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Fiscal multipliers: A heterogeneous-agent perspective

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We use an analytically tractable heterogeneous-agent (HANK) version of the standard New Keynesian model to show how the size of fiscal multipliers depends on (i) the distribution of factor incomes, and (ii) the source of nominal rigidities. With sticky prices but flexible wages, the standard representative-agent (RANK) model predicts large multipliers because profits fall after a fiscal stimulus and the resulting negative income effect makes the representative worker work harder. Our HANK model, where workers do not own stock, and thus do not receive profit income, predicts smaller fiscal multipliers. In fact, they are smaller with sticky prices than with flexible prices. When wages are the source of nominal rigidity, in contrast, fiscal multipliers are close to one, independently of income heterogeneity and price stickiness.

Keywords. Fiscal policy, heterogeneous agents, new Keynesian model.

JEL classification. E32, E62.

1. Introduction

After monetary policy interest rates reached their lower bound of zero following the Great Recession, a growing literature has looked at the ability of fiscal policy to stimulate aggregate activity. Particular attention has been paid to the *fiscal multiplier* (the ratio of the equilibrium output response to the increase in government spending) in New Keynesian economies where price rigidities make output partly demand determined. Because standard representative-agent New Keynesian (RANK) models are inconsistent with key empirical features of household consumption-savings behavior, this literature is moving fast toward heterogeneous-agent New Keynesian (HANK) models as its new

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benchmark.[1] This paper presents a very simple HANK environment to study the role of two central determinants of the fiscal multiplier in New Keynesian economies: (i) the distribution of factor incomes (profit vs. wage income), and (ii) the source of nominal rigidities (sticky prices vs. wages). In particular, our model allows us to clarify the role of income heterogeneity and wage stickiness for fiscal multipliers in richer, quantitative HANK economies compared to simpler RANK economies.[2]

Our HANK model extends the one we studied in an earlier paper (Broer, Harbo Hansen, Krusell, and Öberg (2020)) to include government spending shocks. In particular, relative to the standard RANK environment, the model has a more realistic specification of worker income that allows for idiosyncratic risk and accounts for the fact that the vast majority of workers do not own stock and thus do not receive firm profits in the form of dividends. This is in contrast to the representative worker in RANK, who receives all factor incomes. Our distinction between workers (who only receive labor income) and capitalists (who only receive dividends) not only captures the strong concentration of equity holdings in the data. It also highlights how the functional income distribution and assumptions about the source of nominal rigidity together determine the effect of fiscal shocks on hours worked. We argue that such a supply-side focus is a necessary complement to previous analyses of tractable HANK models that predominantly focus aggregate demand (Galí, Lopez-Salido, and Valles (2004), Bilbiie (2008), Colciago (2011), and Bilbiie (2020)). In addition, a particularly attractive feature of our model is that the government spending multiplier has a closed-form solution in the benchmark cases of fully flexible and fully rigid wages.

The analysis of our simplified HANK environment shows, first, that in the RANK model without wage rigidity the sticky-price amplification of fiscal shocks results entirely because workers receive profit income. The key intuitive insight here is that the representative worker adjusts her labor supply due to the combined income effects caused by the changes in taxes, wages, and profits relative to the substitution effect caused by changes in wages. When a fiscal expansion increases wages, the output and labor supply response is thus stronger, the less positively total worker income responds relative to wages. By providing households with an extra source of income that is less procyclical than wages (in fact countercyclical in the typical version of the model), firm profits thus boost the output and labor supply response to a fiscal shock. This mechanism whereby sticky prices raise the fiscal multiplier through an income effect is implausible, not only because profits are procyclical in the data but also because workers barely hold stock. As any reasonably calibrated HANK model would respect this fact—and our simple HANK model makes this point by assuming workers own no stock at all, and thus do not receive profits through dividends—we conclude that such models cannot offer large fiscal multipliers (at least not without adding other features). Moreover, while the countercyclical response of profits does not affect labor supply in our

[1] For an introduction to the study of fiscal multipliers, see Farhi and Werning (2016). For a survey of the HANK literature, see Kaplan and Violante (2018).

[2] The importance of wage rigidity for the transmission mechanism that we document is, in our view, an appealing feature as it captures the importance of wage setting institutions for monetary transmission in data for advanced economies; see, for example, Olivei and Tenreyro (2007, 2010), Björklund, Carlsson, and Skans (2019).

simple HANK model it implies more procyclical wages than with flexible prices (where real wages are constant). Because post-tax wage income moves more than proportionally with wages, income effects dampen the labor supply response to wage changes, and the spending multiplier is therefore lower, compared to the flexible-price equilibrium.

A second feature of fiscal transmission in New Keynesian models that our simplified HANK model highlights is that, with rigid wages, the multipliers are larger relative to the flexible-price-flexible-wage equilibrium in both the RANK model and our HANK model. In fact, with fully rigid wages, the multiplier is exactly equal to one in both models.

More generally, when wages are partially rigid but with prices flexible, nominal wages and prices move in tandem, leaving real wages and factor shares unaffected by fiscal shocks. So, fiscal multipliers in HANK and RANK are the same, and their size is determined by the degree of wage rigidity that dampens inflation, and thus limits the crowding-out effect of counteryclical monetary-policy responses to fiscal expansions.

