness, on the other hand, generates not only the right sign of impulse responses for key macro variables relative to empirical evidence. The model can also deliver a hump shape of impulse responses for consumption, wages, and the labor share without having to introduce frictions such as external habits in consumption. This is important because, as Auclert *et al.* (2019) note, standard models of habit formation commonly used to generate "macro humps," are inconsistent with the empirical evidence on "micro jumps," notably the behavior of iMPCs.

Throughout we emphasize that the role envisioned for TANK models – in general and for CW-TANK in particular – is not to 'compete' with HANK models. Instead, they are seen as having different scope of application. While unable by construction to explore the implications of macroeconomic shocks for the entire distribution of households, TANK models are potentially useful tractable laboratories both for understanding the aggregate consequences of macroeconomic policy in the presence of heterogeneous agents and for approximating distributional effects of such policy at a high level. Additionally, they are fast to solve even when a wide range of "bells and whistles" are added to a baseline specification and, as such, lend themselves to estimation. Consistent with this perspective, we utilize the CW-TANK model in two distinct applications. First, we explore what the implications of the model are for the effectiveness of fiscal stimulus packages under alternative financing schemes. We believe this question to carry particular significance given potentially limited scope for monetary policy in heading off a future recession as well as calls by policymakers and economists for a greater emphasis on discretionary fiscal stabilization policy in general and the countercyclical use of public debt in particular (see, e.g., Blanchard (2019); Furman and Summers (2019)). In simulations we find – consistent with the result and reasoning of Mitman *et al.* (2019) – that deficit-financed discretionary spending measures are more effective in stimulating the economy than tax-financed expenditures. The interaction between household heterogeneity and deficit-financing is crucial in delivering this result.

In a second application, we enrich the model with a range of frictions familiar from the quantitative DSGE literature (e.g., Smets and Wouters (2007)) and estimate it by means of Bayesian impulse response matching as in Christiano *et al.* (2005, 2010, 2016); Lewis and Winkler (2017).[4] The main result from this exercise is that the aggregate dynamics implied by the CW-TANK match the macro data for a plausible set of parameter values. Relative to OR-TANK, the crucial parameter is the proportion of different types of agents in the economy. While the OR household structure requires around 70% of agents without any access to financial markets to match the data, the CW specification achieves a good fit assuming that 90% of people are workers while 10% are capitalists. Inevitably given the two-agent premise, both OR and CW represent household heterogeneity in a simplistic fashion. Countenancing the idea that almost three quarters of households do not have any access to financial markets in the US seems particularly difficult, however. By contrast, a "90/10" split where the great majority of people rely almost exclusively on labor income but have some ability to smooth consumption while 10% have significant asset income seems to capture in a stylized manner the idea that wealth is highly concentrated.

Related Literature. Beyond the references cited above, our paper relates to several themes in the economic literature. In the first instance, there are a few other articles likewise exploring the ability of tractable models to mimic properties of heterogeneous-agent models that we consider complementary to the present work. This category includes RANK models that introduce bonds in the utility function (BU), as studied by Kaplan and Violante (2014), Hagedorn (2016) and Michaillat and Saez (2018) as well as a hybrid of OR-TANK and BU models.[5] Bilbiie (2019a) develops an analytical HANK framework that incorporates self-insurance against the risk of having to live hand-to-mouth which, in his model, any agent faces (rather than an exogenously fixed fraction, as in TANK). The presence of idiosyncratic risk in his model is another avenue to capture the intertemporal Keynesian cross logic of Auclert *et al.* (2018) that is missing from OR-TANK and present in CW-TANK. Bilbiie likewise

[4] We see the labor share response to a fiscal stimulus, in particular, as a natural *identified moment* (in the terminology of Nakamura and Steinsson (2018), also see Wolf (2019)) in a two-agent capitalist/worker framework.

[5] Indeed, Auclert *et al.* (2018) note that a model combining a fraction of rule-of-thumb agents with the assumption that holding bonds yields a utility gain also manages to fit the data well.

stresses the importance of cyclical inequality – between workers and capitalists, in our terminology – for understanding macroeconomic dynamics but uses his model to different ends than we employ CW-TANK, with an emphasis on monetary policy. Our distinction between workers and capitalists and the assumption that the former are more financially constrained than the latter is in line with Walsh (2017). With that paper we also share the emphasis that shifts in the functional distribution of income matter for aggregate economic activity. Unlike Walsh, we allow workers to have access to bond markets, albeit in a constrained manner, which is critical to capturing the intertemporal response of consumption to fiscal shocks. Also, our concern lies more immediately with fiscal policy, whereas Walsh evaluates the welfare consequences of wage flexibility and the interaction with monetary policy. Finally, Kumhof *et al.* (2015) also consider a two-agent model with "top earners" and "bottom earners," but employ it to study household leverage prior to the Great Recession rather than looking at business cycle dynamics.

The research question pursued in this article relates to two further strands of the economic literature, addressing respectively the cyclical behavior of the labor share and the empirical evaluation of fiscal policy shocks. On the former, Cantore *et al.* (2019) find that monetary policy tightening increased the labor share in a panel of developed economies during the Great Moderation period.[6] Like us, Kaplan and Zoch (2019) then use this evidence about conditional labor share dynamics as an empirically identified moment against which to test theoretical models, except that we condition on a fiscal instead of a monetary policy shock. To the best of our knowledge, there is little evidence available about the effect of discretionary fiscal policy on the labor share, therefore this is the first contribution that this paper makes. The empirical literature on fiscal policy offers a range of approaches to identifying government spending shocks.[7] In this paper, we draw on the identification method proposed in Forni *et al.* (2016) – which is closely related to that of Ricco (2015) – and use data from the Federal Reserve Bank of Philadelphia's Survey of Professional Forecasters to "purify" recursively identified fiscal shocks of anticipation effects.[8]

Outline. The remainder of the paper is organized as follows. Section 2 presents the empirical evidence. Section 3 outlines a simple version of the model, highlights the transmission mechanism and compares it with standard TANK models. Section 4 comprises two applications: one considers alternative financing schemes of a fiscal stimulus; the other estimates a medium-scale version of the model. Finally, section 5 concludes.

[6]See also Ríos Rull and Santaeulalia-Llopis (2010) on technology shocks and the labor share.

[7]The literature is too extensive to summarize comprehensively; relevant contributions include, amongst others, Blanchard and Perotti (2002); Caldara and Kamps (2008); Mountford and Uhlig (2009); Ramey (2011); Ben Zeev and Pappa (2015); Caldara and Kamps (2017); Ramey and Zubairy (2018). Several contributions have highlighted the challenge arising from fiscal foresight (Yang, 2005; Leeper *et al.*, 2013).

[8]There furthermore exists a small but growing literature on the distributional consequences of fiscal policy shocks (Pappa, 2009; Giavazzi and McMahon, 2012; Ball *et al.*, 2013; Furceri *et al.*, 2018), which the present study also contributes to.

2 Empirical Evidence

We start by establishing how government spending shocks affect key aggregate macroeconomic variables as well as the ("functional") distribution of income between workers and capitalists. Given the focus of our paper, this empirical evidence serves a concrete purpose in two ways. First, the distributional effects of fiscal policy to be described shortly help motivate the development of our capitalist-worker TANK model from a data angle. In a second step, we furthermore use the empirical impulse response functions obtained to estimate the theoretical model.

Our baseline econometric tool is the SVAR approach recently devised by Forni and Gambetti (2016). We summarize the methodology and how we implement it in practice in Subsection 2.1, while Subsection 2.2 reports the baseline results. A battery of robustness checks and extensions as well as a full account of data sources and transformation are provided in the appendix.

2.1 Methodology

2.1.1 Identification Strategy

The econometric strategy of Forni and Gambetti (2016) essentially combines the recursive identification approach of Blanchard and Perotti (2002) with a news variable constructed based on data from the Survey of Professional Forecasters (SPF). Jointly, these two components allow extracting "surprise" government spending shocks from the data. We find this approach appealing for two reasons. First, it allows purifying recursively identified shocks of any anticipated component. Second, unlike identification methods based on the use of defense spending, this methodology allows analyzing the response of the labor share to government spending shocks in general and not only the narrower subset of military spending shocks.

The inclusion of the SPF variable is motivated by concerns over the implications of fiscal foresight. A defining property of SVAR models is that the structural shocks, denoted ϵ_t, can be recovered linearly from past and present values of the observed data, y_t. Yet this assumption may be violated if the econometrician does not observe all variables relevant to the decisions of forward-looking agents. In the context of government spending shocks specifically, agents receive signals about fiscal changes prior to their implementation because of the existence of lags in the legislative and implementation process (for evidence of fiscal foresight see, among others, Ramey (2011); Leeper *et al.* (2013); Forni and Gambetti (2016)). Such fiscal foresight means that recursive identification, by itself, may not be sufficient to clearly distinguish between unanticipated and anticipated shocks, because some changes in fiscal expenditures are anticipated by agents even though they are unpredictable based on the variables in the econometrician's information set. Including the SPF news variable serves to enrich this information set and thus help identify spending shocks "purified" of the anticipated component.[9] Specifically, define the implied cumulated forecasts for government spending growth between $t = s$ and $t = h$, $s < h$ as $F_t(s,h) = \sum_{j=s}^{h} E_t^P g_{t+j}$, where E_t^P denotes the median expectation in the SPF in period t and g_{t+j} denotes the realized growth rate of government spending at $t + j$. In practice, we follow Forni and Gambetti (2016) and use $F_t(1,4)$, placing it as the second variable in the SVAR after government spending.

2.1.2 Implementation

The baseline specification is a nine-variable VAR estimated for the U.S. relying on quarterly data spanning from 1981:Q3 to 2007:Q4 and using standard Bayesian methods. The data comprises: (i) log real government spending (consumption plus gross investment); (ii) the cumulated forecast of government spending growth over the next four quarters, $F_t(1,4)$; (iii) log real net taxes; (iv) log real GDP; (v) log real consumption (durables and non-durables); (vi) log real investment; (vii) log labor share; (viii) log real corporate profits; and (ix) the 10-year real interest rate. Appendix A.2.1 contains further details. For all series except for the interest rate and the SPF variable, we take the natural logarithm and multiply the resulting series by 100, yielding the series used in the estimation.

The labor share deserves particular attention. Theoretically, it is defined as the share of total (nominal) compensation of the labor force, i.e. the product of average wages, W, and employed labor force, L, in aggregate (nominal) output of the economy (the product of price level P and real output Y), $LS = \frac{WL}{PY}$.[10] However, the empirical counterpart to this theoretical construct is ambiguous, as both the numerator and the denominator of the ratio can be measured in various ways (Gollin, 2002).[11] As our baseline measure we use the labor share in the domestic corporate non-financial business sector, constructed in line with the methodology of Gomme and Rupert (2004).[12] Details about the construction of the labor share series, alongside a description of five alternative proxies, and details about sources and transformation of all other variables are provided in Appendix A.1.

[9] In general, the problem of *non-fundamentalness* or *non-invertibility*, of which fiscal foresight is one specific cause, may accordingly be understood as a problem of deficient information, akin to an omitted variables problem. Our use of SVAR methods in the face of this potential threat to validity is then premised on the insight that, in applied work, the necessary condition for recovering the IRFs for a particular shock is not fundamentalness but sufficient information (Forni and Gambetti, 2014), a shock-specific generalization of the fundamentalness concept. Suppose that the structural shock of interest is $\epsilon_{1,t}$ and denote as H_t^y the econometrician's information set based on VAR data y_t. Then the VAR is informationally sufficient for $\epsilon_{1,t}$ if $\epsilon_{1,t} \in H_t^y$. We may relate this concept to fundamentalness noting that ϵ_t is fundamental for y_t if and only if y_t is informationally sufficient for $\epsilon_{i,t}, i = 1, ..., n_\epsilon$.

[10] Equivalently, we may express LS as the ratio of real wages over labor productivity: $LS = \frac{WL}{PY} = \frac{W^r}{LP}$, where $W^r = \frac{W}{P}$ and $LP = \frac{H}{Y}$.

[11] Creating a sound measure of the labor share requires explicitly addressing several questions, including how to apportion the income of the self-employment, the government sector and indirect taxes, the housing sector, and depreciation (McAdam *et al.*, 2015).

[12] Excluding the public sector, in particular, alleviates concerns that increased spending on public sector employment might mechanically increase the labor share of the economy as a whole.

2.2 Findings

2.2.1 Baseline Results

Figure 1 depicts the impulse responses to a surprise government spending shock. Three results stand out. First, and focusing on the novel aspect of our empirical exercise, the labor share exhibits a positive, persistent and hump-shaped response with a peak effect (in percentage deviations from baseline) that is comparable to that of GDP. In addition, the response is statistically significant for several quarters around its peak. Especially when viewed in conjunction with the U-shaped dynamics of corporate profits, this suggests that the expansionary government spending shock involves a redistribution of national income away from owners of capital (broadly understood to include recipients of firm profits) towards workers.

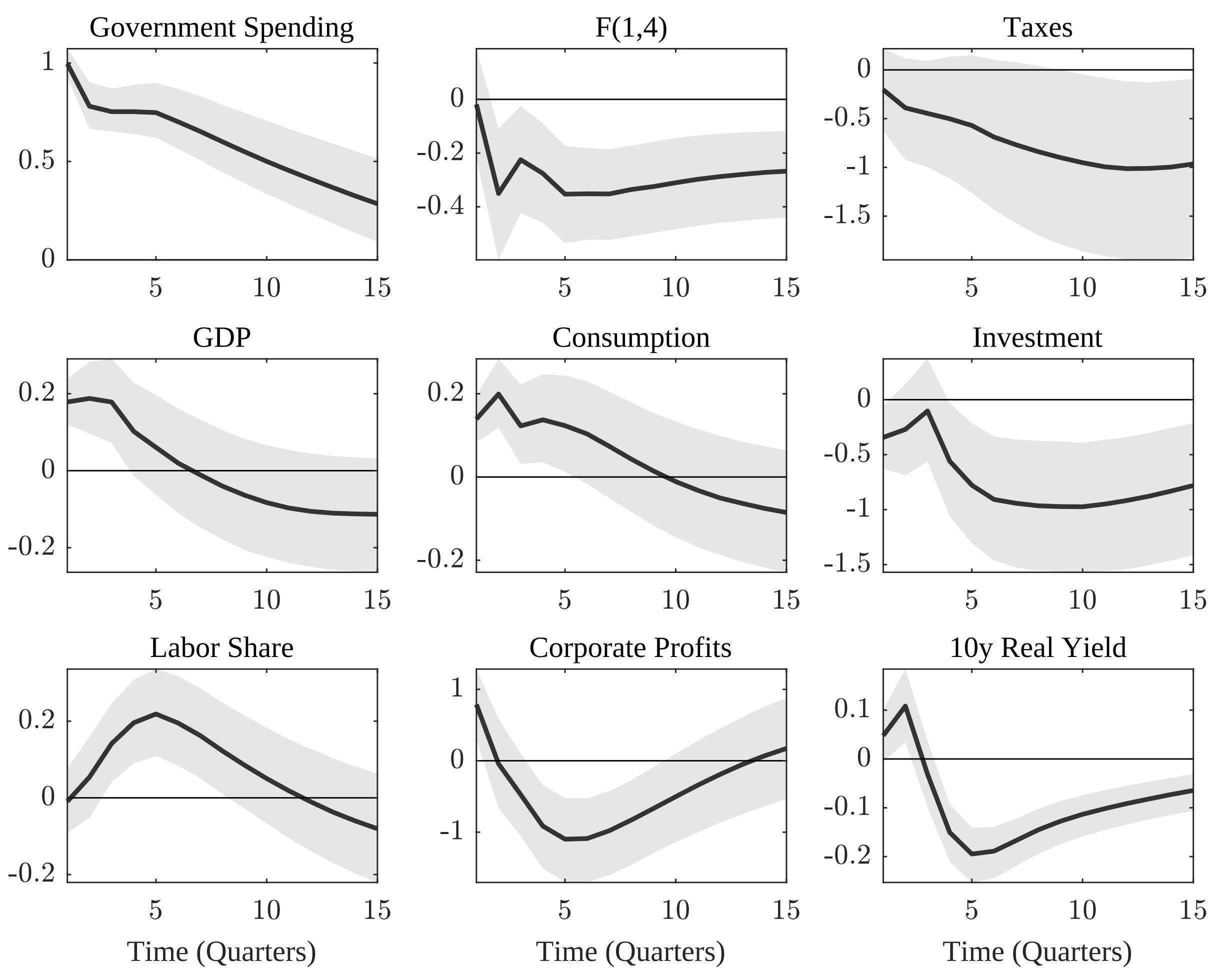


Figure 1: VAR: Surprise Shock to Government Spending – US

Notes: Impulse responses are scaled such that the log change of government spending is unity at its peak. Solid lines indicate the median posterior density of impulse responses, while the shaded area represents the 16th to 84th percentiles. All series except interest rate and news variable shown in %.

Second, the response of real output is positive for about one year and statistically significant for the first two quarters. The magnitude and (relatively low) persistence of the output response is consistent with other studies that noted the decline of the output effect after 1980 in U.S. data (see, e.g., Perotti (2005) and Caldara and Kamps (2008)). Considering the components of national income, aggregate consumption is crowded-in following an expansionary unanticipated government spending shock whereas investment falls. Third and finally, the median response of net taxes is negative, suggesting that on average we capture a mostly deficit-financed government spending stimulus. In appendix A.2, we validate our empirical results for the U.S. using a large number of robustness checks that deviate from our baseline specification in a number of dimensions.

In principle, a positive response of the labor share to a government spending shock could be due to two different relationships between the two components of the labor share, that is, real wages and labor productivity: either wages (the numerator) increase by more than productivity (the denominator), or productivity decreases by more than wages. When replacing real GDP and the labor share with labor productivity and real wages (in this order), then we find that wages grow more rapidly than productivity (see Appendix A.2.3). This pattern is likely responsible for the decline in corporate profits documented above.

2.2.2 Other Countries

The scope of the new stylized fact about the response of the labor share to government spending shocks is not restricted to the US, as this section demonstrates by examining the cases of Canada, Australia and the UK. In all three cases, we limit ourselves to recursive identification given limited data availability in terms of proxies for news shocks, and we study the sample 1970:I-2007:IVs for which high-quality data is available for all three countries.[13] Figure 2 shows that in all three countries, in response to a surprise government spending shock, the labor share initially increases in a statistically significant manner before reverting back to the mean, potentially with a degree of undershooting after several years. Qualitatively, these dynamics are remarkably close to those reported earlier for the US.[14]

[13]For a description of the variables and data sources, see the appendix. We use two lags for Canada and Australia and three for the UK.

[14]The magnitude of the labor share increase for the Canada and Australia is notably larger than observed for the US, but it is significantly smaller for the UK where, in addition, the multiplier is negative (consistent with Afonso and Sousa (2012)).