With price rigidity in addition to wage rigidity, the dynamics of factor shares again imply different labor supply dynamics in HANK versus RANK (unless rigidity is perfect, in which case labor inputs are entirely demand determined and multipliers are again equal to one in both models). But our quantitative analysis shows that, with realistic degrees of rigidity, both models still imply fiscal multipliers close to unity.

We believe these results are useful for clarifying the interaction of household heterogeneity and nominal rigidities in determining the stabilizing effect of fiscal policy. In particular, models with flexible wages may obscure the role of heterogeneity in affecting aggregate dynamics, through their implausible implications for the dynamics of profit income. Based on our analysis, nominal wage rigidity makes a more plausible starting point, in line with the quantitative HANK models developed in Auclert, Rognlie, and Straub (2018) and Hagedorn, Manovskii, and Mitman (2019) to study fiscal multipliers.[3]

Our analysis also highlights the fact that the transmission of fiscal shocks in the NK setting is rather different from that of monetary shocks (which we analyzed in our previous paper), for at least two reasons. First, since a fiscal shock directly affects households' budgets, its effect directly depends on other sources of income and their endogenous dynamic responses over time. Assumptions about the distribution of factor incomes thus have a first-order effect on the propagation of fiscal shocks. Second, it is well known that the effect of fiscal shocks depends on the response of real interest rates (Woodford, 2011). Here, we note that accounting for wage rigidity dampens the inflation response to fiscal shocks, and thus the endogeneous reaction of monetary policy that, typically, counteracts the demand effect of fiscal shocks. This raises the fiscal multiplier relative to the standard version of the model with only price rigidities, but also makes it less sensitive to the current stance of monetary policy. In particular, previous analysis based on representative-agent models has shown that fiscal multipliers can be particularly potent

[3]Two recent and complementary papers support this view: Auclert, Bardóczy, and Rognlie (2023) show that it is impossible for New Keynesian models with flexible labor markets to simultaneously match empirical estimates for marginal propensities to earn, marginal propensities to consume, and fiscal multipliers. Cantore and Freund (2021) show that the implausible income effect of profit on labor supply can be reduced by introducing portfolio adjustment costs in a two-agent New Keynesian (TANK) model, but that this also implies smaller fiscal multipliers.

in situations where the monetary authority is constrained by a zero lower bound (ZLB) on the nominal interest rate.[4] In our concluding section, we discuss the ZLB constraint and argue that the ZLB is actually not critical from the perspective of the simple models we consider here. The RANK model's high multipliers in such situations only materialize due to the implausible transmission mechanism, and the sticky-wage fiscal multiplier, whether in a RANK or HANK model, is close to one and largely unaffected by the presence of the ZLB.

2. Two simple RANK and HANK economies

The goal here is to compare the responses to fiscal shocks across two models: the standard RANK model and our simple HANK model. We describe the two models in turn, with particular focus on the household problem. Most of the model components are standard and the description of these components is therefore brief. Like the "textbook" representative-agent New Keynesian (RANK) model, we abstract from physical capital and government debt, which allows us to solve both models analytically.

2.1 *RANK*

There is a representative final-good firm that operates a linear production function in a CES composite of differentiated intermediate goods. The intermediate goods are produced by a continuum of monopolistically competitive firms operating a production function that is linear in a CES composite of differentiated labor inputs. These firms set their output prices subject to the Calvo (1983) friction. They are owned by a representative household with "KPR preferences" over consumption and leisure as in King, Plosser, and Rebelo (1988), to be consistent with balanced growth; for convenience, we use the additively separable version from MaCurdy (1981), where φ regulates the (constant) Frisch elasticity of labor supply. There is a continuum of household members, indexed by j. Each member provides a differentiated labor service in a monopsonistic fashion, and pays a Rotemberg (1982)-type adjustment cost when changing the wage.[5] The monetary authority sets interest rates according to a Taylor rule that only reacts to inflation and the fiscal authority taxes the household lump-sum to fully finance its spending period-by-period. In other words, we abstract from the effects of distortionary taxes and positive government debt.

Anticipating full insurance within the household, such that all household members have the same level of consumption $C_{jt} = C_t$, the representative family problem is to choose consumption C_t, savings B_t, and wages $\{W_{jt}\}$ to maximize the objective

$$E_0 \sum_{k=0}^{\infty} \beta^t \left(\log C_t - \int \left(\frac{N_{jt}^{1+\varphi}}{1+\varphi} \right) \right) \tag{1}$$

[4] See, for example, Woodford (2011), Christiano, Eichenbaum, and Rebelo (2011), and Eggertsson (2011).

[5] To a first-order approximation, an isomorphic model would also be obtained if assuming a Calvo-type friction in the wage setting problem, as in Erceg, Henderson, and Levin (2000). We opt for the Rotemberg adjustment cost as it is easier to solve when we move to our heterogeneous-agent version of the NK model, given that the equilibrium wage distribution becomes degenerate.

subject to the budget constraint

$$P_t C_t + Q_t B_t + P_t T_t = \int \left(W_{jt} N_{jt} - \frac{\chi}{2} \left(\frac{W_{jt}}{W_{jt-1}} - 1 \right)^2 W_{jt} N_{jt} \right) + P_t D_t + B_{t-1} \tag{2}$$

and the CES demand curve for hours N_{jt}. Here, T_t are taxes paid in period t, and D_t dividends received from firms, and the last term in the budget constraint. The quadratic term is the adjustment cost for changing the wage level.

It is straightforward to derive a log-linear equilibrium around the symmetric zero-inflation steady state; for details, see Broer et al. (2020). The log-linear equilibrium is described by the following equations:

$$\text{IS:} \quad \hat{c}_t = E_t \hat{c}_{t+1} - \big(\hat{\imath}_t - E_t \pi^p_{t+1}\big), \tag{3}$$

$$\text{Price Phillips:} \quad \pi^p_t = \beta E_t \pi^p_{t+1} + \lambda_p \hat{\omega}_t, \tag{4}$$

$$\text{Wage Phillips:} \quad \pi^w_t = \beta E_t \pi^w_{t+1} - \lambda_w \big(\hat{\omega}_t - (\hat{c}_t + \varphi \hat{n}_t)\big), \tag{5}$$

$$\text{Wage accounting:} \quad \hat{\omega}_t = \hat{\omega}_{t-1} + \pi^w_t - \pi^p_t, \tag{6}$$

$$\text{Resources:} \quad (1-\bar{\tau})\hat{c}_t + \bar{\tau}\hat{\tau}_t = \hat{n}_t, \tag{7}$$

$$\text{Taylor rule:} \quad \hat{\imath}_t = \phi_\pi \pi^p_t, \tag{8}$$

$$\text{Tax policy:} \quad \hat{\tau}_t = \rho \hat{\tau}_{t-1} + \nu_t. \tag{9}$$

Here, $\hat{x}_t$ denotes the log-deviation of x at t from its steady-state value. Let us now briefly describe the equations one-by-one.

Equation (3) is the New Keynesian IS curve, a Euler condition that links current consumption $\hat{c}$ to expected future consumption and the expected real interest rate. Equation (4) is the New Keynesian–Phillips curve, relating current price inflation π^p to expected inflation and the current real marginal cost; the latter, with linear production, equals the real wage ω. λ_p is a combination of structural preference parameters and the price-resetting probability, which together govern the price response to changes in marginal costs.[6] Equation (5) is the Phillips curve for wages implied by the household's wage-setting problem. It describes how nominal wage inflation π^w responds to changes in the difference between the real wage and the marginal rate of substitution between consumption and hours, where λ_w is another combination of structural parameters, including the adjustment-cost parameter for wages.[7] Equation (6) is an accounting identity, describing the evolution of the real wage in terms of wage and price inflation. Equation (7) is the economy's resource constraint. On the right-hand side, we have total household income, or output, which with constant productivity equals total hours worked $\hat{n}_t$. On the left-hand side, we have private consumption and taxes, where the tax share in total household income $\bar{\tau}$ equals that of government expenditures g.

[6]Specifically, $\lambda_p = \frac{(1-\theta_p)(1-\beta\theta_p)}{\theta_p}$, where β is the discount factor and θ_p the per-period Calvo probability that a firm cannot reset its price.

[7]Specifically, $\lambda_w = -\frac{\epsilon_w - 1}{\chi}$ where ϵ_w is the elasticity of substitution between labor inputs and χ is the Rotemburg adjustment-cost parameter.

For given expectations, the system (3)–(7) determines the five unknown endogenous variables—$\hat{c}$, π^p, π^w, $\hat{\omega}$, and $\hat{n}$—uniquely as a function of the policy variables $\hat{\imath}$ and $\hat{\tau}$. Equations (8) and (9) then provide the policy rules (a Taylor rule and an AR(1) for the fiscal shock). For our calibrated model, the implied full dynamic system has a unique stable solution around its zero-inflation steady state.

The equilibrium response of household income plays a key role in our analysis. Real income in this economy is the sum of labor earnings, $\hat{\omega}+\hat{n}$, and dividends from the monopolistic firms, $\hat{d}$; time-t dividends can therefore be solved residually from the household budget:

$$\text{Household income:} \quad \hat{n}_t = \bar{S}(\hat{\omega}_t + \hat{n}_t) + (1-\bar{S})\hat{d}_t. \tag{10}$$

Here, the weights $\bar{S}$ and $1-\bar{S}$ are the steady-state shares of earnings and dividends in terms of total income, respectively.

Finally, note that in the limit of flexible wage setting, $\lambda_w \to \infty$ in the wage Phillips curve (5), implying that the real wage equals the marginal rate of substitution:

$$\hat{\omega}_t = \hat{c}_t + \varphi \hat{n}_t. \tag{11}$$

In this case, the model equations can be collapsed into the familiar 3-equation representation, augmented with the tax policy equation. Analogously, in the limit of flexible price setting, the goods price Phillips curve (4) implies $\hat{\omega}_t = 0$; real wages simply equal TFP, which is assumed to be constant.

2.2 *HANK*

The HANK model is the natural extension of the RANK model to the kind of incomplete-markets model studied in Huggett (1993): instead of perfect insurance within a single household as in RANK, we assume that individuals are subject to mean-zero productivity shocks against which they can only imperfectly insure by trading a risk-free bond subject to a borrowing constraint. We consider a particularly simple HANK model here. The household sector consists of *workers* and (a small mass of) *capitalists*. These are ex ante identical in all aspects (including their tax share of income) except that the capitalists own the firms and derive income from firm dividends, whereas workers only receive wage income. This assumption captures the fact that equity ownership is extremely concentrated (see, e.g., Kuhn and Rios-Rull (2016)). We also follow Krusell, Mukoyama, and Smith (2011), Werning (2015), McKay and Reis (2017), and Ravn and Sterk (2021) and assume a zero borrowing constraint such that households cannot borrow at all. Together with the assumption of zero government debt, this implies that agents cannot save in equilibrium, and the equilibrium wealth distribution is degenerate with a single mass point at 0. This assumption allows closed-form expressions for our key aggregates.