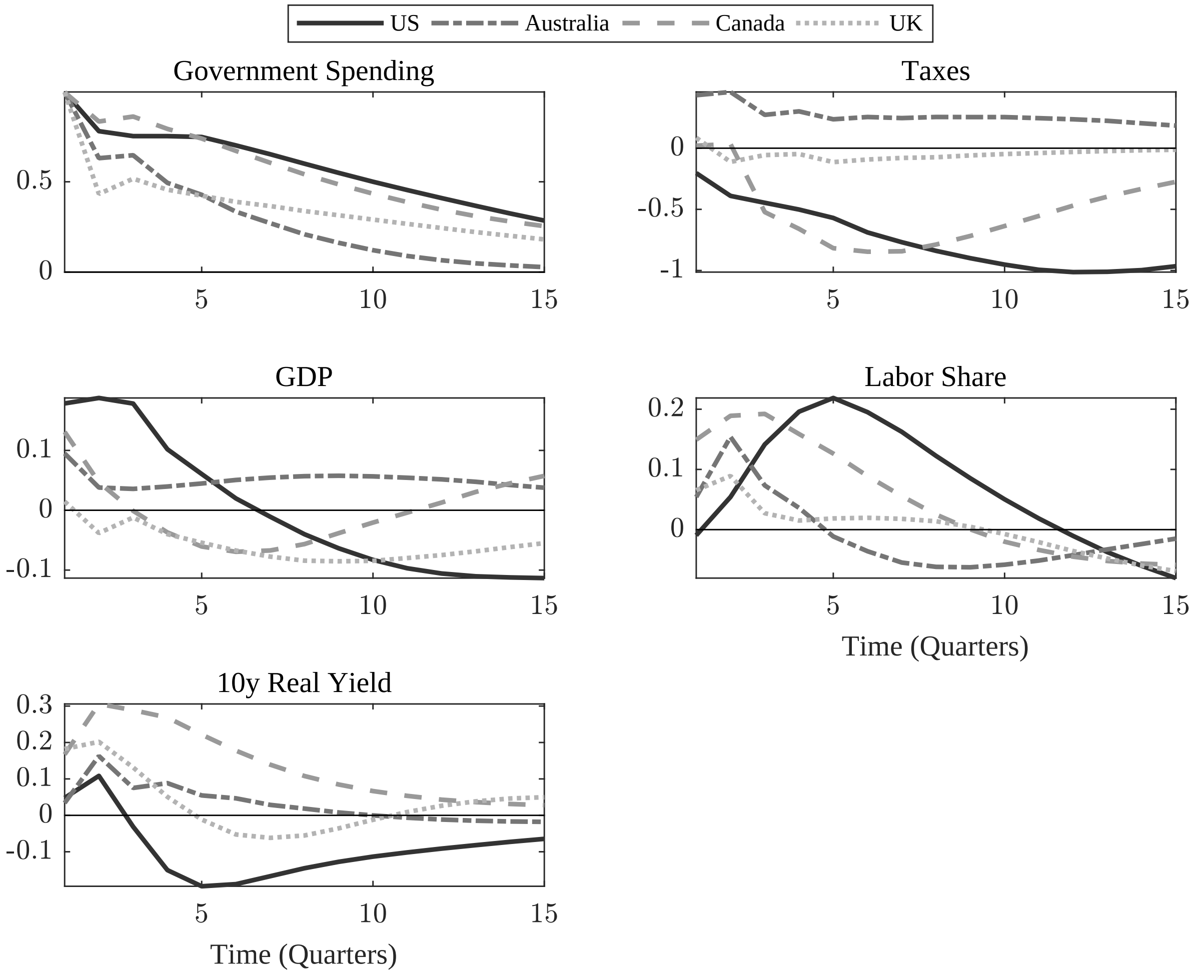


Figure 2: VAR: Surprise Shock to Government Spending – Australia, Canada, UK

Notes: Impulse responses are scaled such the log change of government spending is unity at its peak. All series except interest rate shown in %.

The preceding few paragraphs made the point that unanticipated government spending shocks have not only aggregate consequences but also induce a redistribution from firm owners to workers. This observation helps motivate, from an empirical and conceptual angle, the development of a novel two-agent New Keynesian model that distinguishes in a stylized fashion between agents primarily relying on labor income (workers) and those owning the economy's physical capital as well as dividends-distributing firms.

3 The Model

This section presents the capitalist-worker (CW) TANK model at the heart of this paper and explains its key properties. CW-TANK has obvious roots in the traditional OR-TANK model (Galí *et al.*, 2004, 2007), featuring optimizers and rule-of-thumb agents. In a motivating step, we therefore begin by summarizing two sets of limitations that the OR-TANK suffers from (Subsection 3.1). Against this backdrop, Subsection 3.2 describes a bare-bones version of the CW-TANK model and Subsection 3.3 carefully describes how our two main modeling innovations affect the transmission mechanism of fiscal policy.

3.1 Motivation

While highly tractable and influential, the macroeconomic literature has flagged two distinct dimensions of problems confronting the the traditional OR-TANK model.[15] The first set of issues relates to the aggregate dynamics in response to shocks implied by the OR-TANK model and, specifically, difficulties it has in matching the empirical evidence under a plausible parameterization. Second, and as emphasized in the introduction, the recent HANK literature has pinpointed limitations to the transmission mechanism of the OR-TANK model that arise due to the characteristic OR household structure. Considering these two items in turn, it bears repeating first that the OR-TANK model of Galí *et al.* (2007, GLV herewithin) was built primarily to overcome the wealth effect present in representative-agent models following a government spending shock that implies a crowding-out of consumption that is inconsistent with the empirical evidence. Consider Figure 3, which reproduces Figure 5 in Colciago (2011) and shows the responses of three variants of the OR model to a one percent increase in government spending. As in Colciago (2011), 50% of people are assumed to follow rule-of-thumb behavior across model variants. With flexible prices (dark-solid line) output is not demand-determined and, consequently, the stimulative effect of an increase in government purchases is negligible. We note, furthermore, that the labor share does not move. Adding sticky prices we obtain the GLV model. In this setup, output is now demand-determined and, therefore, the fiscal stimulus boosts output by shifting the labor demand curve outwards (as per dark-dash-dotted line).

Importantly, the presence of limited asset market participation in the form of rule-of-thumb households raises the average impact MPC in the model and generates higher aggregate consumption (*crowding-in*). The labor share now is just the mirror image of the price mark-up and therefore increases in line with our empirical evidence, however, without displaying the hump shape noted in the VAR study. There are, however, some drawbacks to this setup. For one thing, Colciago (2011) and Ascari *et al.* (2017) show that the implications of limited asset market participation as in the OR-structure, while attractive from a data-matching perspective, are not robust to, or at least significantly dampened by the introduction of nominal wage stickiness (see also Furlanetto (2011)). Even if the implied dynamics for consumption

[15]This two-part structure is motivated by the framing used by Kaplan and Violante (2018) in their comparison of representative agent New Keynesian (RANK) and HANK models. The authors disambiguate between three distinct notions of equivalence. Non-equivalence describes situations where the impulse response functions (IRFs) are different; weak equivalence occurs when IRFs are highly comparable, however, the underlying transmission mechanisms differ; and strong equivalence captures those situations where both IRFs and transmission mechanisms are the same.

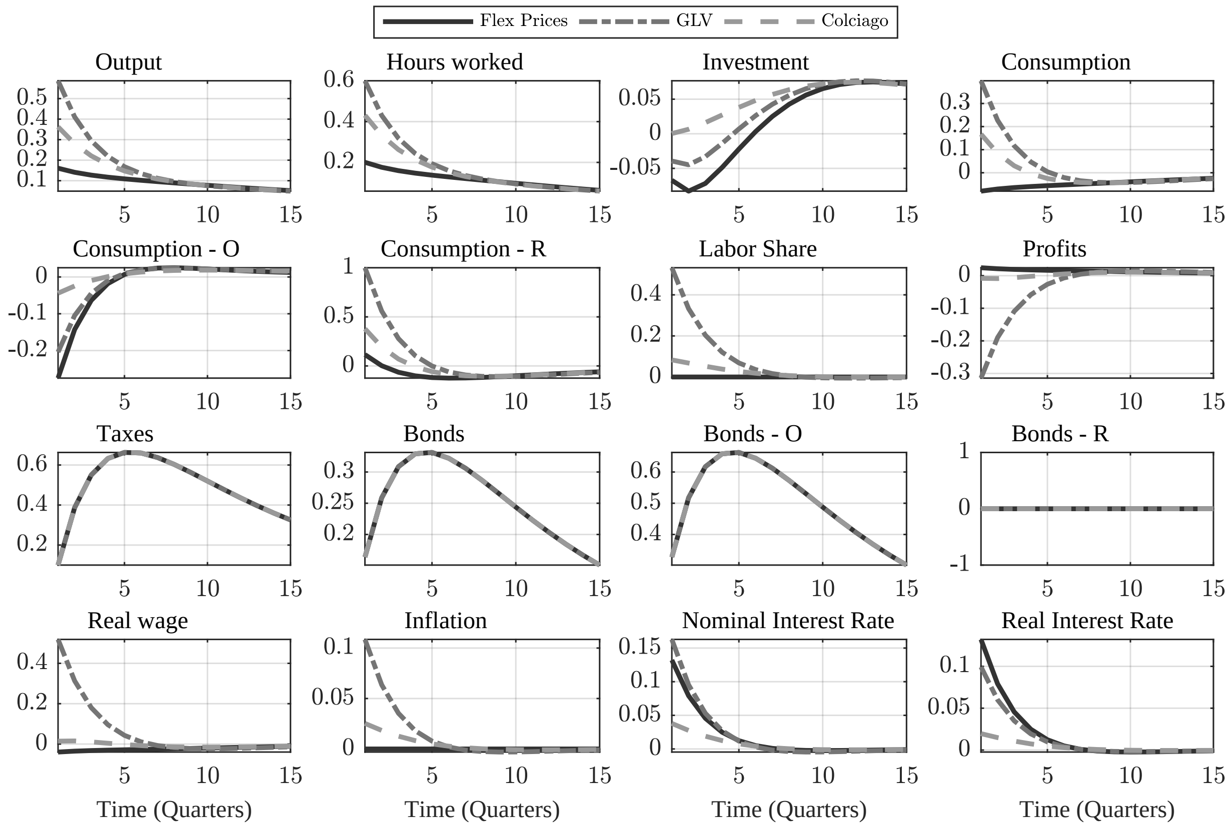


Figure 3: Impulse Responses to a Shock to Government Spending – Motivation

Notes: Selected variables in OR type models with: (i) flexible prices, (ii) sticky prices as in Galí *et al.* (2007, GLV), (iii) sticky wages as in Colciago (2011, Colciago). Relative to Colciago (2011), we add some extra variables of interest and use investment adjustment costs as opposed to capital adjustment costs, without this choice affecting the qualitative properties of the IRFs. Everything else, including the calibration, is exactly as in Colciago (2011). All series are in proportional deviations from the steady-state (in %) except for profits and bonds (absolute deviations). Shock size: one percent increase in government spending.

and output are reasonable, adding nominal wage stickiness to OR-TANK has the drawback of generating (conditionally) acyclical wages and weakly procyclical investment following government spending shocks (grey-dashed lines), two results that are at odds with the empirical evidence.[16]

As far as the second nexus of issues is concerned, Auclert *et al.* (2018) stress that the OR-TANK model is unable to capture the pattern of intertemporal marginal propensities to consume (iMPCs) that may be found in micro data and matching which is crucial for replicating the dynamic response of consumption and output to a change in the path of fiscal variables. Figure 4 shows how in both Norwegian administrative data (as prepared by Fagereng *et al.* (2018)) and the Italian Survey of Household Income and Wealth (SHIW), in response to an unanticipated temporary increase in income, households consume around half of the windfall in the year of the impact, on average. Notably,

[16]A distinct but related problem starts with the observation that in the baseline OR-TANK model, a very high Frish elasticity of labor supply – a value of around ten – is required to ensure determinacy, as GLV underscore. Adding sticky wages resolves this indeterminacy problem, however, this comes at the costs mentioned in the main text.

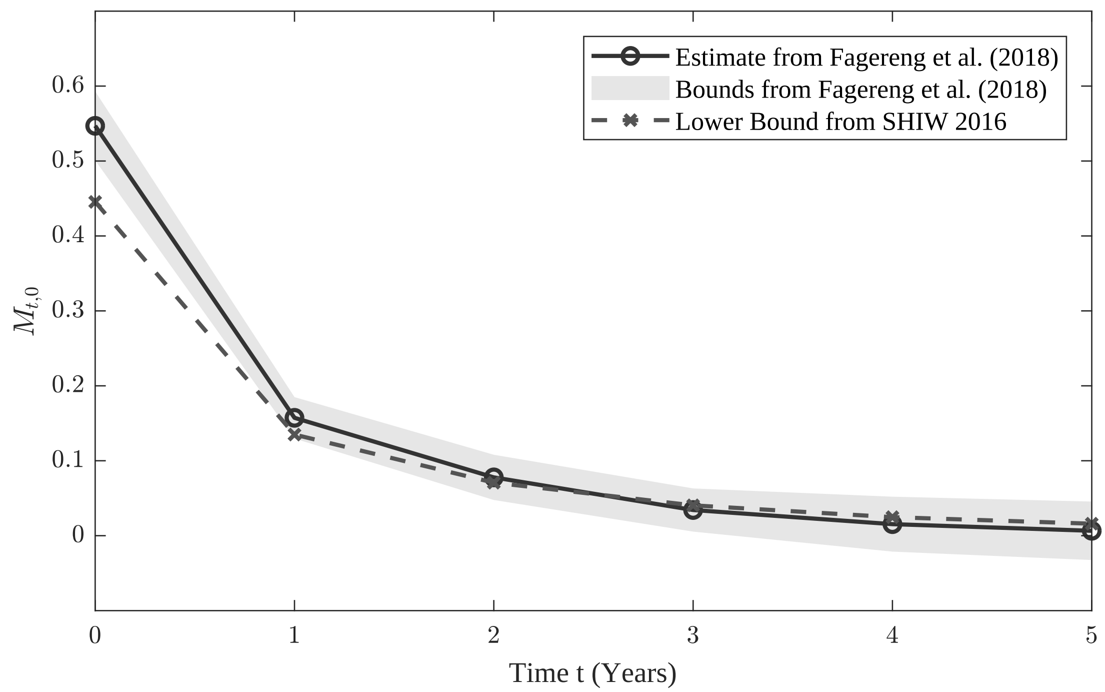


Figure 4: iMPCs in the Data

Notes: Replication of Figure 1 in Auclert *et al.* (2018). We are grateful to the authors for generously sharing their source data.

the iMPCs remain elevated thereafter, displaying a pattern of gradual decay. By contrast, while the OR-TANK can be calibrated to match the high impact effect, the iMPCs sharply drop in the following periods as rule-of-thumb households consume all the additional current income immediately upon receipt. The stark form of limited asset market participation in OR-TANK also mans that the model entirely misses the intertemporal path of iMPCS when it comes to past income shocks (Bilbiie, 2019a). The second theoretical drawback, common to RANK and OR-TANK, is that the presence of both profits and labor income in the budget constraint of optimizers generates implausible labor supply effects due to variations in profits over the business cycle. Broer *et al.* (2019) discuss this issue in the context of the textbook RANK model, whereas Bilbiie (2008) underscores its significance for the transmission mechanism embedded in the OR-TANK model.

3.2 Capitalist-Worker TANK Model

Here we present the CW-TANK model in its simplest possible version. It deviates from the standard OR-TANK model of GLV along two dimension. First we replace rule-of-thumb (R) households with "workers" (W). The latter as the former receive income only from supplying labor but not from renting out physical capital or holding firm shares, however, we generalize Rs behavior insofar as Ws can partially smooth consumption through borrowing and saving in government bonds in a constrained manner. The degree of financial constraints is controlled by a quadratic portfolio adjustment cost. When this adjustment cost approaches to infinity, the behavior of Ws reduces to that of following a rule-of-thumb. The second modification is that capitalists (C) do not provide labor to the representative firm and therefore do not receive wage income, different from standard optimizers (O). Capitalists invest in capital and receive profit income from firms ownership. We allow the proportion of types to vary: Households in the interval $[0, \lambda]$ are workers and the remaining people in $(\lambda, 1]$ are referred to as capitalists. Variables associated with the former are indexed by W, those linked to capitalists by C.

As the remainder of the model is as in GLV – a continuum of firms produces differentiated intermediate goods given a standard Cobb-Douglas production function and are subject to Calvo staggered price-setting, while the retail sector is competitive – we omit most details in the interest of space and only discuss the ingredients that are crucial for our analysis.[17] We start by looking at a setting in which product prices are sticky while wages are flexible in order to analyze the transmission mechanism driven by our modeling choices when workers are still on their labor supply curve. We include endogenous capital accumulation subject to investment adjustment costs because we want to match the response of investment to fiscal shocks. Fiscal policy is financed through a combination of government debt and lump sum taxes; for now we assume government debt to equal zero in steady-state. Monetary policy follows a simple Taylor-type rule that responds only to inflation.

3.2.1 Capitalists

Capitalists' preferences are defined over consumption C_t^C and described by the utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t U^C(C_t^C), \tag{1}$$

where E_t denotes rational expectations conditional on the information set at time t, $\beta \in (0, 1)$ is the discount factor, and U^C is a period utility function assumed to be strictly concave and strictly increasing in C^C. In addition to trading in the risk-free nominal government bond (B_t^C), capitalists save by investing in (end of period) physical capital K_{t-1}^C, subject to depreciation (at rate δ), investment (I_t^C) adjustment costs ($S(X_t)$) with $X_t = I_t^C / I_{t-1}^C$.[18] They also receive profits from the ownership of firms (D_t^C). Capitalists pay (or receive) a net amount of lump sum taxes (transfers) from the government T_t^C. Finally Q_t denotes the price of capital in terms of consumption and R_t^K stands for the rental rate of capital.

[17]In Appendix A.3.1 we list the full set of equilibrium conditions of the medium scale version of the CW-TANK model estimated in section 4.2.

[18]Function S is assumed to satisfy $S(1) = S'(1) = 0$ and $S''(1) > 0$.

Denoting gross inflation by Π_t, capitalists' budget constraints can then be written as:

$$C_t^C + I_t^C + B_t^C \leq D_t^C + R_t^K K_{t-1}^C - T_t^C + \frac{R_{t-1}^n}{\Pi_t} B_{t-1}^C \tag{2}$$

$$K_t^C = (1-\delta) K_{t-1}^C + I_t^C \left[1 - S\left(\frac{I_t^C}{I_{t-1}^C} \right) \right]. \tag{3}$$

Box 3.1 compares the maximization problems of optimizers in OR-TANK and the one of capitalists here, showing that the only difference lies in the fact that capitalists do not suffer disutility from labor and do not receive any labor income.