The worker problem is to maximize

$$E_t \sum_{k=0}^{\infty} \beta^k \left(\log C_{jt} - \frac{N_{jt}^{1+\varphi}}{1+\varphi} \right) \tag{12}$$

subject to the budget constraint

$$P_t C_{jt} + Q_t B_{jt} + P_t T_{jt} = W_{jt} N_{jt} - \frac{\xi}{2}\left(\frac{W_{jt}}{W_{jt-1}} - 1\right)^2 W_{jt} N_{jt} + B_{jt-1}, \tag{13}$$

and the borrowing constraint

$$B_{jt} \geq 0, \tag{14}$$

and the CES demand function of firms for differentiated labor services. We assume that i.i.d. productivity shocks are realized after the wage has been set but before consumption and asset trade take place. Heterogeneity in realized income $W_{jt}N_{jt}$ arises as with a given CES demand function: a positive productivity shocks raises firm demand for labor type j, and so her hours worked N_{jt} rise.

The capitalists' problem is identical to (12) apart from the fact they do not earn any labor earnings but do earn dividend income from a fully diversified portfolio of firms.[8] Anticipating zero bond trade in equilibrium, capitalist consumption simply equals their dividend payment every period.

A zero bond trade equilibrium must have that the real interest rate is low enough to deter all households from saving except the agent with the highest propensity to save. We moreover posit that (i) aggregate shocks are small relative to idiosyncratic shocks to worker productivity (and thus income), (ii) that there is a fixed cost of employment, and (iii) that the mass of capitalists is sufficiently small. Together, these assumptions imply that capitalists do not work in this economy (as per-capita dividend income is sufficiently high to make working not worth their while); and that the "marginal saver" is always a worker, as the worker, but not the capitalist, faces income variation due to idiosyncratic productivity shocks. For details, see Broer et al. (2020).

The log-linear equilibrium of the HANK model can be described by a set of equations similar to (3)–(9). The set of equations of the HANK model is different from the RANK model in two ways. One is that consumption, $\hat{c}$, now refers to worker (and not aggregate) consumption. The second, and implied, difference is that the resource constraint (7) is now replaced by the worker's budget constraint (13), evaluated at equilibrium (where bond holdings are zero):

$$\text{Worker income:} \quad (1-\bar{\tau})\hat{c}_t + \bar{\tau}\hat{\tau}_t = \hat{\omega}_t + \hat{n}_t. \tag{15}$$

The key in equation (15) is that income, on the right-hand side, is not aggregate income $\hat{n}$ (which, expressed in terms of factor payments as in (10), would include dividends) but rather worker earnings: $\hat{\omega} + \hat{n}$. Thus, $\bar{\tau}$ is the worker tax share of worker earnings. We assume that this earnings tax share is the same as the capitalist tax share of capitalist income, or, equivalently, the same as the the total tax share of total income, as in the RANK economy.

[8]The assumption that workers, but not capitalists, work can be microfounded with a fixed cost of labor market participation. If the cost is high enough, capitalists will choose not to work as due to their additional source of income.

Before moving on to the analysis of fiscal multipliers we note that, in terms of aggregates, our HANK model has equilibrium properties that are identical to those of a two-agent model with an unconstrained worker and a hand-to-mouth capitalist. Our model is different, however, from many previous TANK models, for example, Galí, Lopez-Salido, and Valles (2004), Bilbiie (2008), Colciago (2011), and Bilbiie (2020). There, a fraction of households is assumed to consume their labor income hand-to-mouth, while the remainder are unconstrained households who collect profits and also supply labor. By assumption, bonds are thus priced by these worker-capitalists that also receive profit income. In our framework, in contrast, who prices bonds is endogenously determined, and turns out to be a worker, whose only income source are wages. Our contrasting assumption of workers versus capitalists not only captures the strong concentration of equity holdings in the data but also allows us to highlight how the factor income distribution and different assumptions about the source of nominal rigidity together determine hours worked. In other words, we focus on the effect of heterogeneity on the *supply* side of the model.

We view this analysis as complementary to that of the earlier literature, in particular Bilbiie (2020) who points out how the correlation between the marginal propensity to consume and the cyclicality of income across two consumer types affects aggregate consumption *demand*. We show how wage rigidity reduces the effect of household heterogeneity from the perspective of the labor market equilibrium, by equalizing movements in factor income shares and, therefore, the difference in the income effects generated by response of wage and profit income. From the perspective of the goods-market equilibrium, the aforementioned papers have highlighted that shocks are amplified in HANK models because incomes of high-MPC agents are more procyclical than that of low-MPC agents. Whenever this differential cyclicality results from assumptions about the distribution of factor incomes, as in Bilbiie (2020), wage rigidity reduces amplification by reducing movements in factor income shares. This effect is present in our model, too. In fact, the analysis in Bilbiie (2020) applies directly to our model, as our model can be viewed as a version of a standard limited-participation TANK model where the government fully redistributes the profit (labor) income of asset-market participants (nonparticipants) to the remaining households.

3. Fiscal multipliers

We now consider the implications of an innovation in government spending in the RANK and HANK models.