Box 3.1 Optimizers vs Capitalists

Optimizers' optimization problem [O]:

$$\max_{C_t^O, B_t^O, I_t^O, \mathbf{H_t^O}} E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^O, \mathbf{H_t^O})$$

subject to

$$C_t^O + I_t^O + B_t^O \leq D_t^O + \mathbf{H_t^O W_t} + R_t^K K_{t-1}^O - T_t^O + \frac{R_{t-1}^n}{\Pi_t} B_{t-1}^O,$$
$$K_t^O = (1-\delta) K_{t-1}^O + I_t^O \left[1 - S\left(\frac{I_t^O}{I_{t-1}^O} \right) \right].$$

Capitalists' optimization problem [C]:

$$\max_{C_t^C, B_t^C, I_t^C} E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^C)$$

subject to

$$C_t^C + I_t^C + B_t^C \leq D_t^C + R_t^K K_{t-1}^C - T_t^C + \frac{R_{t-1}^n}{\Pi_t} B_{t-1}^C,$$
$$K_t^C = (1-\delta) K_{t-1}^C + I_t^C \left[1 - S\left(\frac{I_t^C}{I_{t-1}^C} \right) \right].$$

3.2.2 Workers

Workers preferences are defined over consumption C_t^W and labor H_t^W:

$$E_0 \sum_{t=0}^{\infty} \beta^t U^W(C_t^W, H_t^W), \tag{4}$$

In addition to receiving labor earnings ($W_t H_t^W$), workers are also able to save in the risk-free nominal government bonds (B_t^W). Workers' budget constraint can then be written as:

$$C^W{}_t + B_t^W + \frac{\psi^W}{2}\left(B_t^W - \bar{B}^W\right)^2 \leq H^W{}_t W_t - T_t^W + \frac{R_{t-1}^n}{\Pi_t} B_{t-1}^W + f_t^W. \tag{5}$$

where we follow Schmitt-Grohe and Uribe (2003) and introduce a portfolio adjustment cost (ψ^W) which penalizes workers in case their real bond holdings deviate from some benchmark level $\bar{B}^W$.[19] Finally to rule out any wealth effects, these costs are rebated to the workers as a lump-sum f_t^W (without being taken into account when taking savings decisions).

In box 3.2 we compare the maximization problems of rule-of-thumb in OR-TANK to that of workers, showing that the only difference lies in the fact that workers are allowed to save in government bonds, albeit at a cost that is higher than that faced by capitalists.

Box 3.2 Rule-of-Thumb Households vs Workers

Rule-of-thumb households' optimization problem [R]:

$$\max_{C_t^R, H_t^R} U(C_t^R, H_t^R)$$

subject to

$$C_t^R = H_t^R W_t - T_t^R.$$

Workers' optimization problem [W]:

$$\max_{C_t^W, H_t^W, \mathbf{B_t^W}} \sum_{t=0}^{\infty} \beta^t U(C_t^W, H_t^W)$$

[19] In general, portfolio adjustment costs can be rationalized along the lines of several explanations proposed for limited participation in asset markets (see discussion in Gálvez (2018)): the presence of trading costs (e.g., Vissing-Jorgensen (2002)); financial sophistication and financial literacy, or the lack thereof (e.g., Calvet *et al.* (2007); van Rooij *et al.* (2011)); and (the absence of) trust in financial markets (e.g., Guiso *et al.* (2008)).

subject to

$$C^W{}_t + \mathbf{B_t^W} + \frac{\psi^W}{2}\left(\mathbf{B_t^W} - \mathbf{\bar{B}^W}\right)^{\mathbf{2}} \leq H^W{}_t W_t - T_t^W + \\ + \frac{\mathbf{R_{t-1}^n}}{\mathbf{\Pi_t}}\mathbf{B_{t-1}^W} + \mathbf{f_t^W}.$$

3.2.3 Government and Aggregation

The fiscal authority finances government spending (G_t) by issuing debt (B_t) and levying lump sum taxation (T_t):

$$B_t = G_t + \frac{R_{t-1}}{R_t}B_{t-1} - T_t. \tag{6}$$

Lump sum taxes/transfers are given by the rule:

$$\frac{T_t^i - \bar{T}^i}{\bar{Y}} = \phi^{\tau B}\frac{B_t - \bar{B}}{\bar{Y}} + \phi^{\tau G}\frac{G_t - \bar{G}}{\bar{G}}, \tag{7}$$

with $i = C,\ W$. The central bank sets the nominal interest rate:

$$\log\left(\frac{R_t^n}{R^n}\right) = \theta^\pi \log\left(\frac{\Pi_t}{\Pi}\right) + \varepsilon_t^M. \tag{8}$$

The clearing of the bonds market requires:

$$B_t = (1-\lambda)B_t^C + \lambda B_t^W. \tag{9}$$

Given the two-agent structure of the model we follow standard TANK practice and define aggregate consumption, lump sum taxes/transfers, hours, capital, investment, and profits as:[20]

$$C_t = \lambda C_t^W + (1-\lambda)C_t^C \tag{10}$$

$$T_t = \lambda T_t^W + (1-\lambda)T_t^C \tag{11}$$

$$H_t = H_t^W \lambda \tag{12}$$

$$I_t = I_t^C(1-\lambda) \tag{13}$$

$$K_t = K_t^C(1-\lambda) \tag{14}$$

$$D_t = D_t^C(1-\lambda) \tag{15}$$

[20]The only differences with the standard OR-TANK in terms of aggregation are, therefore, in equations (6) and (12).

To close the model, the resource constraint can be written as:

$$Y_t = C_t + I_t + G_t. \tag{16}$$

3.2.4 Functional Forms and Calibration

In terms of functional forms, we adopt standard time-separable CRRA utility functions:

$$U^C(C_t^C) = \frac{{C_t^C}^{1-\sigma_c}}{1-\sigma_c} \tag{17}$$

$$U^W(C_t^W, H_t^W) = \frac{{C_t^W}^{1-\sigma_c}}{1-\sigma_c} - \nu^W \frac{{H_t^W}^{1+\varrho}}{1+\varrho}. \tag{18}$$

Table 1 summarizes how we parameterize the simple model. As the purpose of this section is primarily to explain how the CW-TANK model differs from the traditional OR-TANK specification, we adopt the same calibration as in Galí *et al.* (2007) whenever feasible in order to make the comparison in the fairest possible way. Most values are standard and we accordingly limit discussion to three key parameters: the relative share of agents of one type compared to the other, λ; ψ^W which indexes portfolio adjustment costs faced by workers; and the inverse Frisch labor supply elasticity ϱ. For the first of these, we follow GLV and set $\lambda = 0.5$, thus supposing that half of the population is of one type and half of the other.

Description	Parameter	OR	OW/CW
AR1 G shock	ρ^G	0.9	
Discount factor	β	0.99	
IES	σ_c	1	
Inverse Frish elasticity	ϱ	0.2	
Capital depreciation	δ	0.025	
Investment adj. costs	ϕ^X	2.5	
Price mark-up	$\zeta/(\zeta-1)$	1.20	
Calvo prices	ξ_p	0.75	
% of $\mathbb{R}/\mathbb{W}$	λ	0.5	
Portfolio adj. costs	ψ^W	∞	0.25 $\bar{Y}$
Tax response to B	$\phi^{\tau B}$	0.33	
Tax response to G	$\phi^{\tau G}$	0.1	
Interest rate response to Π	θ^π	1.5	
Steady State Hours	H	0.33	
Gov spending/Output	G/Y	0.2	
Labor Share	$1-\alpha$	0.67	
Debt to GDP ratio	B/Y	0	
Workers bond holdings benchmark	$\bar{B}^W$	-	0

Table 1: Calibrated Parameters (Simple Model)

Notes: This table lists the parameter values of the model. One period in the model corresponds to one quarter.

Second, for models involving workers we specify $\psi^W = 0.25\bar{Y}$ which in the present setting amounts to $\psi^W = 0.23$. In brief, this value targets the evidence from micro data on household-level partial equilibrium consumption responses to policy changes. Specifically, in a partial equilibrium consumption-savings problem, and conditional on $\lambda = 0.5$, this value of ψ^W delivers a an impact marginal propensity to consume at quarterly horizon, $M^q_{0,0} = \partial C_0/\partial Y_0$, equal to 0.2 (see Subsection 3.3.1 for an illustration). We take this magnitude for $M^q_{0,0}$ to be reasonable in light of the empirical literature (for a succinct overview of that literature, see Wolf (2019)). For instance, Mitman *et al.* (2019) cite the middle range of *annual* impact iMPCs out of transitory income as 0.4, while Auclert *et al.* (2018) find the median year-1 iMPC in the Norwegian administrative data evaluated by Fagereng *et al.* (2018), to be approximately equal to 0.55 (in the Italian Survey of Household Income and Wealth it is equal to 0.45; see Figure 4). While there is no immediate way to convert these figures to quarterly frequency, we take $M_{0,0} = 0.2$ to be a reasonable quarterly value to target.[21] Finally, because the OR-TANK model requires a high Frisch elasticity of labor supply to avoid indeterminacy, as explained by GVL, we set $1/\varrho$ equal to 5. This is higher than usual and lies above the values typically found in the empirical literature (see, e.g., Attanasio *et al.* (2018)) and we switch to a more conventional unit value in quantitatively oriented applications.[22]

3.3 Model Comparison

In order to bring out as clearly as possible the implications of both departures from the standard OR-TANK model, we add each new type of agent in turn. That is, we first introduce workers alongside optimizers – the resulting model is labeled OW-TANK – thus highlighting the effects of quadratic portfolio adjustment costs. We then substitute capitalists for optimizers (yielding CW-TANK) to show how removing income effects due to profits on labor supply alters the properties of the model.

3.3.1 OR vs OW

Introducing workers who have the ability to save in form of government bonds, but constrained by portfolio adjustment costs into the model instead of rule-of-thumb households allows capturing an important feature in the micro data: the jump followed by a gradual decline of marginal propensities to consume following an income shock that is prominent in both the data and multi-asset HANK models. To see this, we first consider a partial equilibrium exercise. Figure 5 displays iMPCs based on

[21] If the simple relationship $M^a_{0,0} = 1-(1-M^q_{0,0})^4$ is used to convert between annual and quarterly figures, the annual impact iMPC of 0.55 would correspond to a quarterly rate equal to 0.18. Kaplan and Violante (2014) take 25 percent to be a reasonable approximation of the fraction of fiscal stimulus payments households spend on nondurable consumption in the quarter that they are received. With $M^q_{0,0} = 0.2$ we choose an in-between value (also cf. Fig. 2a in Kaplan *et al.* (2017)).

[22] For comparability, we also set up steady-state lump sum net taxes such that the consumption of two agents is equalized in steady state.

a simple consumption-savings intertemporal choice problem solved under perfect foresight. The top row considers an unanticipated income windfall received in period $t = 0$ while the bottom row instead suppose that the income shock hits in $t = 3$ and is anticipated from period $t = 0$ onward. Panels 5a and 5c are derived under the assumption that the economy is made up of Os and Ws, whereas panels 5b and 5d follow the traditional OR setup.[23]

In response to an unanticipated, temporary income shock, optimizers consume a constant fraction every period in line with the permanent income hypothesis. In stark contrast, consumers following a rule-of-thumb consume *all* the extra income on impact. Workers represent an intermediate case: the impact effect on (marginal) consumption is high but instead of dropping to $zero$ thereafter, the iMPCs remain elevated for several periods thereafter. As a result, the behavior of aggregate iMPCs in the OW model is remarkable similar to that found in the data and multi-asset HANK models. Put differently, even if the two models are calibrated such that the impact MPC $M_{0,0}$ is equal across the OW and OR configurations, as is deliberately the case in the Figure, the subsequent shape is in line with the empirical evidence only for the OW model but highly counterfactual for the OR model. The contrast between Ws and Rs can be visualized in a different way by considering an anticipated shock. Because Rs consume all of the extra disposable income in the period when the shock hits, the aggregate iMPC diagram is akin to a narrow tent. Given their limited ability to smooth consumers, Ws likewise consume *more* in period $t = 3$ when they actually receive additional income, but they also *borrow* against the future prior to the windfall and *save* some of it afterwards. As a result, the iMPC "tent" is wider.

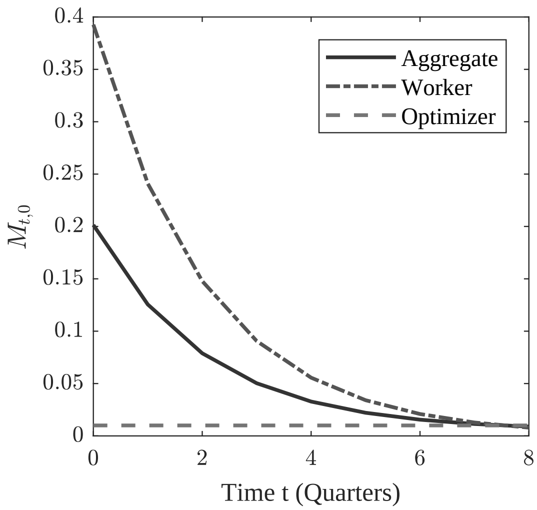
The OW model nests the OR model in that the latter is a special case of the former with $\psi^W \to \infty$. Viewed through this lens, our argument amounts to saying that the OW model is a useful generalization of the OR model, and that a more modest degree of limited asset market participation is not only more intuitively compelling but also has desirable implications for the behavior of iMPCs and, thus, the micro-structure of the model.

What are the implications of replacing R-agents with W-agents for macroeconomic dynamics and the transmission of fiscal policy in general equilibrium?[24] Figure 6 compares the impulse responses of selected variables under the two model specifications (the case of CW is discussed below). In both models, the increase in government purchases raises the overall level of aggregate demand and, in the presence of sticky prices, shifts the labor demand curve outwards. As result, both hours worked and real wages increase. As is characteristic of TANK models, limited asset market participation raises impact-MPCs above the level implied by the permanent income hypothesis. Consequently, both Rs and Ws use their now higher levels of disposable labor income to increase their levels of consumption.

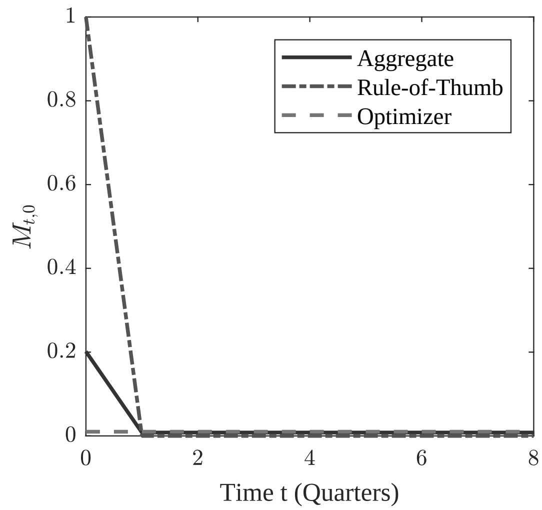
[23]When interpreting magnitudes and comparing them to the empirical iMPCs in Figure 4, note that a period in Figure 5 is a quarter, whereas the empirical data are in annual terms.

[24]Since all variables are simultaneously determined in a dynamic general equilibrium, the following description of the transmission mechanism is inevitably simplifying. Notwithstanding, it conveys the underlying intuition and draws attention to the relevant points of difference between the two models.

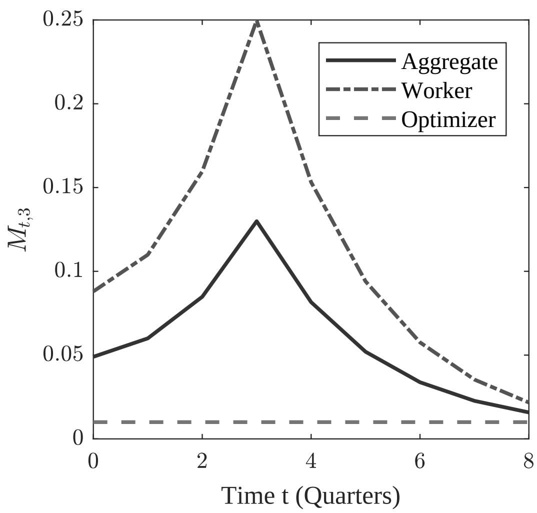
(a) OW: unanticipated $t = 0$ shock



(b) OR: unanticipated $t = 0$ shock



(c) OW: anticipated $t = 3$ shock



(d) OR: anticipated period $t = 3$ shock

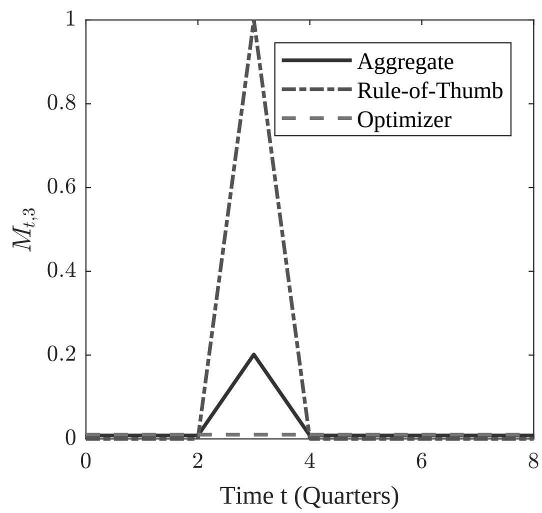


Figure 5: iMPCs – The Role of Portfolio Adjustment Costs

Notes: Panels 5a and 5b show the dynamic response to a period $t = 0$ unanticipated income shock for the model with workers and rule-of-thumb agents, respectively. Panels 5c and 5d show the responses to a foreseen income shock, with the additional income being received in $t = 3$. All figures are based on a simple, partial equilibrium consumption-savings problem with perfect foresight. In the OW model, the fraction of optimizers is set to $1 - \lambda = 0.5$, with $\psi^W = 0.25$, yielding an impact MPC $M_{0,0}$ equal to 0.2; in the OR model λ is adjusted such that the model likewise yields $M_{0,0} = 0.2$ (with $\psi^R \to \infty$).

Meanwhile, for optimizers the combination of relatively less benign income dynamics – the flipside of rising wages is a fall in profit income – and the anticipation of higher future taxes and relatively higher absorption of government bonds means that the consumption of Os falls. As such, fiscal policy shocks have not only *aggregate* but also important *redistributive* effects, in line with the empirical evidence. Additionally, optimizers increase their labor supply as a matter of intra-temporal smoothing, which in general equilibrium dampens the rise in real wages (the opposite income effects operate for Rs and Ws, respectively).

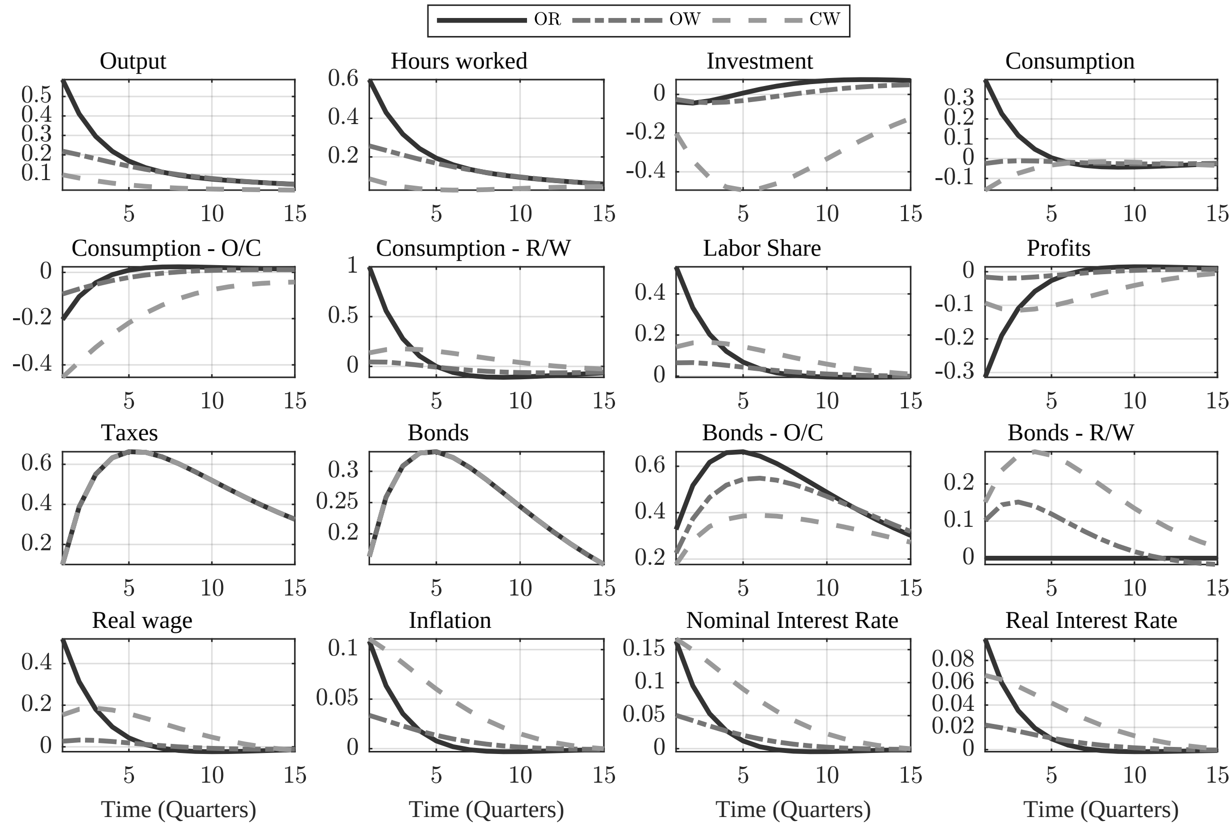


Figure 6: Impulse Responses to a Shock to Government Spending – Simple Models

Notes: Selected variables in OR, OW and CW models. All series are in proportional deviations from the steady-state (in %) except for profits and bonds (absolute deviations). Shock size: one percent increase in government spending.

Comparing the two models, aggregate dynamics in the OW-TANK are significantly more dampened. The ability of Ws to save in form of government bonds (see panel for B_t^W) reduces their iMPCs on impact and, therefore, reduces their consumption following the fiscal expansion. As a result, labor demand and, ultimately, wages likewise rise by less. Furthermore, in a reflection of the empirically realistic, gradual decay of iMPCs, workers' consumption level not only jumps up less on impact than that of Rs but it also declines more slowly thereafter. Importantly, this generates a more gradual and (mildly) hump-shaped path for consumption as well as wages. A by-product of matching the micro data on iMPCs is, therefore, that the model does not required habits in consumption to generate a hump shaped IRF for aggregate consumption. This property is more pronounced for higher values of λ, as appendix A.3.2 shows (e.g., Figure 16). We believe this to be significant in light of the argument of Auclert *et al.* (2019) that the standard way of introducing habits into DSGE models may help capturing "macro humps," but is inconsistent with such empirical evidence on "micro jumps," as exemplified by the study of dynamic consumption responses to income shocks. [25] In summary, by mimicking

[25]Indeed, as the authors demonstrate, adding habits to a standard RANK model implies increasing rather than decreasing

the distribution of dynamic iMPCs characteristic of the data and replicated by HANK models, the OW-TANK model delivers a plausible dynamic consumption response.

3.3.2 OW vs CW

Figure 6 also show the IRFs for the CW model. As just described, the OW model has attractive properties compared to OR, yet it still features the undesirable income redistribution effect on labor supply highlighted by Broer *et al.* (2019) in the context of their analysis of the NK monetary policy transmission mechanism (also see Bilbiie (2008)). The distinguishing feature of CW compared to OW is that Cs unlike Os do not work and, accordingly, do not receive any labor income.[26] Unlike Os, capitalists' disposable income does not include the procyclical component of labor earnings. Given the constraints imposed by the presence of investment adjustment costs and access to bond markets, they optimally use all three margins of income adjustment in response to a government spending shock. That is to say, they curtail consumption by more than Os; they cut back on investment spending more severely; but they also purchase relatively fewer of the bonds issued by the government to finance the now higher fiscal expenditures. Importantly, even though capitalists' consumption suffers to a significant extent, by construction this has not implications for total hours worked. In particular, the drop in profits does not exert an expansionary wealth effect on labor supply. As a result, aggregate hours and production barely move. The combination of an increase in labor demand due to additional government expenditures combined with (no labor supply response by capitalists and) a decline in labor supply by now better off workers implies that real wages rise relatively more strongly. Combined with the behavior of consumption by Cs and Ws, respectively, it may be inferred that according to CW-TANK: (i.) government spending shocks do affect the economy by boosting national income, but the fiscal multiplier may be muted; and (ii.) discretionary fiscal policy interventions of this type have significant redistributive effects by shifting income from capitalists to workers.

first differences for the dynamic consumption response to an unanticipated income shock. The same would hold for OR-TANK.

[26]Of course, this is unrealistic insofar as even the income of the wealthiest ten percent of individuals in the US, for instance, derives from labor, according to the Survey of Consumer Finances. From a modeling perspective, the point, though, is that variations in profit income do not have income effects. Our "capitalist" specification captures this idea in a stylized form. One rationale is that having high levels of income decreases the *relative* income effect of profit variations. An alternative, and complementary view assumes employment elasticities that are lower for highly paid and capital-owning individuals on the view that those tend to derive greater utility from their jobs than less well paid workers do. Indeed, since in this paper we care not about steady-state levels but, rather, about deviations, one could also imagine that capitalists *do* receive income from working but their labor supply is not subject to income effects.

3.3.3 Robustness

Before considering the introduction of nominal wage rigidities, this section briefly presents a sensitivity analysis with respect to key parameters and discusses stability properties in order to further clarify the mechanics of the model(s).

Sensitivity. Up to now we presented results assuming that half of the agents in the economy are Os/Cs and half are Rs/Ws, respectively. But how does varying λ alter the dynamics of the model? As we show in Appendix A.3.2, a higher λ is associated with a higher average MPC and, therefore, generates a more positive consumption response in both OR and CW. Compared to the rule-of-thumb case, however, introducing portfolio adjustment costs (or more precisely, costs less than infinity) implies that the elasticity of consumption (and output) with respect to discretionary government spending is lower. Consequently, CW need a larger value of λ than OR does in order to generate a given amount of consumption crowding-in. As we show in the next section, however, introducing sticky wages mutes or even reverses this difference between OR and CW.

The second key parameter is the portfolio adjustment cost ψ^W. Appendix A.3.3 shows that raising this parameter value has complex effects in CW-TANK. In the OW setting, raising ψ^W strengthens both redistributive and aggregate effects of fiscal policy insofar as consumption of Os (Ws) falls (rises) more but overall consumption is generally more positive. In the CW model, this is not necessarily the case. An increase in the adjustment costs still increases the redistributive effect of fiscal policy by raising workers' marginal propensity to consume out of current income yet aggregate consumption actually falls. What explains this difference is the behavior of labor supply. In OW, redistribution towards workers straightforwardly increases the general equilibrium effects of government spending on overall demand, but the fall in optimizers' disposable income also induces them to supply more labor, boosting total production other things equal. In CW, on the other hand, this second, supply-side effect for capitalists is deliberately turned off, so that the rise in labor demand is combined with a response in workers' labor supply only, which is potentially negative due to the rise in workers' labor income.[27]

Stability. The CW-TANK model does not suffer from the usual indeterminacy issues associated with the conventional OR framework. A major issue with the latter specification is the presence of an inverted Taylor principle for high enough values of λ (Bilbiie, 2008). In Appendix A.3.4 we compare the stability properties of the three models and show how adding portfolio adjustment costs re-establishes a standard Taylor principle (see Figure 19).[28] Indeed, almost any combination of λ and price stickiness generates a stable and unique equilibrium in CW-TANK. Moreover we find that,

[27]The net effect of higher market income, on the one hand, and higher taxes, on the other hand, is ultimately a numerical question and, furthermore, significantly depends on the financing mix between taxes and debt. See Section 4.1 for details. We furthermore stress that in CW-TANK, the effects on output of raising ψ^W importantly depend on the value of the Frisch labor supply elasticity.

[28]In the CW model we find the presence of an inverted Taylor principle but only for implausibly low values of λ.

contrary to the standard OR-TANK, the stability of the CW model is independent of the value of the Frish elasticity of labor supply. In the latter, sticky wages can be used to mitigate indeterminacy issues, however, with potentially undesirable side effects (Ascari *et al.*, 2017). We next ask if this same problem presents itself also in the context of CW-TANK.

3.3.4 Nominal Wage Stickiness

Introducing nominal wage stickiness to the simple CW-TANK model is not only consistent with ample empirical evidence on the existence of nominal wage rigidity (Barattieri *et al.*, 2014), but it turns out to also help with matching conditional moments. Indeed, here we show that adding wage stickiness as in Schmitt-Grohe and Uribe (2004) helps the simple CW-TANK model to match the signs of all the variables studied in the empirical part of the paper. Additionally, it also aids with matching the dynamic profile over time.[29]

As extensively highlighted in the DSGE literature, making nominal wages rigid has two main effects. First, the shift in labor demand triggered by the fiscal spending shock results in larger responses in employment and a more modest response in real wages compared to the flexible wage case (cf. Ascari *et al.* (2017)). This is the main reason why wages are acyclical in Colciago (2011), Furlanetto (2011), and Figure 3. As a result, variations in profits and hence in the dividend income of Cs (or Os) are likewise more modest. Unlike in the OR model, however, these more muted variations have no direct implications for the labor supply of capitalists – in that sense, the predictions of the CW model for aggregate dynamics tend to be more robust to the introduction of nominal wage stickiness. Second, nominal wage stickiness reinforces the hump-shaped profile of wages and, hence, also labor income following a government spending shock. The intuition is straightforward: initially, only a fraction of wages is raised; gradually, as wages can adjust to a greater degree, labor income grows more rapidly.

Figure 7 confirms that sticky wages limit the extent to which government spending shocks have general equilibrium income redistribution effects compared to the case with only sticky prices. Notably, shifts in labor demand and labor supply now generate a mix of greater employment and hence production, on the one hand, and higher wages, on the other hand. As a result, workers dispose of greater labor income, which they partially use for consumption purposes while also taking some of the additional income in form of savings through bonds. The flip-side of this is that capitalists' experience a less drastic fall in profit income and, consequently, reduce expenditures on consumption and capital formation to a lesser degree compared to the flexible wage case. Importantly, aggregate output rises more strongly despite investment falling, as consumption gets crowded-in (modestly given $\lambda = 0.5$, but more strongly for

[29]Since in CW only one type of households earns labor income, the setup of wage stickiness is simpler insofar as the union negotiating on behalf of workers need not weigh the consumption of different types according to different marginal utilities.

higher values).

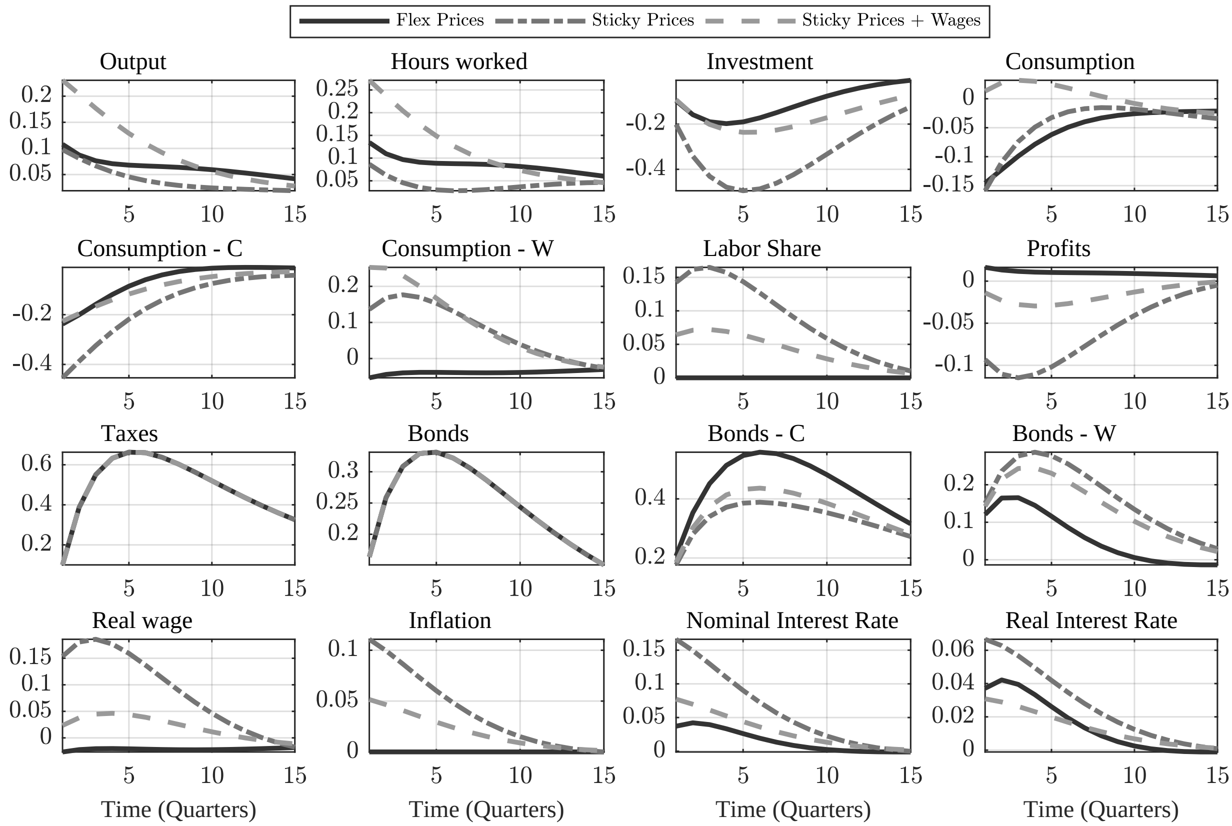


Figure 7: Impulse Responses to a Shock to Government Spending – Nominal Rigidities

Notes: Calvo parameter values under the different specifications are as follows: flexible prices: $\xi_p = \xi_w = 0$, sticky prices only: $\xi_p = 0.75$, $\xi_w = 0$; sticky prices + wages: $\xi_p = 0.75$, $\xi_w = 0.8$ All variables in proportional deviations from steady-state except profits and bonds, which are shown in absolute deviations. Shock size: one percent increase in government spending.

4 Applications

4.1 CW-TANK and Fiscal Stimulus Design

This section uses the CW-TANK model developed in Section 3 to study how alternative designs of a fiscal stimulus differ in terms of both *aggregate* and *distributional* effects. The application has a threefold purpose: to further illustrate the transmission mechanism(s) embedded in the CW-TANK model; to demonstrate the suitability of this tractable, structural framework as a laboratory for policy experiments; and, finally, to verify that our two-agent framework captures the *logic* and *implications* for fiscal policy developed by both Auclert *et al.* (2018) and Mitman *et al.* (2019) in full-blown heterogeneous-agent models. As stressed at the outset, we do not believe that TANK models of any kind represent a substitute for HANK models but, instead, are interested in the ability of such a simplified framework to replicate some of the key ideas identified as significant in a more complex setting. To maximize transparency, we retain the simple model described in Section 3.2 with sticky wages, that is, without the additional frictions we include subsequently when estimating the model. We note, though, that the logic of the experiment carries through to a larger model; indeed, the quantitative implications as it relates to the magnitude of consumption crowding-in, for instance, are likely more plausible when incorporating bells and whistles. We compare two alternative financing schemes for an unanticipated, one percent discretionary increase in government spending. Specifically, we examine the implications of raising the degree of deficit financing compared to the benchmark. Practically, we implement this by lowering the fiscal policy rule coefficient on government spending in the rule for lump-sum taxes. To illustrate, in the extreme with $\phi^{\tau G} = 0$ the government does not rely on any tax increase to finance the stimulus, whereas with $\phi^{\tau G} = 1$ no additional debt is issued.

Figure 8 shows that in the CW-TANK model, raising the degree of deficit-financing – as illustrated by comparing the black-solid line to the grey-dashed line – implies more stimulative effects of government spending shocks for aggregate output. There is, furthermore, a stronger redistribution from capitalists to workers, as reflected in the greater increase of the labor share but also the more pronounced rise in the consumption of workers and fall in that of capitalists. Notably, aggregate consumption is crowded in only if the degree of deficit financing is sufficiently high, whereas the fall of investment following the shock is correspondingly deeper. As such, deficit-financing implies differential dynamics not only for *aggregate* variables but also has implications for the *composition* of private sector expenditures both in terms of *who* is spending and *what* they are purchasing.