3.1 *Analytical results*

In this subsection, following Bilbiie (2011) and Woodford (2011), we focus on the limit cases of fully flexible or fully rigid prices and wages, which allow a simple analytical solution for the response of current output to current taxes in both the RANK and the HANK

model.[9] This allows us to transparently study how the models' output multipliers are affected by the source of the nominal rigidity: sticky prices or sticky wages. We define the current-period multiplier as $M^i = \frac{\partial \hat{y}_t^i}{\bar{\tau} \partial \hat{g}_t}$, that is, the ratio of the current output response to the current deviation of the output share of government spending from its steady-state value, for $i =$ RANK, HANK. Taking the forward-looking sum of the denominator and numerator, we get the time-zero cumulative multiplier. Since production is linear, the response of output is the same as the response of hours worked, and much of analysis below focuses on the determination of the latter.

Flexible prices and wages First, consider the case of flexible prices and wages (λ_p, $\lambda_w \longrightarrow \infty$). In this case, we have a constant real wage $\hat{\omega}_t = 0$, $\forall t$. Given this, we find the multipliers

$$M^{\text{RANK}} = M^{\text{HANK}} = \frac{1}{1 + (1 - \bar{\tau})\varphi} < 1. \tag{16}$$

In both models, hours worked increase in response to a positive fiscal shock, but less than one-for-one: there is a negative income effect from the increase in taxes, which is partly offset by the increase in market income. The responses are identical, because with constant returns to labor inputs, labor earnings and profits scale one-to-one with output, that is, factor shares are constant. Alternative assumptions about the distribution of profit income thus leave the dynamics of worker income unaffected, and thus do not affect the labor supply decision.

Rigid prices, flexible wages Second, consider the the limit case of flexible wages and fully rigid prices ($\lambda_p \longrightarrow 0$, $\lambda_w \longrightarrow \infty$), such that price inflation is constant at 0. A Taylor rule that responds to inflation only then implies a constant real interest rate $r_t = 0$, $\forall t$. Equation (3) in turn implies $\hat{c}_t = 0$, $\forall t$, such that consumption remains constant at its steady-state level. The labor supply condition (11) and resource constraint (7) then imply in the RANK model

$$\hat{y}_t = \hat{n}_t = \bar{\tau} \hat{\tau}_t$$

such that

$$M^{\text{RANK}} = 1.$$

This results echoes the analysis in Woodford (2011). More generally, whenever price rigidity and monetary policy are such that real interest rates are constant, fiscal multipliers in simple representative-agent New Keynesian economies are *larger* than with flexible prices.[10]

In the HANK model, in contrast, we have

$$\hat{y}_t = \hat{n}_t = \frac{\bar{\tau}}{1 + \varphi} \hat{\tau}_t \tag{17}$$

[9] See Broer, Krusell, and Öberg (2021) for a more general analytical characterization in the case of imperfectly rigid prices.

[10] Bilbiie (2011) shows that with nonseparable preferences within the KPR family the fixed-price multiplier in RANK can be larger than 1 when hours and consumption are complements.

such that

$$M^{\text{HANK}} = \frac{1}{1+\varphi}, \tag{18}$$

which is smaller than the corresponding flexible-price multiplier in equation (16).

Why do sticky prices raise the responses of hours and output in RANK, but dampen them in HANK? When wages are fully flexible but prices are not, factor income shares change over the business cycle: firms cannot raise prices, and in booms they must hire more labor to satisfy the demand for their products. This raises wages and squeezes profits. To see how this affects the responses to a fiscal shock, we combine the optimality condition for labor supply (11) with the worker's equilibrium budget—(7) and (10) for the RANK model and (15) for the HANK model—to obtain the following conditions for the determination of hours worked:

$$\text{RANK:} \quad \left[\varphi(1-\bar{\tau}) + \bar{S}\right]\hat{n}_t = \bar{\tau}(\hat{\tau}_t - \hat{\omega}_t) + (1-\bar{S})(\hat{\omega}_t - \hat{d}_t), \tag{19}$$

$$\text{HANK:} \quad \left[\varphi(1-\bar{\tau}) + 1\right]\hat{n}_t = \bar{\tau}(\hat{\tau}_t - \hat{\omega}_t). \tag{20}$$

In HANK, the increase in wages *depresses* hours worked because post-tax labor income is smaller than wage earnings (as the the share of government expenditures $\bar{\tau}$ is positive), implying that the income effect of wage rises dominates the substitution effect in (20) with standard KPR preferences. In RANK, the wage rise *stimulates* labor supply for two reasons: first, for any level of positive profit income ($\bar{S} < 1$ in (19)), the relative income effect of the wage rise is dampened. Second, a rise in wages implies smaller profits, which in itself has a negative income effect on hours worked. In the realistic case where the profit share is smaller than the tax share of total income ($1 - \bar{S} < \tau$), profit income is not high enough to make households work more in response to higher wages. In this case, sticky prices deliver a higher spending multiplier solely because they imply a countercyclical response of profits $\hat{d}_t$.

Flexible prices, rigid wages Third, consider the the limit case of flexible prices and fully rigid wages. With flexible pricing, final-good firms set their prices as a constant markup over nominal marginal cost in every period. Again, real wages, and thus factor shares, are therefore constant. Hence, the fiscal multipliers in HANK and RANK are again the same. In the limit case of perfectly rigid wages, both wage and price inflation are zero. The Taylor rule then again implies $c_t = 0, \forall t$. Labor market clearing requires $\hat{y}_t = \hat{n}_t = \bar{\tau}\hat{\tau}_t$, or

$$M^{\text{RANK}} = M^{\text{HANK}} = 1. \tag{21}$$

Rigid prices and wages Finally, consider the case where both wages and prices are fully rigid. Since rigid wage setting in itself implies that both wages and price inflation are zero, the additional assumption of rigid price setting does not change anything. We again have that multipliers are the same in both models, and equal to 1.

We collect these results in Proposition 1.

Proposition 1. *Fiscal multipliers in the four cases that combine perfectly flexible or rigid prices and wages are as given in Table* 1.

TABLE 1. Output multipliers with perfectly flexible or rigid prices and wages.

	RANK	HANK
Flexible prices and wages	$\frac{1}{1+(1-\bar{\tau})\varphi}$	$\frac{1}{1+(1-\bar{\tau})\varphi}$
Fixed prices, flexible wages	1	$\frac{1}{1+\varphi}$
Flexible prices, fixed wages	1	1
Fixed prices and wages	1	1

Proposition 1 shows how nominal rigidity increases the potency of fiscal policy in the RANK model independently of its source. Summarizing the previous analysis, this is because the effects of rigidity in prices or wages are identical in the RANK model: both allow temporary deviations from the flexible-price markup of the marginal rate of transformation in technology over the marginal rate of substitution between labor and consumption in worker preferences. Moreover, for a given path of the marginal rate of substitution they act to dampen inflation responses, and thus reduce the crowding-out effect that results when contractionary monetary policy fights the inflationary effect of fiscal expansions. By reducing the variability of markups relative to marginal costs, price rigidity, however, makes profit shares more countercyclical when wages are flexible. Wage rigidity, in contrast, leaves profit shares unaffected with flexible prices, and reduces their cyclicality when prices are also rigid. This is why the two sources of rigidity have different effects for the potency of fiscal policy in the HANK model where fluctuations in income shares affect labor supply.

3.2 *Quantitative illustration*

We now illustrate how our analytical results from the previous section generalize to a numerical example where the degrees of price and wage rigidity are set to standard values. Again, we look at three different cases that we compare to the flex-price equilibrium: only price rigidities, only wage rigidities, and both. We set the tax/output share to 30% and study the quarterly response to a 1% shock to government spending with autocorrelation $\rho = 0.5$. The other parameter values are taken from Galí (2008, Chapters 3 and 6). The discount factor equals 0.99, the Frisch elasticity $1/\varphi$ is set to 1, the elasticity of substitution between goods as well as that between labor inputs equals 6, the price reset probability is 1/3 and the Rotemberg adjustment cost for wage setting is set so as to replicate a corresponding Calvo wage reset probability of 1/4, and the Taylor coefficient on inflation is 1.5.

The resulting IRFs for wages, profits, and output are displayed in Figure 1 (see the Appendix Figure 2 for the IRFs for a larger set of variables), where the gray solid lines are the responses of the RANK model and the black dashed lines are the responses of the HANK model. The two upper rows show, respectively, the responses of real wages and profits as percent deviations from their steady-state values. The bottom row shows the response of the output gap (the log-difference between the response of output in the three models with rigidities, and that under flexible prices and wages). Table 2 reports the cumulative output multiplier.

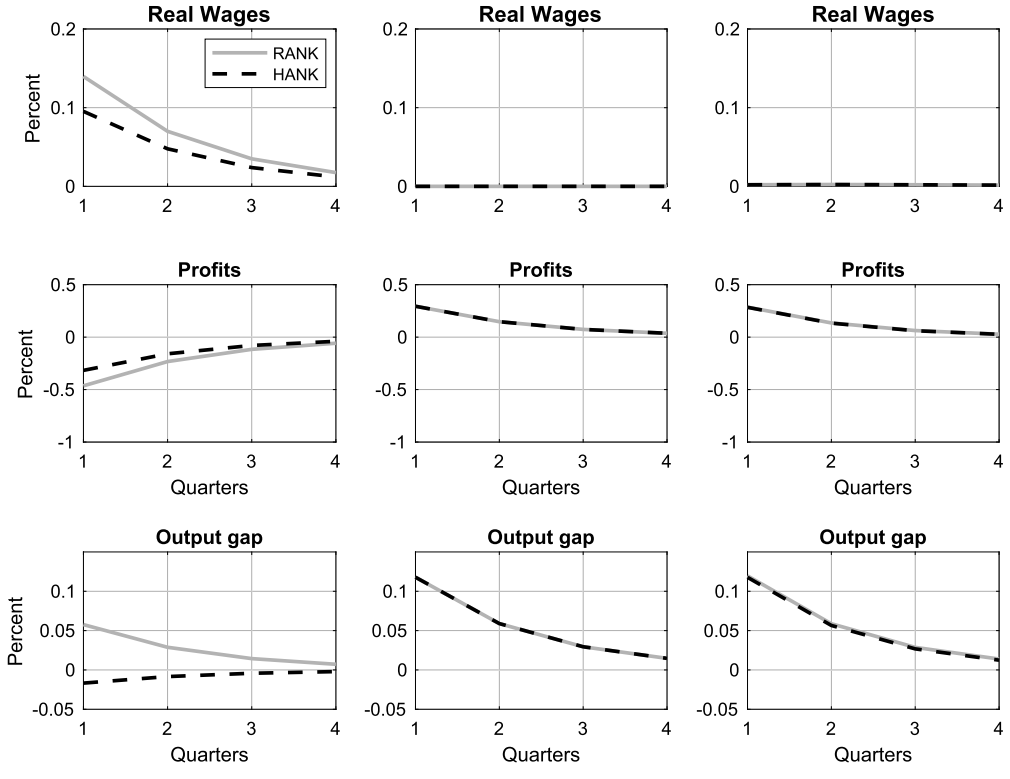

FIGURE 1. Responses to a shock that raises government spending by 1% relative to steady state. Rows 1 and 2 show responses relative to steady state. Row 3 shows responses relative to the flexible-price equilibrium.