These results are in line with the finding of Mitman *et al.* (2019) in the context of a medium-scale HANK model that deficit-financed spending is more effective in stimulating the economy than tax-financed expenditures. In addition, the CW-TANK also mimics the transmission channel described in that paper, which hinges on a redistributive component. In their environment, deficit financing "implicitly redistributes from asset-rich households with low MPCs who finance their consumption more from asset income to low-asset households with high MPCs who rely more on labor income so that the aggregate MPC increases" (p. 7). The transmission mechanism embedded into the CW-TANK model is similar in spirit. A fiscal expansion increases labor demand and therefore workers' earnings. Under deficit-financing, the offsetting effect through higher taxes is more limited and, hence, workers' post-tax disposable income is higher. Given workers' relatively high propensity to consume, their goods demand increases in a sustained manner. On the other hand, capitalists act in a Ricardian fashion and, therefore, when the government alters the balance between deficit- and tax-finance this has no *direct* impact on capitalists' consumption choices. There is, however, an important *indirect* effect based on implicit redistribution. When aggregate demand is higher due to deficit-financing (as per the aforementioned logic), wages are pushed up whereas profits are compressed. Workers consequently are in a position

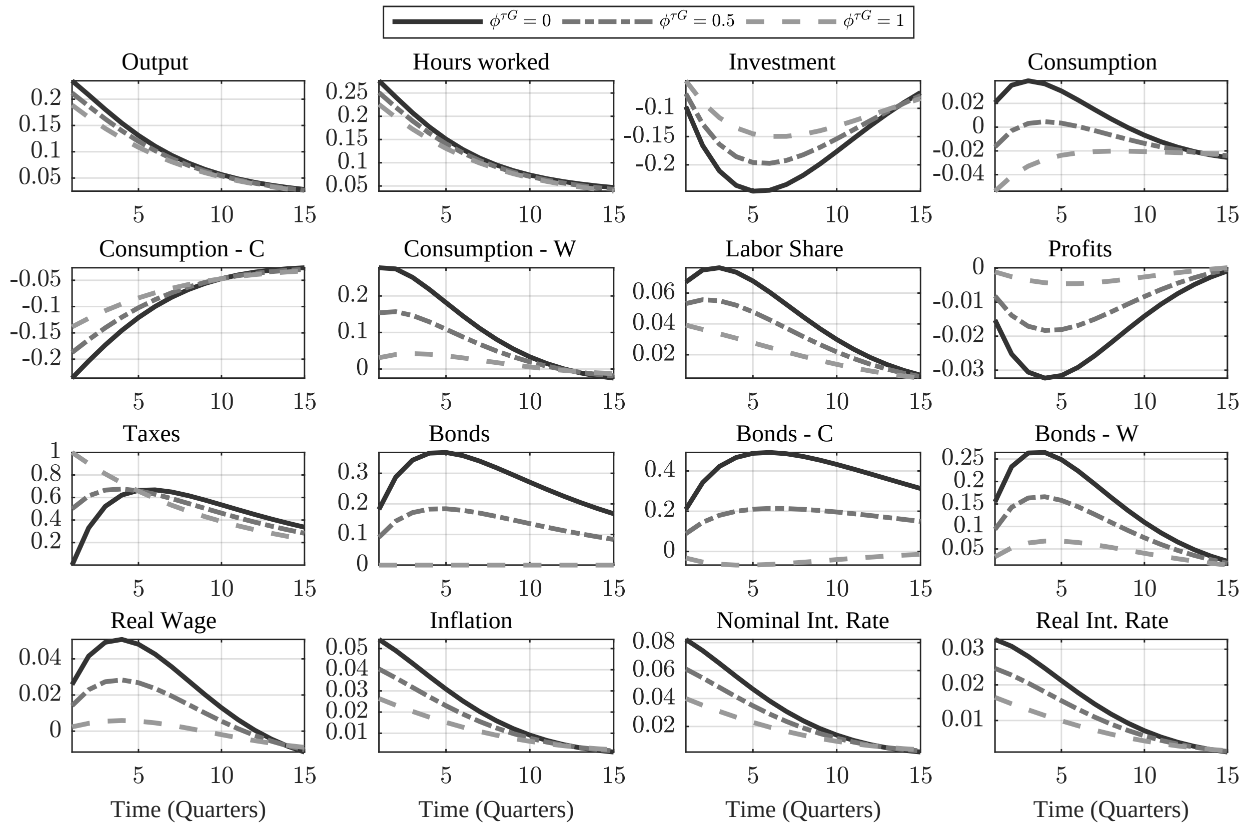


Figure 8: Fiscal Stimulus Design – Deficit-Financing

Notes: All variables are in proportional deviations from the steady-state (in %) except for profits and bonds (absolute deviations). Shock size: one percent increase in government spending. The lower is $\phi^{\tau G}$, the greater the degree of deficit-financing.

to increase their consumption even further while capitalists are forced to cut back theirs. Given heterogeneous spending propensities this redistribution further reinforces the demand-led boom.[30] As in Mitman *et al.* (2019) and Auclert *et al.* (2018), greater deficit-spending also leads to a more positive response of inflation and, hence, of the real interest rate, triggering a stronger crowding-out effect for investment. In total, output still increases significantly because the crowding-in of worker consumption due to the redistribution channel is stronger than the crowding-out of investment.

4.2 An Estimated Medium-Scale CW-TANK Model

The simple CW-TANK framework is successful on multiple accounts: it matches dynamic consumption responses without resorting to extreme iMPCs, removes the income effects of profits on labor supply,

[30]Another way of seeing the redistributive element draws attention to what is happening on the supply side of the economy: the rise in production is not proportional to the increase in workers' consumption. The reason is that now richer workers reduce their labor supply, which has a negative effect on hours worked but also pushes up wages and, hence, the labor share of income.

and generates a substantial redistribution from profits to wages following a government spending shock in line with our empirical evidence. Here we study the ability of an enriched CW-TANK model to match the empirical impulse responses to a government spending shock identified in Section 2 using Bayesian impulse response matching. The key questions are whether the model (i.) is able to fit the data, and (ii.) can do so for a plausible set of parameter values. Additionally, the exercise turns out to have the corollary benefit of illustrating the capacity of the CW-TANK model to generate a quantitatively relevant degree of consumption crowding-in. For recall that in the simple model and assuming equal shares of workers and capitalists, a side effect of the strong fall in capitalists' consumption is to drag down aggregate consumption, limiting the extent of consumption crowding-in that was the primary *raison d'être* of OR-TANK models. In the estimated model, instead, the fraction of workers is greater than that of capitalists and the conditional response of private consumption to a fiscal shock is significantly positive.

As our objective is to match the empirical impulse responses, and making use of the fact that TANK models are easily enriched, solved, and estimated, we extend the framework to allow for other ingredients typically found in medium-scale DSGE models. These are: price and wage indexation, fixed costs in production, variable capital utilization, and a more general Taylor rule featuring both interest rate smoothing and a non-zero response to the output gap.[31] In Appendix A.3.1 we present the full list of equilibrium conditions of the medium-scale CW-TANK model.

4.2.1 Calibration and Bayesian Impulse Responses Matching

Here we describe the calibration and estimation of medium-scale variants of OR- and CW-TANK. To this end, we follow Christiano *et al.* (2010) and estimate the DSGE model using Bayesian impulse response matching. This technique consists in estimating a selected number of parameters in the model by minimizing the distance between the SVAR- and the theoretical IRFs of interest. The impulse response matching technique was initially proposed by Christiano *et al.* (2005) in a monetary policy context, but has also been more recently applied to fiscal policy by Lewis and Winkler (2017). Here we opted for the more recent Bayesian variant proposed by Christiano *et al.* (2010) and subsequently used also by Christiano *et al.* (2016).[32]

We partition the model's parameters into two groups. The first group comprises parameters for which there exist conventional values in the literature (see Table 2). The values of the discount factor (β =

[31] Also, given that we now calibrate the model with a positive debt-to-GDP ratio in steady-state, we no longer need to write the fiscal rules in deviation from output as before and can adopt a more conventional specification. It would be no problem to add yet further frictions. Here we restrict ourselves to a "small medium-scale" model to demonstrate the ability of such a model to match the empirical IRFs.

[32] Given that we follow these papers closely, we refer the interested reader to Christiano *et al.* (2010) for a detailed technical discussion of the minimum distance estimator used here.

0.99) and of the capital depreciation rate (δ = 0.025) are standard for models calibrated at a quarterly frequency. We set the parameters of the utility function to deliver a logarithmic utility in consumption ($\sigma_c = 1$) and a Frisch elasticity of labor supply equal to unity (ϱ = 1). Results are, however, robust to different choices for the utility function. Intertemporal elasticities of substitution in the goods and labor market ($\zeta = 6$ and $\mu = 21$, respectively) are set as in Zubairy (2014) in order to match average mark-ups in the product and labor markets. In line with historical U.S. data, at the steady state, we set a government spending share of output of 20% ($G/Y = 0.20$). The gross inflation rate ($\Pi = 1$) implies a zero-inflation steady state, while the steady-state labor supply is set equal to 1/3 of the available time ($H = 0.33$). However, results do not hinge on these last two assumptions. The steady-state values of government debt is set to 57% of annual output ($\frac{B}{Y} = 4 \times 0.57$), which corresponds to the average value of the U.S. government debt to GDP ratio post II WW. In line with Dolado *et al.* (2018), workers' steady state bond holdings and benchmark level for the portfolio adjustments costs ($\bar{B}^W$) is set equal to 0.[33] Finally, in line with the bulk of the TANK literature, steady-state lump sum transfers/taxes are set such that there is no steady-state consumption inequality, since in this paper we are only interested in deviations from steady-state.

Description	Parameter	OR | CW
Discount factor	β	0.99
IES	σ_c	1
Inverse Frish elasticity	ϱ	1
Capital depreciation	δ	0.025
Price mark-up	$\zeta/(\zeta-1)$	1.20
Wage mark-up	$\mu^w/(\mu^w-1)$	1.05
Steady State Hours	H	0.33
Gov spending/Output	G/Y	0.2
Labor Share	$1-\alpha$	0.67
Debt to GDP ratio	B/Y	4*0.57
Workers bond holdings benchmark	$\bar{B}^W$	$-$ | 0

Table 2: Calibrated Parameters (Medium-Scale Models)

Notes: This table lists the calibrated parameter values of the medium-scale versions of the OR- and CW-TANK models. One period in the model corresponds to one quarter.

The second group of parameters is estimated such as to minimize the distance between the SVAR responses and the model's responses of five key variables: government spending, GDP, the labor share, private consumption and investment. Table 3 shows the choice of prior distributions. We use a Gamma distribution for the standard deviation of the government spending shock and a Beta distribution for the autoregressive parameter. For the percentage of rule-of-thumb/workers in the economy we use a Normal distribution centered around 0.5. The prior distribution for ψ^W is a normal centered around

[33]This choice is justified also by the analysis of Kaplan *et al.* (2017) who shows that the top decile of the wealth distribution holds 86% of liquid wealth.

0.19, a value chosen following the same rationale applied in calibrating the simple model (cf. 3.2.4).[34] Furthermore, for the Calvo price and wage rigidity parameters we use a Beta distribution centered around 0.5. The same distribution, with higher mean (0.7), is used for price and wage indexation. A Gamma distribution centered around usual values found in the literature is also used for investment adjustment costs, variable capital utilization, the response to inflation and output in the Taylor rule. Lastly, we use a Beta distribution for interest rate smoothing, tax smoothing and the response to government spending and debt in the fiscal rules.

4.2.2 Results

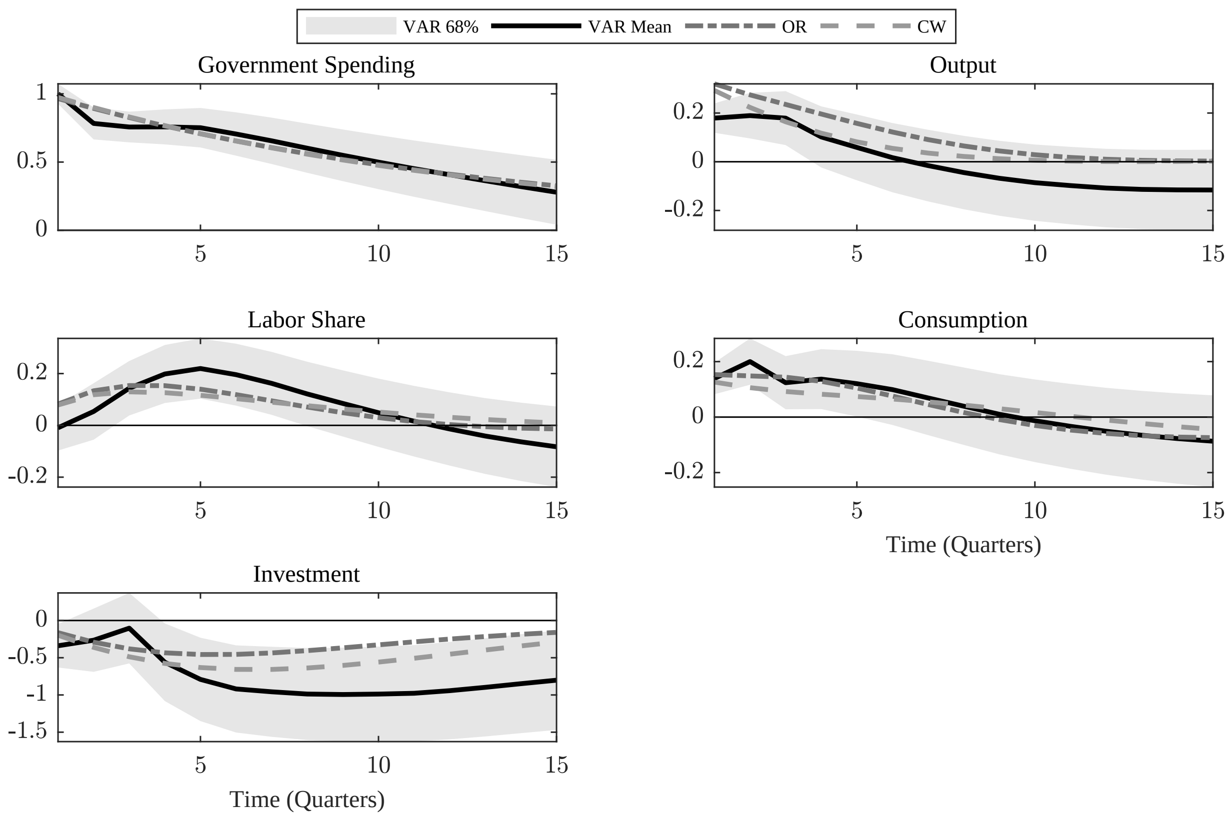


Figure 9: Bayesian Impulse Responses Matching – Model Fit

Notes: All series shown in %. Shock size: one percent increase in government spending.

Figure 9 illustrates the results of the IRF matching exercise. It reports as a shaded area the 68% empirical posterior density while the solid line represents the median responses from the SVAR. The theoretical IRFs are based on the posterior mean of the estimated parameters and presented as dashed-dotted (OR-TANK) and dashed (CW-TANK) lines, respectively. At a first sight, either model is

[34]The presence of fixed costs in this setup changes the steady-state value of net output and accordingly changes the prior mean of ψ^W compared to the calibration presented for the simple model.

capable of reproducing all the empirical reduced-form data remarkably well, except perhaps for the impact response of output and, only in the OR case, the response of investment 7 quarters after the shock. As such, this picture by itself does not give a strong reason to prefer one model over the other. To make such a ranking on credible grounds it is important to also consider whether the estimated set of parameter values underlying the theoretical IRFs is plausible.

Description	Parameter	Prior	Posterior Mean (95% HDP interval)	
			OR	CW
G shock	ε^G	$\Gamma(1, 0.05)$	0.97 (0.89, 1.04)	0.97 (0.90, 1.05)
AR1 G shock	ρ^G	$B(0.7, 0.15)$	0.93 (0.90, 0.95)	0.92 (0.90, 0.95)
Inv. adj. costs	ϕ^X	$\Gamma(4, 2)$	4.74 (1.37, 8.61)	3.17 (0.82, 5.99)
Calvo prices	ξ_p	$B(0.5, 0.2)$	0.81 (0.62, 0.97)	0.87 (0.77, 0.95)
Calvo wages	ξ_w	$B(0.5, 0.2)$	0.59 (0.41, 0.76)	0.62 (0.42, 0.81)
price index.	γ^p	$B(0.7, 0.2)$	0.34 (0.03, 0.82)	0.58 (0.20, 0.99)
wage index.	γ^w	$B(0.7, 0.2)$	0.80 (0.47, 1.00)	0.72 (0.35, 1.00)
Capital utilization	$\frac{\gamma^1}{\gamma^2} - 1$	$\Gamma(0.5, 0.2)$	0.45 (0.14, 0.82)	0.47 (0.14, 0.85)
% of $\mathbb{R}/\mathbb{W}$	λ	$N(0.5, 0.2)$	0.71 (0.53, 0.91)	0.87 (0.63, 1.00)
Portfolio adj. costs	ψ^W	$N(0.19, 0.1)$	∞	0.18 (0.06, 0.32)
Tax smoothing	ρ^{τ^T}	$B(0.5, 0.2)$	0.23 (0.02, 0.49)	0.29 (0.04, 0.57)
Tax response to B	ϕ^{τ^B}	$B(0.5, 0.2)$	0.32 (0.07, 0.67)	0.27 (0.05, 0.62)
Tax response to G	ϕ^{τ^G}	$B(0.5, 0.2)$	0.34 (0.03, 0.71)	0.21 (0.01, 0.48)
Rn smoothing	ρ^r	$B(0.7, 0.2)$	0.49 (0.22, 0.75)	0.57 (0.29, 0.83)
Rn response to Π	θ^π	$\Gamma(1.7, 0.15)$	1.70 (1.42, 2.00)	1.71 (1.43, 2.01)
Rn response to Y	θ^y	$\Gamma(0.1, 0.05)$	0.11 (0.02, 0.22)	0.11 (0.02, 0.22)

Table 3: Bayesian Impulse Responses Matching – Parameters

Notes: Distributions are abbreviated as: Γ - Gamma; B - Beta; U - Uniform; N - Normal.

Table 3 reports the estimated mean of the posterior distribution of the parameters and their respective 95% confidence bands in parenthesis. At a high level, all parameters are in line with what usually found in the literature with full information estimation methods.Moreover, most of the point estimates are similar across the two models. One exception is the investment adjustment cost parameter which is lower in CW, a result that is not surprising given the presence of other features in the CW model that generate curvature; we also note a higher degree of price indexation in CW. Considering policy, the tax rule parameters as well as the parameters of the Taylor rule are almost indistinguishable between models, save for the tax response to government spending which is larger in OR (pointing towards a relatively higher degree of debt-financed fiscal policy). Portfolio adjustment costs are estimated to lie very close to the prior mean and hence the value used in all the simulations presented in the paper thus far.

The crucial parameter to select CW over OR insofar as we take the criterion to be if a model can fit the data for a plausible set of parameter values is λ, that is the proportion of rule-of-thumb households (in OR) respectively workers (in CW) in the economy.[35] In the former case, the estimated value of $\lambda = 0.71$ means that 71% of agents are without any access to financial markets. In the latter model, 87% of households are workers. As is inevitable within the confines of a two-agent framework, either division of households is overly simplifying relative to the rich heterogeneity that may be observed in the data. But whereas it is hard to countenance the idea that almost three quarters of households do not have any access to financial markets in the US or in any advanced economy, a "90/10" split where 90% people rely almost exclusively on labor income but have some ability to smooth consumption and 10% have significant asset income seems to capture in a stylized manner the idea that wealth, and ownership of firms in particular, is highly concentrated.

5 Conclusion

This paper makes two key contributions. First, it adds to the literature on cyclical fluctuations in the distribution of income by highlighting a novel stylized fact: the response of the labor share of income to unanticipated increases in government purchases is positive, persistent and hump-shaped. Second, the paper develops and estimates a capitalist-worker two-agent New Keynesian (CW-TANK) model that incorporates insights from the recent heterogeneous agent, incomplete markets literature (prominent examples being Auclert *et al.* (2018); Broer *et al.* (2019); Mitman *et al.* (2019)) while preserving the tractability of a two-agent framework. The result is an easy-to-extend framework that incorporates a more realistic transmission mechanism for fiscal policy and fits aggregate dynamics using a plausible parameterization.

In CW-TANK, capitalists earn income only from firm profits and investing in physical capital. By contrast, workers only receive labor income and their bond-savings choices are subject to quadratic portfolio adjustment costs. From a theoretical perspective, this setup has several advantages: it delivers realistic intertemporal marginal propensities to consume, which matters for labor demand; and it avoids implausible income effects on labor supply. In an application to fiscal stimulus design, the model predicts that a higher degree of deficit-financing strengthens the aggregate effects of government spending. This result as well as the underlying transmission mechanism, which crucially hinges on an implicit redistribution from capitalists to workers, is consistent with recent findings in the heterogeneous-agent literature. From a conceptual vantage point, our specification allows neatly isolating different sources of income, notably labor income as contrasted with receipts from holding physical capital or having equity ownership stakes in firms. Empirically, the model captures the high concentration of wealth holdings in a stylized fashion. In a quantitative application, an estimated version of the model is able to replicate the characteristic response of the labor share to government

[35] In addition, comparing log-likelihoods unequivocally favors CW-TANK over OR-TANK, with a log data density for CW equal to 43.95 as compared to 29.37 for OR.

spending shocks as well as the dynamics of other key macroeconomic variables for a set of parameter values that depicts a "90/10" division of the population into workers and capitalists, respectively.