The figure shows that the analytical results on fiscal multipliers with perfect rigidity of prices or wages carry over quantitatively to the case of imperfect rigidities: HANK and RANK again share the same output response when there is imperfect wage rigidity (columns 2 and 3 of Figure 1). And with rigid prices but flexible wages (column 1), the output response is again smaller than with flexible prices in HANK, equivalent to a negative response in the output gap, but larger in RANK. The same is true for the cumulative multipliers reported in Table 2 (although the multiplier with rigid prices and wages is slightly smaller in HANK than in RANK).

The results again illustrate the main mechanism behind this ranking of fiscal multipliers: whenever prices are flexible, markups, real wages, and labor-income shares are

TABLE 2. Cumulative fiscal multipliers.

	No Rigidity		Price Rigidity		Wage Rigidity		Wage and Price Rigidity	
Model	RANK	HANK	RANK	HANK	RANK	HANK	RANK	HANK
Cumulative multiplier	0.59	0.59	0.78	0.53	0.98	0.98	0.98	0.96

constant. This makes responses to fiscal shocks the same in HANK and RANK in column 2, independently of the degree of wage rigidity. Because with a realistic degree of wage rigidity nominal wages respond very little to fiscal shocks, adding price rigidity (column 3) does not affect these responses materially. When wages are flexible but prices rigid (column 1), profits shrink and real wages rise in response to a fiscal expansion. This makes total post-tax worker income respond less than wages in RANK, but more than wages in HANK (where, in percentage terms, a given wage change affects income after taxes more than wages itself). Relative to flexible prices, where real wages are constant, income effects of real-wage fluctuations thus amplify the labor-supply response in RANK (implying a positive output gap in the bottom left panel), but dampen it in HANK.

4. Concluding remarks

For robustness of the quantitative illustration, we also examined models with significantly less wage rigidity (by doubling the probability that firms can reset prices from 1/4 to 1/2) and found very small differences between the HANK and RANK models and only marginally lower multipliers. We also found that the assumption of linear production is not material for our results: with a labor input elasticity of output equal to 0.7, the responses in the sticky-wage versions of the RANK and HANK models are still close to identical; with sticky prices, the difference between RANK and HANK increases, since profits respond even more countercyclically in this case.

A more interesting other case is that when the monetary authority is constrained by a zero lower bound (ZLB) on the interest rate. In particular, representative-agent models with nominal rigidities have been found to predict multipliers that can be significantly larger than one in those circumstances, providing a rationale for using discretionary fiscal policy as a stabilization tool (see, e.g, Woodford (2011), Christiano, Eichenbaum, and Rebelo (2011), and Eggertsson (2011)). The reason for their prediction is simple. With active monetary policy, real interest rates rise in response to higher inflation and partly crowd out the positive effect of a fiscal shock on output. When monetary policy is constrained and nominal interest rates unaffected by shocks, in contrast, the rise in inflation in response to a fiscal stimulus implies a *fall* in real interest rates, thus further stimulating consumption and increasing both the output response and the multiplier. What can we learn about this mechanism from our analysis? First, under sticky prices, the insight that under reasonable parametric restrictions, countercyclical profits are a necessary condition for amplification does not depend on the state of monetary policy, but follows directly from the household's labor supply decision together with the market clearing condition. Thus, the amplification of the multiplier is only consistent with the representative agent's optimal choice of labor supply because profits respond countercyclically. That is, for multipliers to be larger in the ZLB case, it must be that profits respond more strongly (negatively) to the fiscal stimulus. That is, to the extent one agrees with our term "implausible" to describe the sticky-price model's amplification mechanism, this mechanism becomes even more implausible in the case of the ZLB. How does the behavior of the rigid-wage model change when monetary policy is constrained? Virtually not at

all: the multiplier remains one. As hightlighted in our analysis, wage rigidity reduces the response of inflation and, therefore, the interest rate to the fiscal shock. The responses are literally zero will fully rigid wages, and very close to zero with realistically calibrated rigid wages; see the Appendix, Figure 2. In consequence, the lower bound on the nominal interest rate has virtually no effect. More broadly, integrating this rigid-wage setting in business-cycle models dampens the fluctuations in marginal costs and, therefore, restrains the amplification of the multiplier at the zero lower bound.[11]

Our analysis assumed that there is no asset trade in equilibrium. This follows naturally from the standard textbook RANK model (which has no assets), and kept the analysis tractable. But it begs the question: how would the results change when households trade assets in equilibrium? Generally, asset trade reduces the role of heterogeneity by allowing partial insurance against idiosyncratic shocks. With rigid prices, this acts to move the HANK model closer to the RANK model, as asset trade between workers and capitalists would smooth their consumption relative to income, but less so than in RANK, where their incomes are perfectly pooled. With rigid wages, where the dynamics of worker and capitalist incomes are less heterogeneous, we would expect a more limited role of asset trade.