We hope that the CW-TANK model can serve as a tractable framework to study the effects of macroeconomic policy taking account of household heterogeneity. The role envisioned is distinct from that of full-blown heterogeneous agent models. For instance, certain questions of interest are not even well-defined in the present setting but can be fruitfully explored in one of a number of HANK models (examples of such a question being the varied impact of aggregate shocks across the entire income distribution or endogenous variation in asset market participation). We believe that TANK models are, however, potentially useful as tractable laboratories for understanding various macroeconomic experiments; as they are relatively fast to solve and estimate, they also lend themselves to quantitative applications incorporating a wide range of empirically relevant frictions. Relevant questions to consider in future research include the study of distortionary taxation as well as systematic and discretionary monetary policy in the CW-TANK model.

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Appendices

Appendix A

A.1 Data Sources and Transformation

A.1.1 USA

The components of national income, government receipts and the GDP deflator are taken from the NIPA tables of the Bureau of Economic Analysis. Further series are retrieved from the FRED database of the Federal Reserve Bank of St. Louis. All national income series are seasonally adjusted by the source and, unless otherwise stated, are deflated using the GDP deflator. Where necessary we take the arithmetic average of monthly figures to obtain quarterly series. Data from the Survey of Professional Forecasters is available on the website of the Federal Reserve Bank of Philadelphia.[36]

Table 4 lists the data sources used, while Table 5 provides an overview of the properties of the alternative labor share proxies.

Construction of the labor share.

Our baseline measure, which in the table corresponds to **LS6**, considers the domestic non-financial corporate (NFC) sector. As is frequently done especially in sectoral studies, gross value added (GVA) is used. The formula is

$$LS6 = 1 - \frac{CP^{gva} + NI^{gva} - Tax^{gva}}{NVA}.$$

For **LS5**, the key assumption is that the shares of capital (K) and labor (L) in ambiguous income are the same as in unambiguous income. As set out by McAdam *et al.* (2015), we begin by decomposing total

[36]The SPF provides separate forecasts for state, local and federal government spending, whereas our variable of interest is total government spending. We aggregate the individual components to obtain a forecast for the latter, and constructed news variables on this basis. This procedure may introduce bias in our estimates, because in 1996, the U.S. Bureau of Economic Analysis (BEA) switched its method for aggregating the headline components of real GDP and the associated price indexes from the fixed-weight aggregation method to the chain-weight aggregation method. Under the latter ("Fisher ideal"), additivity of real levels does not hold (Whelan 2002). We have verified that the results obtained are robust to using news variables based on federal spending only.

[37]Before 1953:II, interpolated annual data available on Robert Shiller's database at http://www.econ.yale.edu/ shiller/-data.htm

[38]http://econweb.ucsd.edu/ vramey/research.html

[39]See https://www.bls.gov/opub/mlr/2017/article/estimating-the-us-labor-share.h tm

[40]"Naive" meaning labor compensation divided by dollar output, see https://www.bls.gov/lpc/lpcmethods.pdf, page 7; also see https://www.bls.gov/news.release/prod2.tn.htm. This measures excludes e.g. general government; nonprofit institutions; private households; unincorporated business; and those corporations classified as offices of bank holding companies, offices of other holding companies, or offices in the finance and insurance sector. Nonfinancial corporations accounted for about 50 percent of the value of GDP in 2016.

Mnemonic	Description	Source
GOV	Gov. consumption expenditures + gross investment	NIPA 1.1.5.
GOVCON	Gov. consumption expenditures	NIPA 3.9.5
GOVINV	Gov. gross investment	NIPA 3.9.5
TAX	Current receipts - current transfer payments - current interest payments	NIPA Table 3.1
GDP	Gross Domestic Product	NIPA 1.1.5
RINT	10Y Tsy constant maturity rate (quarterly avg.), adjusted by GDP deflator	FRED: GS10[37]
HOURS	Total hours worked, including military	V. Ramey's database[38]
WAGES	Real Hourly Compensation, Business Sector	BLS :PRS84006153
PGDP	GDP deflator	NIPA 1.1.4
LS1	LS in the non-farm business sector	BLS
LS2	LS in the non-financial business sector	BLS
CE	Compensation of employees	NIPA 1.12
CE_{gov}	Wages and salaries: government	NIPA 1.12
RI	Rental income (with CCAdj)	NIPA 1.12
CP	Corporate profits (with IVA and CCAdj)	NIPA 1.12
NI	Net interest income	NIPA 1.12
δ	Consumption of fixed capital	NIPA 1.7.5
PI	Proprietors' Income	NIPA 1.12
TAX^P	Taxes on production - subsidies on production	NIPA 1.12
BCTP	Business current transfer payments	NIPA 1.12
Sdis	Statistical discrepancy	NIPA 1.12
GE	Current surplus of government enterprises	NIPA 1.12
GNP	Gross national product	NIPA 1.7.5
CP^{gva}	Corporate profits, GVA (NFC)	NIPA 1.14
NI^{gva}	Net interest and miscellaneous payments (NFC)	NIPA 1.14
TAX^{gva}	Taxes less subsidies on production and imports (NFC)	NIPA 1.14
NVA	Net value added (NFC)	NIPA 1.14

Table 4: Data Sources (1) – US

income into ambiguous (AI) and unambiguous (UI) income. AI is the sum of proprietors' income, taxes on production less subsidies, business current transfers and statistical discrepancies (none of which is attributable to K or L).

$$AI_t = PI_t + (Tax_t^P - Sub_t) + BCTP_t + SDIS_t.$$

UI is straightforwardly separable into compensation of employees and unambiguous capital income.

$$UI_t = ULI_t + UKI_t = CE_t + UKI_t.$$

The latter is the sum of corporate profits, rental income, net interests, and current surplus of government enterprises.

$$UKI_t = CP_t + RI_t + NI_t + GE_t.$$

Mnemonic	Description	Methodology	Source
LS1	Non-farm business sector (excludes e.g. government, nonprofits, farms)	GVA[39]; imputed SE income	BLS
LS2	Non-financial business sector	GDP; naive[40]	BLS
LS3	Economy-wide excl. gov. sector	GDP; PI and indirect net taxes apportioned to K and L in same proportion as unambiguous components	Following Gomme and Rupert (2004)
LS4	Economy-wide excl. gov. sector	GDP; PI and indirect net taxes apportioned to K and L in same proportion as unambiguous components. No corrections for inventory valuation adjustment and capital consumption.	Following Gomme and Rupert (2004)
LS5	Economy-wide LS adjusted for PI	GDP; proportions in ambiguous income (PI, net taxes on production, business current transfers, statistical discrepancy) assumed to be the same as in unambiguous.	Following McAdam *et al.* (2015)
LS6	Non-financial business sector	GVA; excludes PI and rental income	Following Gomme and Rupert (2004)

Table 5: Alternative LS Proxies

The share of capital in unambiguous income (KS_t^U) is then obtained as

$$KS_t^U = 1 - LS_t^U = \frac{UKI_t + DEP_t}{UI_t} = \frac{RI_t + NI_t + GE_t + CP_t + DEP_t}{RI_t + NI_t + GE_t + CP_t + CE_t},$$

where DEP_t is the consumption of fixed capital. Next, make the following key assumption that factor shares in AI are the same as in UI:

$$AKI_t = KS_t^U AI_t.$$
$$ALI_t = 1 - (KS_t^U AI_t).$$

Finally, we obtain the labor share as follows[41]:

$$LS_t = (1 - KS_t) = 1 - \frac{UKI_t + DEP_t + AKI_t}{GNP_t} = \frac{ALI_t + CE_t}{GNP_t}$$

For LS3:

$$LS3 = \frac{CE - CE_{gov}}{(CE - CE_{gov}) + RI + CP + NI + \delta} = \frac{Y^{UL}}{Y^{UL} + Y^{UK}}.$$

LS4 is essentially the same concept, except not adjusted for inventory valuation and capital consumption when considering RI and CP.

A.1.2 Canada, Australia and United Kingdom

For Australia, Canada and the United Kingdom data are retrieved from the Australian Bureau of Statistics, Canada Statistics and the UK Office for National Statistics, respectively. Table 6 summarizes.

[41]In line with Cantore *et al.* (2019) we use GNP rather than GDP in the denominator.

[42]Seasonally adjusted fiscal data for the UK going back to 1963 were were kindly provided by the ONS.

Mnemonic	Australia	Canada	UK
GOV	General government final consumption expenditure + general government gross fixed capital formation	General government final consumption expenditure + general governments gross fixed capital formation	General government total current expenditure + total net investment[42]
TAX	General government total gross income - general government total income payable - subsidies	General government revenue - current transfers to households - interest on debt	General government total current receipts - net social benefits
GDP	GDP adjusted using the GDP deflator	GDP adjusted using the GDP deflator	GDP adjusted using the GDP deflator
LS	Naive measure calculated as total wages and salaries (including social security contributions) over GDP	Naive measure calculated as compensation of employees over total factor income, computed as (GDP-taxes less subsidies on products and imports)	Naive measure calculated as compensation of employees over gross value added at factor cost
RINT	10 year government bond yield (FRED: IRLTLT01AUQ156N) deflated using the GDP deflator	10 year government bond yield (FRED: IRLTLT01CAM156N) deflated using the GDP deflator	10 year government bond yield (FRED: IRLTLT01GBM156N) deflated using the GDP deflator

Table 6: Data Sources (2) – Australia, Canada, and UK

A.2 Further Empirical Results

A.2.1 Baseline Specification

The baseline VAR specification is a nine-variable VAR estimated for the U.S. using quarterly data spanning from 1981:Q3 to 2007:Q4 using standard Bayesian methods. The data comprises: (i) log real government spending (consumption plus gross investment); (ii) the cumulated forecast of government spending growth over the next four quarters, $F_t(1,4)$;[43] (iii) log real net taxes; (iv) log real GDP;

[43]We note that including the one-step-ahead forecast ($h = 1$) as the second variable in the SVAR, and identifying the "purified" surprise spending shock as the first Cholesky shock would essentially be equivalent to the strategy followed by Auerbach and Gorodnichenko (2012) as well as Born *et al.* (2012). However, if the number of periods of anticipation exceeds one, then this variable will *not* include the news shock. By contrast, using e.g. $F_t(1,4)$ as the news variable in the VAR increases the chances of capturing all relevant anticipation effects. We have also experimented with a news variable

(v) log real consumption (durables and non-durables); (vi) log real investment; (vii) log labor share; (viii) log corporate profits; and (ix) the 10-year real interest rate. We note that the inclusion of the long-term interest rate helps capture agents' expectation and significantly reduces the forecasteability of government spending shocks.

The starting date is dictated by the availability of SPF data for fiscal variables and coincides approximately with the beginning of the Great Moderation. The end date is prior to the start of the Great Recession to avoid potential structural breaks, but below we also report results obtained ending the sample in 2016, and using rolling windows. The lag length is chosen based on information criteria, which suggest the use of two lags for the baseline SVAR. The equations are estimated in levels to preserve potential cointegrating relationships among the variables. We include a quadratic time trend as in Ramey (2016) to capture features such as the productivity slowdown or the effect of the baby boom. Results are robust to the inclusion of a linear trend (or a constant) only. In line with standard Bayesian practice, the (reduced-form) VAR is estimated using Markov Chain Monte Carlo Methods employing a normal-diffuse ("Jeffrey's") prior for the coefficient matrix and the covariance matrix of the reduced-form innovations, respectively. Impulse responses and posterior credible sets are generated based on 10,000 draws.

A.2.2 Robustness Checks

This appendix section provides a number of robustness checks for our main, novel empirical results: that the response of the labor share to an unanticipated increase in government purchases is positive, persistent and hump-shaped during the Great Moderation period in the US. We verify that our results are robust to (a) Jordà's (2005) local projections to compute impulse responses as in Ramey (2016) and Ramey and Zubairy (2018); (b) different labor share proxies; and (c) varying sub-samples. We use a smaller VAR for sake of expositional clarity. Additional details and figures are available upon request.

A.2.2.1 Local Projections As a first robustness check, in the spirit of Ramey (2016) and Ramey and Zubairy (2017), we next use local projection (LP) methods as an alternative econometric approach to obtaining estimates of IRFs to government spending shocks. LP-based impulse responses are sometimes seen as more robust to non-fundamentalness issues caused by fiscal foresight, the reason being that the multivariate system is not specified and estimated in the first place (for details and questions about this view, see Stock and Watson, 2018). Our estimation strategy exactly follows Ramey

capturing expectations revisions ($N_t(1,3)$ in the notation of Forni and Gambetti (2016) and the results are very similar to the $F_t(1,4)$ approach.

(2016) to obtain the impulse responses for each variable z at each horizon h:

$$z_{t+h} = \alpha_h + \theta_h shock_t + \gamma_h(L) w_{t-1} + \text{quadratic trend} + \eta_{t+h}, \tag{19}$$

where z is the variable of interest, $shock$ is the identified shock, w is a vector of control variables, and $\gamma_h(L)$ is a polynomial in the lag operator. All regressions include two lags of the shock (to eliminate any serial correlation), real GDP, real government spending and net taxes. Regressions for variables other than these three also include two lags of the left-hand side variable. The coefficient θ_h gives the response of z at time $t+h$ to the shock at time t.

Figure 10 reports one example of LP-based impulse responses: those identified recursively à la Blanchard and Perotti (2002) and estimated over the baseline sample.[44] The figure shows that the immediate hump-shaped increase in the labor share in response to a surprise shock is robust to the use of LP methods. If anything, the magnitude of the response of the labor share to a surprise shock computed with LP methods is significantly greater than that observed using SVAR methods.

A.2.2.2 Alternative Labor Share Proxies Empirically measuring the labor share of income represents a major challenge, perhaps the most important difficulty confronting the researcher being the question how to ascribe the mixed income of self-employed to labor and capital. Our baseline measure of the labor share is constructed using data for the domestic corporate non-financial business sector extracted from the US NIPA tables following the methodology proposed by Gomme and Rupert (2004). Here we consider five additional metrics of the labor share. These measures differ in several dimensions, including their coverage and how they handle mixed income. Notably, several of the measures exclude the government sector altogether, thus addressing the potential critique that the increase in the labor share is simply due to the direct effect of government spending on public sector employees. The appendix contains a detailed description of the various time series and their construction. Note that 'LS6' denotes the measure used previously as our baseline measure.

Figure 11 compares the response of the labor share to an unanticipated government spending shock over our baseline sample. The central observation is that the patterns are very similar for measures LS2, LS3, LS4, LS5 and LS6, but that the response for LS1 is shifted downwards. Noting that LS1 suffers from many of the measurement difficulties, we consider the results therefore to be positive in terms of verifying the robustness of our findings hitherto. It is also worth noting that there is no clear pattern in terms of which labor share makes for the most clear-cut results.

[44] Since the BP shock is just the part of government spending orthogonal to the lagged values of fiscal spending, GDP and taxes, it is identified from a standard four lag regression of government spending on lagged spending, GDP and taxes.

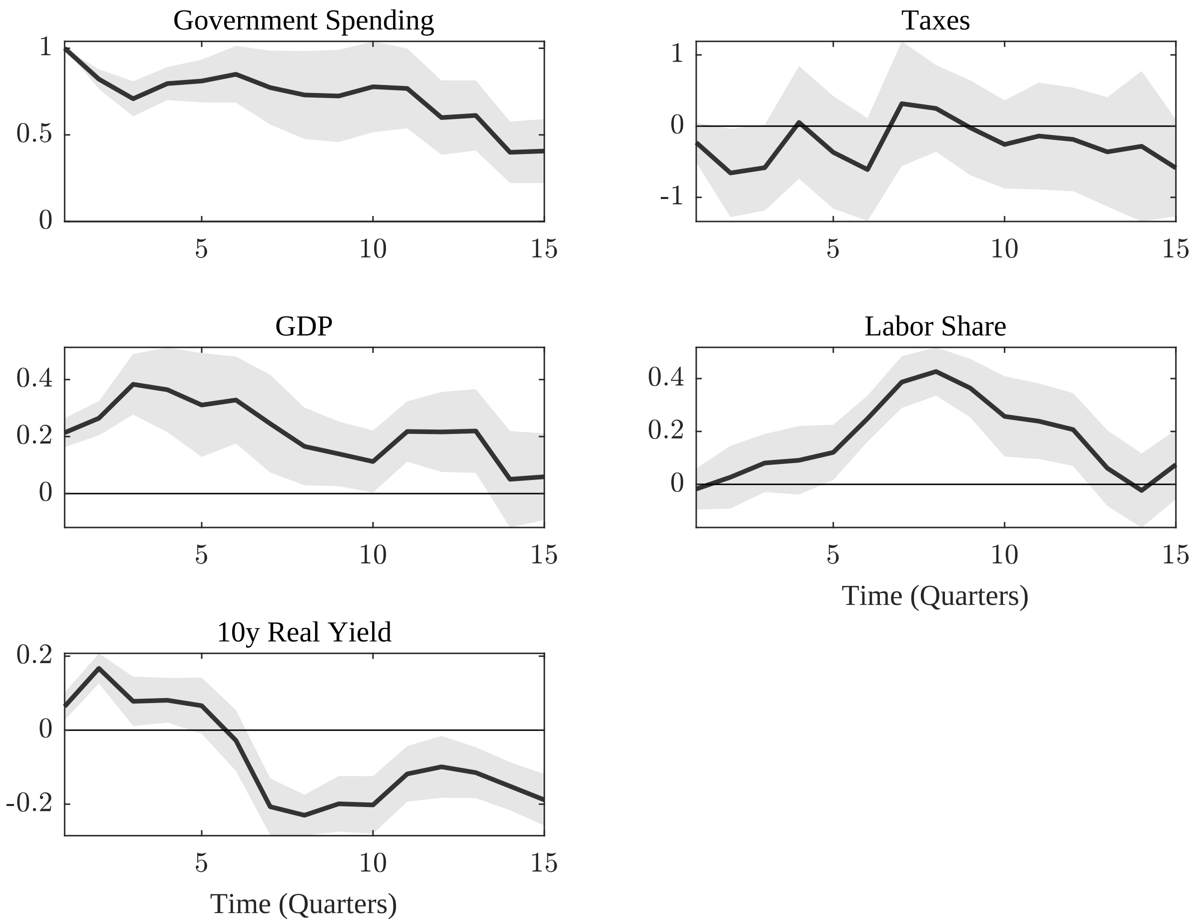


Figure 10: Surprise Shock to Government Spending – Local Projections

Notes: LP-based IRs for a government spending BP surprise shock (1981:III-2007:IV). Dashed lines represent one standard deviation confidence bands based on Newey-West corrections of standard errors. Horizontal axes denote quarters; t=0 is the period of the shock. All series except interest rate shown in %. Shock size: one percent increase in government spending.

A.2.2.3 Sub-Sample Robustness Next, we check the robustness of our result across different subsamples.[45] As figure 12 illustrates (using the median response for expositional clarity), the qualitative properties of the labor share response to unanticipated shock holds across samples. However, there are interesting differences in terms of the magnitude of the deviations from baseline and the persistence of the response. For the two later samples, the labor share reacts more sensitively to fiscal shocks, an observation of note since it is generally held that the *aggregate* effects of government spending shocks have become weaker in more recent samples (see, e.g., Bilbiie *et al.* (2008)).

[45]Given data availability, we employ the natural approach of dividing sample period for which SPF data is available into two and use the preceding years from 1948:I onwards as a third sub-sample period.

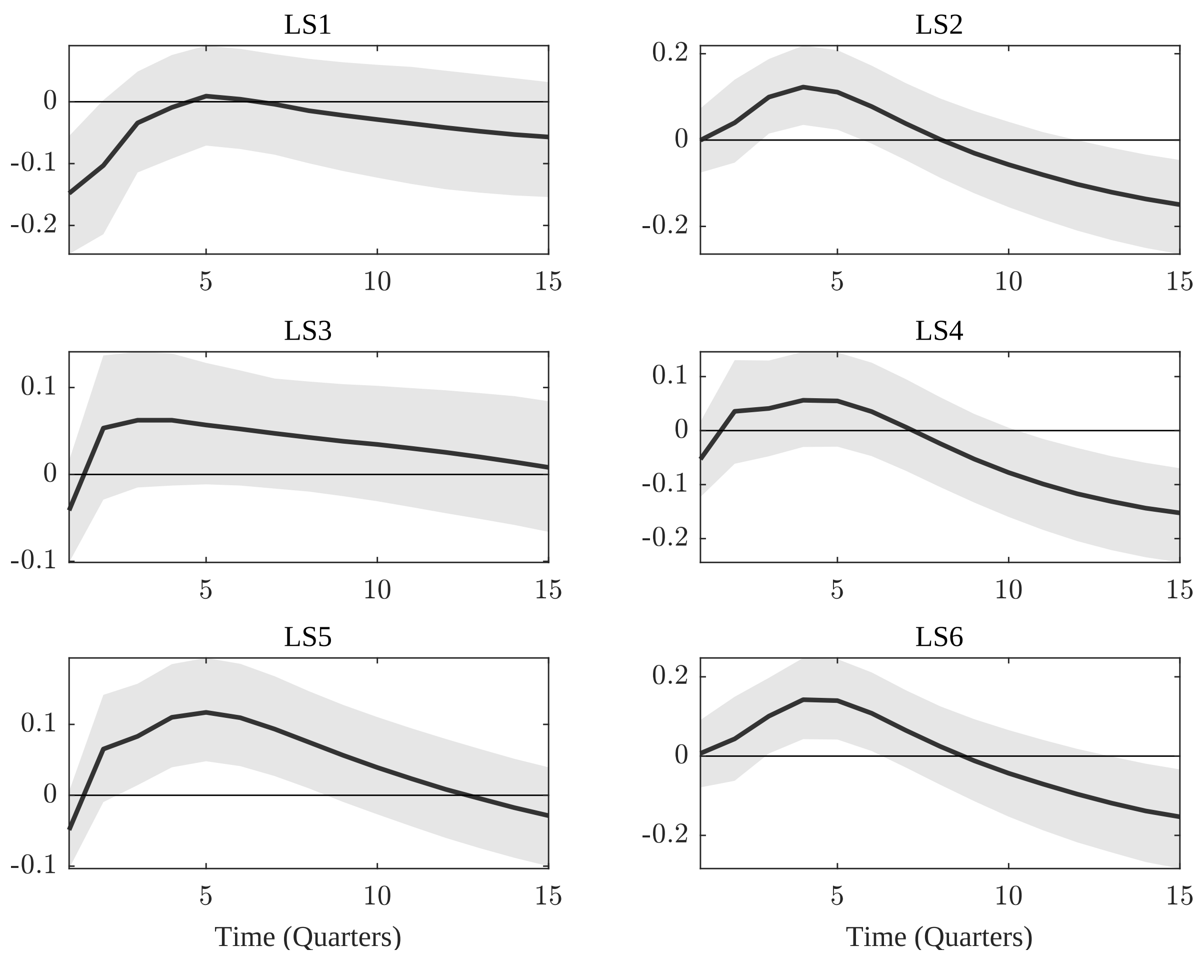


Figure 11: Surprise Shock to Government Spending – All LS Proxies

Notes: IRs for a one standard deviation government spending surprise shock obtained using the F(1,4) identification method. The median posterior density of impulse responses is displayed in form of a solid line while the 16th and the 84th percentiles are shown as dotted lines. All series shown in %.

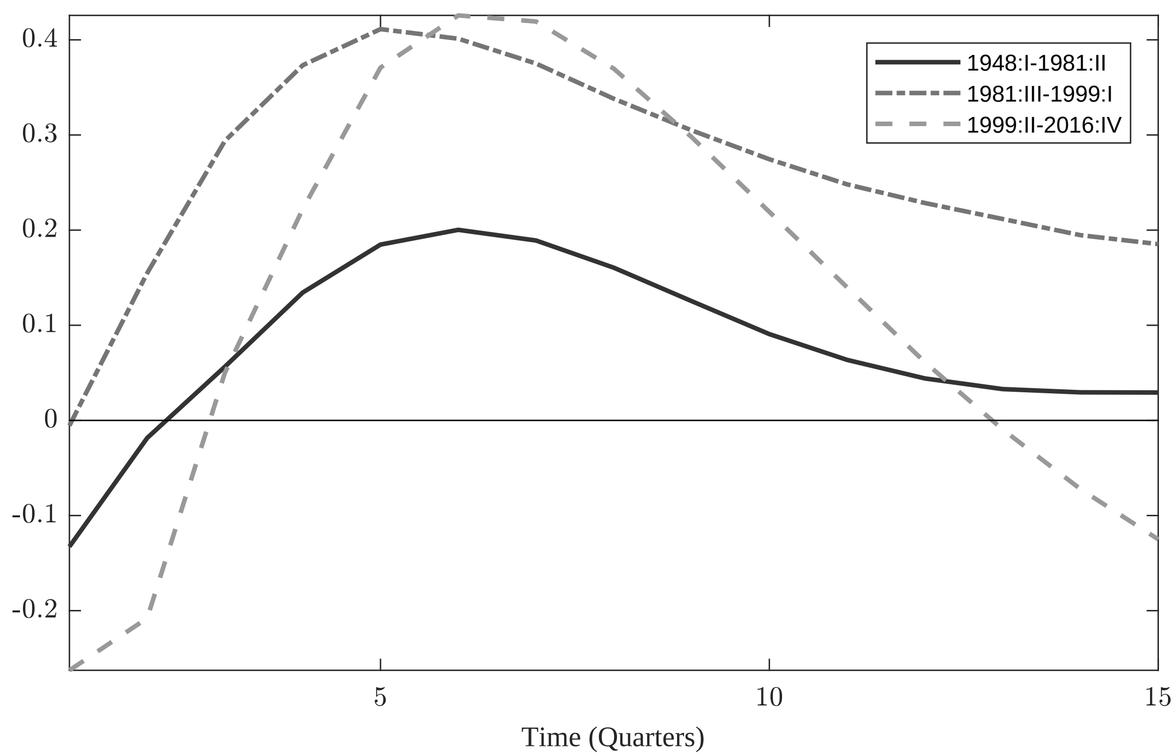


Figure 12: Labor Share Response to Unanticipated Government Spending Shock: Sub-Samples

Notes: IRs for a government spending surprise shock across different sub-samples. For 1948:I-1981:II, the shock is identified á la BP. For 1981:III-1999:I and 1999:II-2016:IV, the F(1,4) method is employed. IRs are scaled such that the log change of government spending is unity at its peak. Solid lines indicate the median posterior density of impulse responses, while the shaded area represents the 16th to 84th percentiles. All series shown in %.

A.2.3 Additional figures

Figure 13 shows the response of real wages and labor productivity to an unanticipated government spending shock estimated using a modified version of our baseline VAR. In Panel 13a, w use series on real hourly compensation and real output per hour in the non-financial corporate sector from the Bureau of Labor Statistics and substitute these variables for real GDP and the labor share with (to avoid collinearity problems). Panel 13b instead computes real wages as the ratio of total labor compensation as defined when constructing LS5 (i.e. the sum of unambiguous labor income and ambiguous income apportioned to labor) deflated by the GDP deflator over total hours worked. Labor productivity is overall real GDP divided by total hours. The figure illustrates that after two quarters real wages tend to grow more rapidly than labor productivity over several periods following a fiscal expansion – consistent with an increase in the labor share.

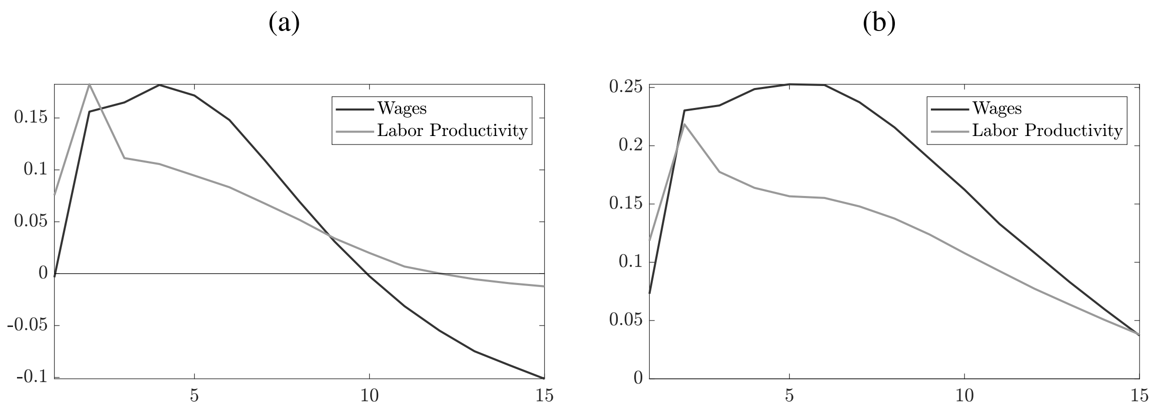


Figure 13: VAR: Real Wage and Labor Productivity Response to Surprise Shock to Government Spending

Notes: Impulse responses are scaled such the log change of government spending is unity at its peak. All series shown in %.

A.3 Further Theoretical Results

A.3.1 Equilibrium Conditions of the Medium Scale CW-TANK

$$ {C^{C}}_{t}^{-\sigma_c} = \beta \, R_t \, {C^{C}}_{t+1}^{-\sigma_c} \tag{20} $$

$$ {C^{W}}_{t} + {B^{W}}_{t} = {H^{W}}_{t} \, W_t - {T^{W}}_{t} + R_{t-1} \, {B^{W}}_{t-1} \tag{21} $$

$$ {MRS^{W}}_{t} = \nu^{W} \, {H^{W}}_{t}^{\varrho} {C^{W}}_{t}^{\sigma_c} \tag{22} $$

$$ {C^{W}}_{t}^{-\sigma_c} \left(1 + \psi^{W} \left({B^{W}}_{t} - b^{\bar{W}}\right)\right) = \beta \, R_t \, {C^{W}}_{t+1}^{-\sigma_c} \tag{23} $$

$$ Y_t = {Y^{w}}_{t} - F \tag{24} $$

$$ {Y^{w}}_{t} = \left(H_t\right)^{1-\alpha} \left(\Upsilon_t \, K_{t-1}\right)^{\alpha} \tag{25} $$

$$ {R^{K}}_{t} = MC_t \alpha \left(\frac{\Upsilon_t \, K_{t-1}}{H_t}\right)^{\alpha-1} \tag{26} $$

$$ W_t = MC_t \, (1-\alpha) \left(\frac{H_t}{\Upsilon_t \, K_{t-1}}\right)^{(-\alpha)} \tag{27} $$

$$ {S^{K}}_{t} = \frac{K_{t-1} \, \Upsilon_t \, {R^{K}}_{t}}{Y_t} \tag{28} $$

$$ {S^{H}}_{t} = \frac{W_t \, H_t}{Y_t} \tag{29} $$

$$ \Psi_t = \gamma^{1} \left(\Upsilon_t - 1\right) + \frac{\gamma^{2}}{2} \left(\Upsilon_t - 1\right)^{2} \tag{30} $$

$$R^K{}_t = \gamma^1 + \gamma^2\,(\Upsilon_t - 1) \tag{31}$$

$$K^C{}_t = I^C{}_t\,(1 - S_t) + K^C{}_{t-1}\,(1 - \delta) \tag{32}$$

$$X_t = \frac{I^C{}_t}{I^C{}_{t-1}} \tag{33}$$

$$S_t = \phi^X\,(X_t - 1)^2 \tag{34}$$

$$S'{}_t = (X_t - 1)\,2\,\phi^X \tag{35}$$

$$Q_t = \frac{1}{R_t}\left(\Upsilon_{t+1}\,R^K{}_{t+1} - \Psi_{t+1} + (1 - \delta)\,Q_{t+1}\right) \tag{36}$$

$$Z_t\,Q_t\left(1 - S_t - X_t\,S'{}_t\right) + Q_{t+1}\,\frac{{C^C{}_{t+1}}^{-\sigma_c}\,\beta\,Z_{t+1}}{{C^C{}_t}^{-\sigma_c}}\,S'{}_{t+1}\,{X_{t+1}}^2 = 1 \tag{37}$$

$$Y_t = C_t + I_t + K_{t-1}\,\Psi_t + G_t \tag{38}$$

$$R_t = \frac{R^n{}_t}{\Pi_{t+1}} \tag{39}$$

$$C_t = C^W{}_t\,\lambda + C^C{}_t\,(1 - \lambda) \tag{40}$$

$$H_t = H^W{}_t\,\lambda \tag{41}$$

$$I_t = (1 - \lambda)\,I^C{}_t \tag{42}$$

$$K_t = (1 - \lambda)\,K^C{}_t \tag{43}$$

$$B_t = (1-\lambda)\, {B^C}_t + {B^W}_t\, \lambda \tag{44}$$

$$JJ_t - \beta\, \xi_p\, \tilde{\Pi}_{t+1}^{\zeta-1}\, JJ_{t+1} = {{C^C}_t}^{-\sigma_c}\, Y_t \tag{45}$$

$$J_t - \beta\, \xi_p\, \tilde{\Pi}_{t+1}^{\zeta}\, J_{t+1} = MC_t\, {{C^C}_t}^{-\sigma_c}\, Y_t\, \frac{1}{1-\frac{1}{\zeta}} \tag{46}$$

$$1 = \xi_p\, \tilde{\Pi}_t^{\zeta-1} + (1-\xi_p) \left(\frac{J_t}{JJ_t}\right)^{1-\zeta} \tag{47}$$

$$\tilde{\Pi}_t = \frac{\Pi_t}{{\Pi_{t-1}}^{\gamma^p}} \tag{48}$$

$$JJW_t = {H^W}_t\, \nu^W\, {{H^W}_t}^{\varrho} \left(\frac{\tilde{W}_t}{W_t}\right)^{(-\mu^w)} + \beta\, \xi_w \left(\frac{\Pi_{t+1}}{{\Pi_t}^{\gamma^w}}\right)^{\mu^w} \left(\frac{\tilde{W}_{t+1}}{\tilde{W}_t}\right)^{\mu^w} JJW_{t+1} \tag{49}$$

$$JW_t = {H^W}_t\, {{C^W}_t}^{-\sigma_c}\, \tilde{W}_t\, \frac{\mu^w - 1}{\mu^w} \left(\frac{W_t}{\tilde{W}_t}\right)^{\mu^w} + \beta\, \xi_w \left(\frac{\Pi_{t+1}}{{\Pi_t}^{\gamma^w}}\right)^{\mu^w-1} \left(\frac{\tilde{W}_{t+1}}{\tilde{W}_t}\right)^{\mu^w-1} JW_{t+1} \tag{50}$$

$$JJW_t = JW_t \tag{51}$$

$${W_t}^{1-\mu^w} = (1-\xi_w)\, \tilde{W}_t^{1-\mu^w} + \xi_w\, {W_{t-1}}^{1-\mu^w} \left(\frac{{\Pi_{t-1}}^{\gamma^w}}{\Pi_t}\right)^{1-\mu^w} \tag{52}$$

$$log\left(\frac{{R^n}_t}{\bar{R^n}}\right) = \rho^r\, log\left(\frac{{R^n}_{t-1}}{\bar{R^n}}\right) + (1-\rho^r)\, \theta^\pi\, log\left(\frac{\Pi_t}{\bar{\Pi}}\right) + (1-\rho^r)\, \theta^y\, log\left(\frac{Y_t}{\bar{Y}}\right) + {\epsilon^M}_t \tag{53}$$

$$B_t = R_{t-1}\, B_{t-1} + G_t - T_t \tag{54}$$

$$T_t = (1-\lambda)\, {T^C}_t + {T^W}_t\, \lambda \tag{55}$$

$$log\left(\frac{{T^C}_t}{\bar{T^C}}\right) = \rho^{\tau^T}\, log\left(\frac{{T^C}_{t-1}}{\bar{T^C}}\right) + \phi^{\tau^B}\, log\left(\frac{B_{t-1}}{\bar{B}}\right) + \phi^{\tau^G}\, log\left(\frac{G_t}{\bar{G}}\right) \tag{56}$$

$$log\left(\frac{{T^W}_t}{\bar{T^W}}\right) = \phi^{\tau^G}\, log\left(\frac{G_t}{\bar{G}}\right) + \phi^{\tau^B}\, log\left(\frac{B_{t-1}}{\bar{B}}\right) + \rho^{\tau^T}\, log\left(\frac{{T^W}_{t-1}}{\bar{T^W}}\right) \tag{57}$$

$$log\left(\frac{G_t}{\bar{G}}\right) = \rho^G\, log\left(\frac{G_{t-1}}{\bar{G}}\right) + \sigma^G\, {\epsilon^G}_t \tag{58}$$

A.3.2 Sensitivity to λ

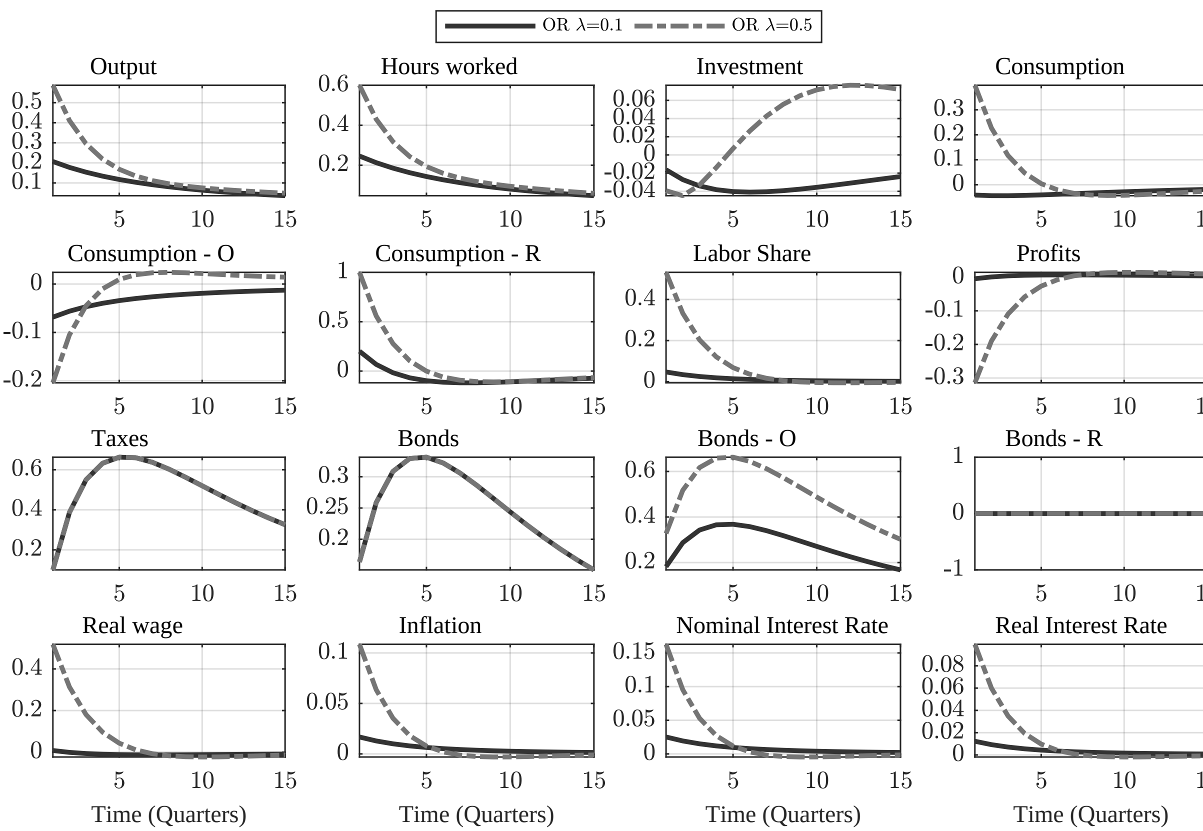


Figure 14: Sensitivity to λ in OR

Notes: All series are in proportional deviations from the steady-state (in %) except for profits and bonds (absolute deviations). Shock size: one percent increase in government spending.