The main take-away from our present note is not a critique of the three-equation representative-agent New Keynesian model. We do think that the representative-agent focus of this model is problematic and that the supply side is inadequate, but this model has been very important in providing a clear mechanism for the dynamics of demand (through its dynamic IS equation and monetary policy). Instead, the main goal here is to provide some guidance in the construction of quantitative HANK models. In particular, models with flexible wages may obscure the role of heterogeneity in affecting aggregate dynamics, through their implausible implications for the dynamics of profit income. Based on our analysis, nominal wage rigidity is a more plausible benchmark, which is also in line with recent developments of the HANK literature concerning fiscal multipliers (Auclert, Rognlie, and Straub, 2018, Hagedorn, Manovskii, and Mitman, 2019). We also think that there is a need to develop such models of rigid wages—in particular their foundations—further; they have received much less attention than models with price rigidities. Such work is at least on our own agenda (Broer, Harmenberg, Krusell, and Öberg (2020)).

Appendix: Impulse responses

In Figure 2, we show impulse responses to the fiscal shock for an expanded set of variables of the calibrated models considered in Section 2.

[11]The ZLB can clearly play a role in a HANK setting with sticky prices and sticky wages, not only since the degree of wage rigidity is ultimately an (open) question for empirical research (see, e.g., Beraja, Hurst, and Ospina (2019)), but also because additional features may disconnect marginal costs from moving one-to-one with wages in more general models. However, for modest departures from the benchmark here, including to cases where the production has some curvature, we found that the ZLB plays a very limited role.

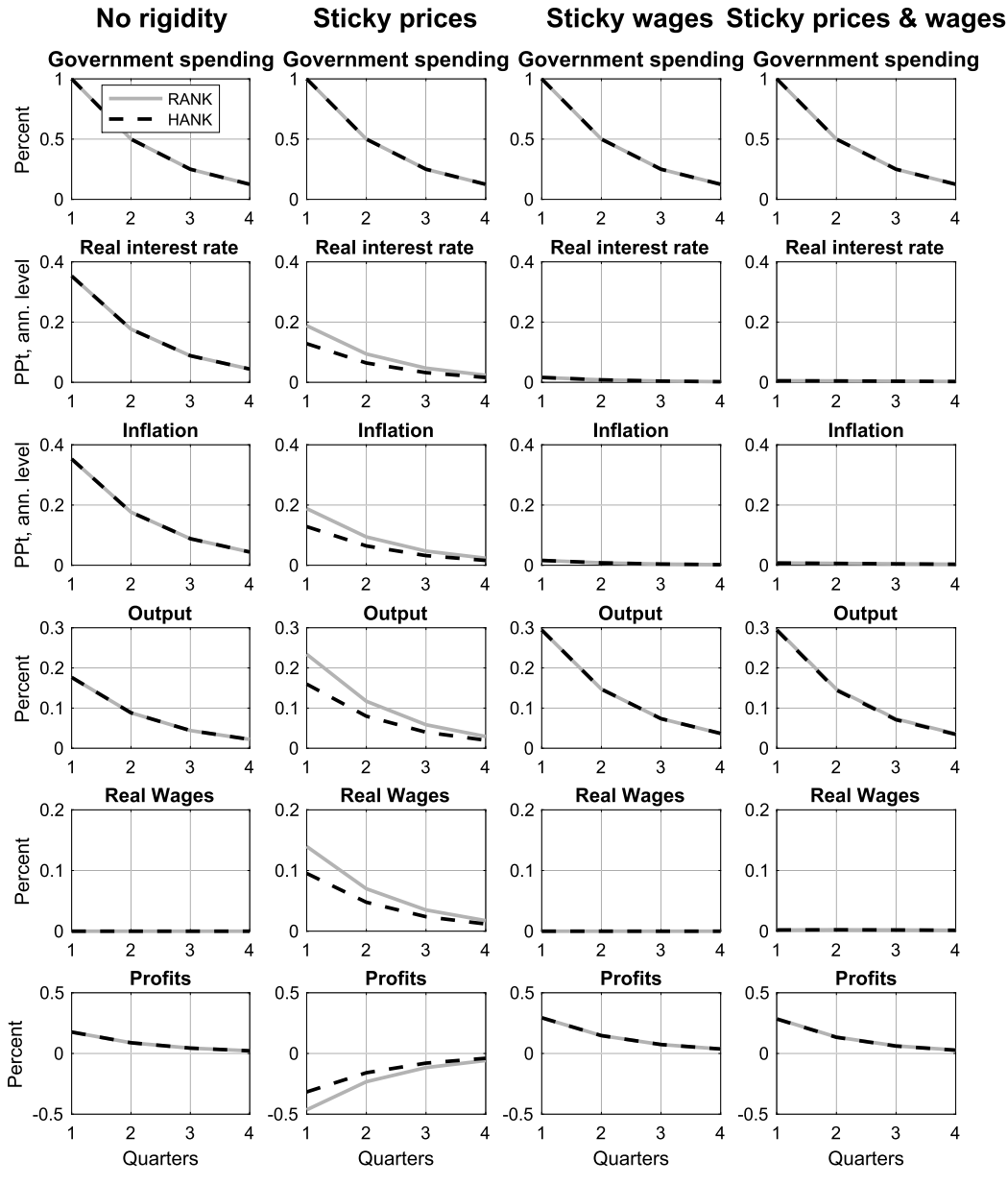

FIGURE 2. Responses to a shock that raises government spending by 1% relative to steady state. All rows show responses relative to steady state.

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