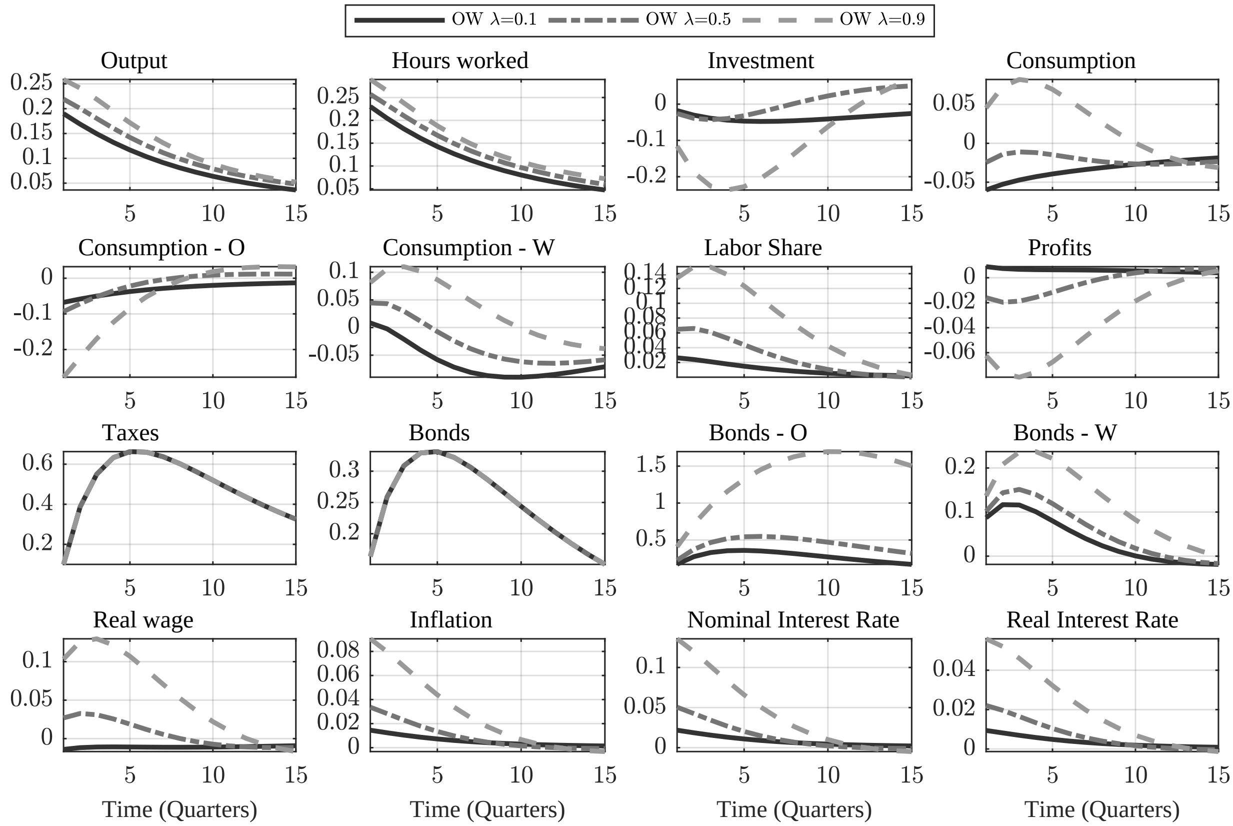


Figure 15: Sensitivity to λ in OW

Notes: All series are in proportional deviations from the steady-state (in %) except for profits and bonds (absolute deviations). Shock size: one percent increase in government spending.

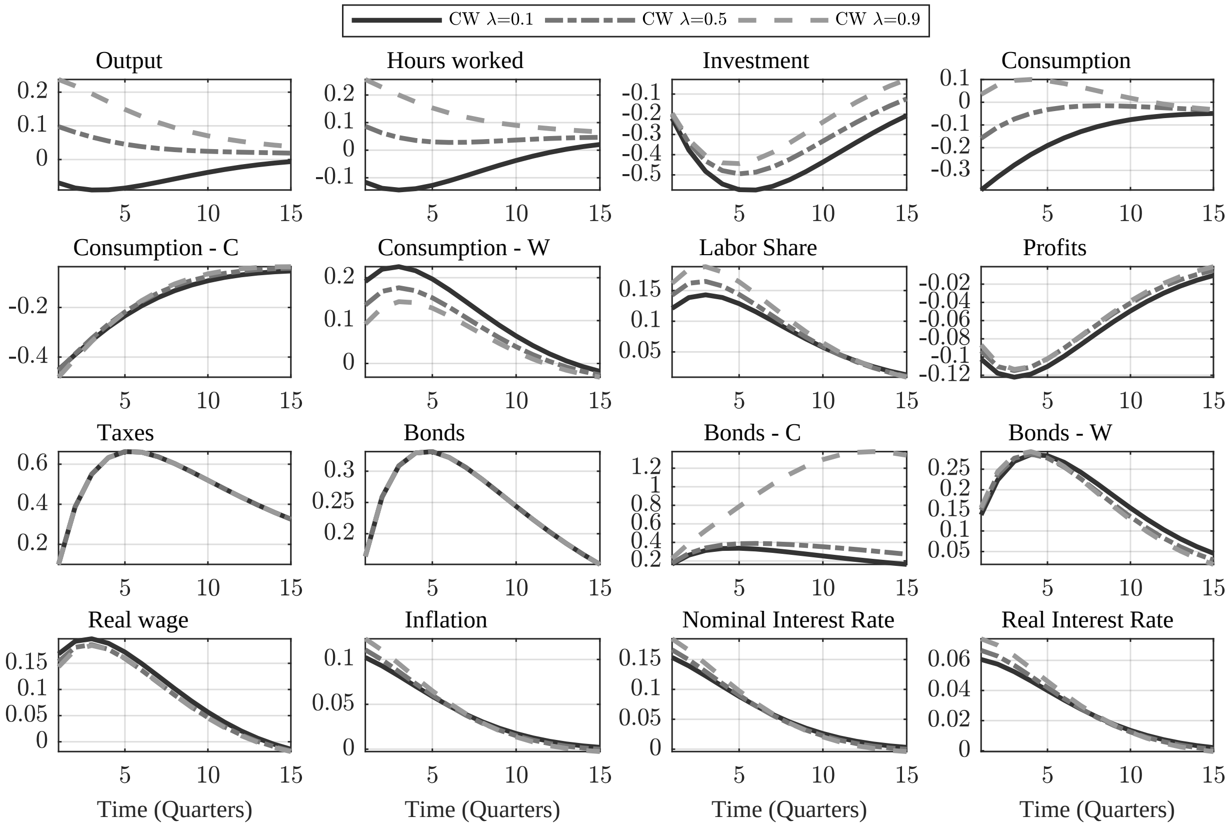


Figure 16: Sensitivity to λ in CW

Notes: All series are in proportional deviations from the steady-state (in %) except for profits and bonds (absolute deviations). Shock size: one percent increase in government spending.

A.3.3 Sensitivity to ψ^W

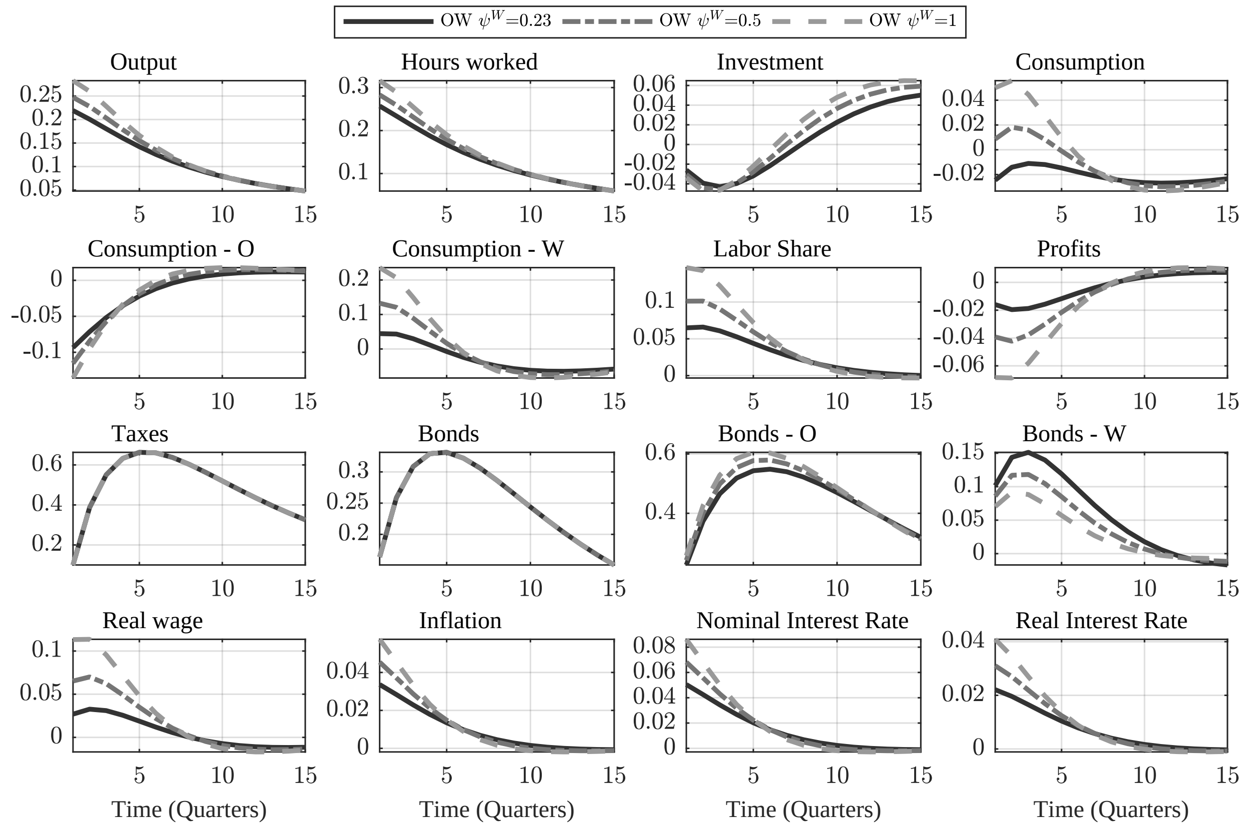


Figure 17: Sensitivity to ψ^W in OW

Notes: All series are in proportional deviations from the steady-state (in %) except for profits and bonds (absolute deviations). Shock size: one percent increase in government spending.

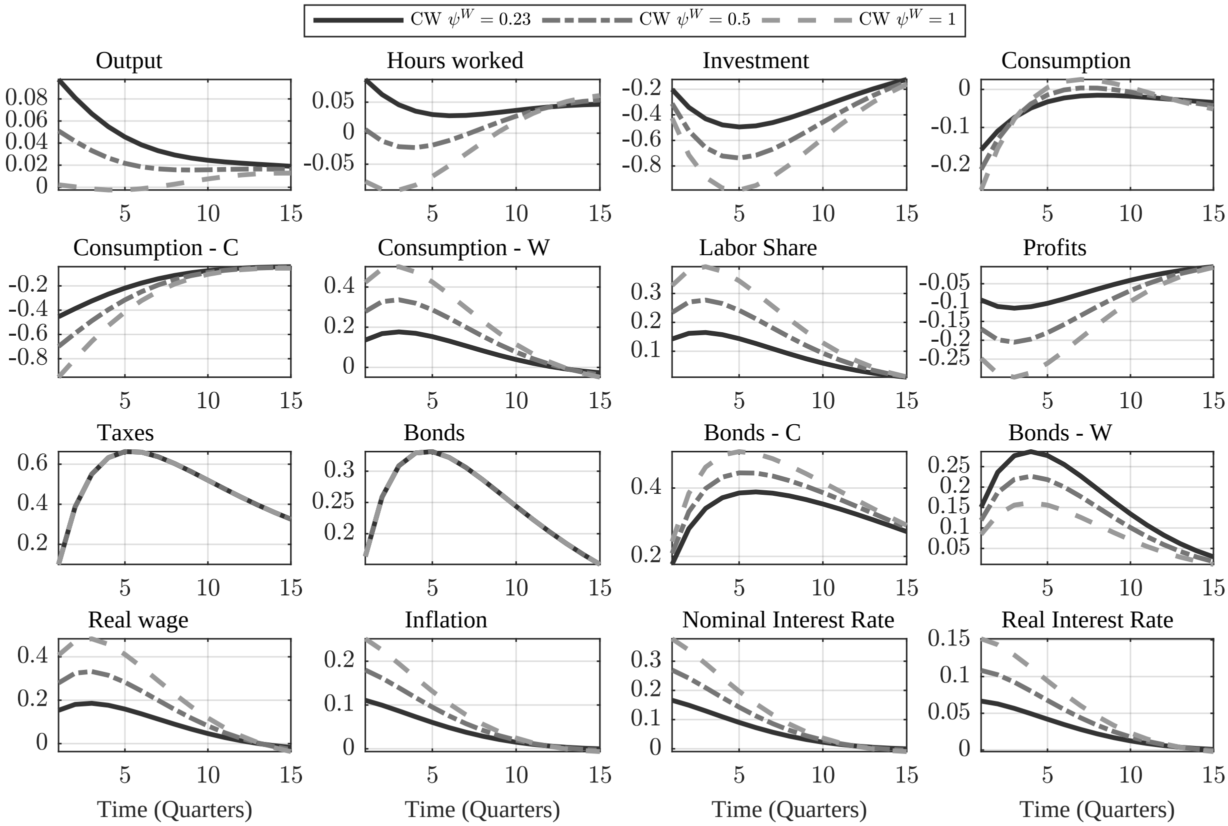


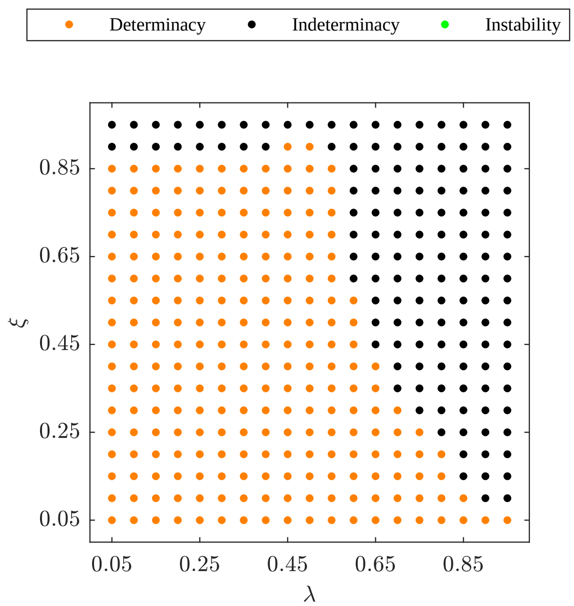
Figure 18: Sensitivity to ψ^W in CW

Notes: All series are in proportional deviations from the steady-state (in %) except for profits and bonds (absolute deviations). Shock size: one percent increase in government spending.

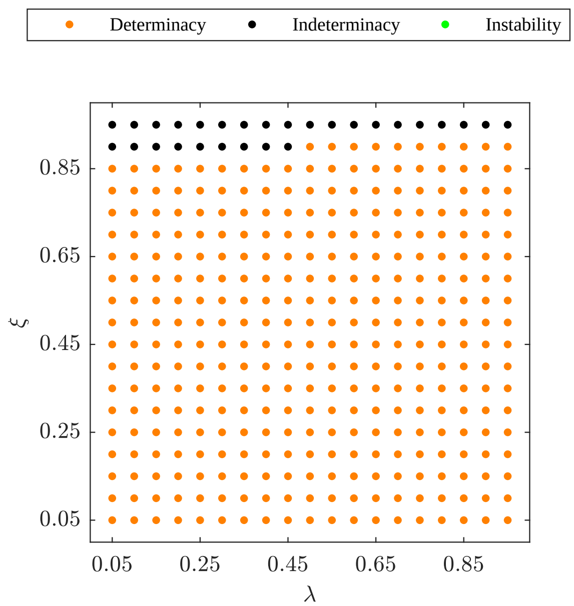
A.3.4 Stability

Figure 19: Stability – λ vs. θ_π

(a) OR



(b) OW



(c) CW

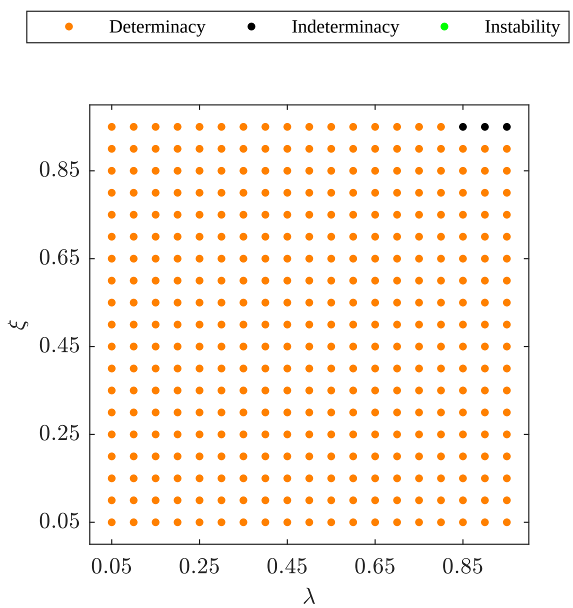


Figure 20: Stability – λ vs. ξ