Wage and Price Rigidities

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Preliminary

Abstract

This paper studies the interaction between wage and price rigidities, with particular attention to the size of the government consumption multiplier. I confirm that in a simple model with price rigidities and no capital, the government consumption multiplier can exceed 1 if the nominal interest rate is unresponsive to government consumption. This may be particularly relevant if the zero lower bound on interest rates is binding. However, I show that whenever the government consumption multiplier is positive, an increase in government consumption reduces welfare. In this model, wage rigidities generate unemployment but do not affect output or consumption. I then extend the model to introduce capital. I show that in the absence of any adjustment costs on capital, a reduction in the nominal interest rates causes a collapse in output and investment. An increase in government consumption amplifies these effects, so the government consumption multiplier is again negative. This suggests that price rigidities and a binding zero lower bound alone do not justify the use of countercyclical fiscal policy.

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1 Introduction

This paper explores the interaction between wage and price rigidities, with a particular focus on the impact of government consumption on private economic outcomes. It is a continuation of my earlier work exploring the impact of real wage rigidities (Shimer, 2011). That research argued that rigid wages of the sort that can be generated from a search and matching model can explain a persistent or even permanent decline in employment, investment, consumption, and output following an adverse shock to the economy. But the model also predicts that firms' labor demand should be very responsive to the real wage, with an elasticity of approximately minus three. Put differently, the model predicts that a three percent reduction in firms' labor costs would eliminate the unemployment and output gap problems faced by the United States as I write this paper. At a purely introspective level, this prediction seems implausible.

Indeed, surveys of firms suggest that lack of demand is the major impediment to hiring. For example, the President of the Federal Reserve Bank of Atlanta recently said, " Recent surveys suggest that most small businesses are cautious about hiring more because of slow sales growth rather than lack of access to credit" (Lockhart, 2011). To my knowledge, there is only one mainstream model that can capture a shortfall in aggregate demand, the New Keynesian model. In this framework, firms would like to cut their price in response to an adverse shock, but they are unable to. Instead, they are forced to supply however much output is demanded at this too high price. With demand low, firms have little need for labor. This too can generate low employment, consumption, and output.

Which theory is more relevant, wage or price rigidities? To begin exploring this question, I put both rigidities into a common framework. For simplicity, I focus on an environment in which both rigidities are extreme: prices never change, nor do wages. I focus on the impact of distortions to the nominal (and hence real) interest rate in this environment.

The paper considers two variants on the New Keynesian model. In the first, there is no capital. I show the well-known result that an increase in the real interest rate above its natural rate reduces economic activity. Intuitively, households would like to defer consumption when the real interest rate is too high, but this is impossible in an economy with no capital. Instead, they simply reduce consumption until they achieve the desired slope in the consumption profile. This depresses the economy today with no beneficial effects tomorrow. With low consumption, demand and employment are low as well. Real wage rigidities play little role in this simple model. In the absence of the wage rigidity, a reduction in labor demand leads to a fall in wages and a shift down along workers' labor supply curve. With rigid wages, workers are taken off their labor supply curve and so the model generates unemployment. However, the level of consumption, employment, and output is unaffected by the wage rigidity.

I then turn to a model with capital. I show that in the most natural version of this model, a reduction in the real interest rate causes a collapse in employment, investment, and output. To be clear, this is the opposite of what is "supposed" to happen in this type of model. Intuitively, a reduction in the real interest rate lowers the user cost of capital. With demand constrained by a fixed price, all firms would like to shift from using labor to using capital. But the capital stock is fixed in the short run, and so this is only possible if all firms reduce employment. Lower employment in turn lowers current output, which pushes down investment. Even after the real interest rate distortion is removed, the economy remains depressed because of the loss in capital.

In this environment, real wage rigidities do have an effect on economic outcomes. With flexible wages, the collapse in labor demand leads to a reduction in both employment and wages; the relative response of quantities and prices depends on the elasticity of labor supply. If wages cannot fall, then the entire burden of the adverse event must be borne by employment. Rigid wages therefore exacerbate the impact of rigid prices. In addition, rigid wages affect the recovery of the economy after the real interest rate returns to its normal level. Low investment during the abnormal period pushes down the capital stock. If wages cannot fall, the economy subsequently experiences a proportional and permanent decline in employment, investment, consumption, and output, never recovering to its normal level (Shimer, 2011).

I also look at the impact of government consumption in both variants of the model. Following Woodford (2011), I assume that an increase in government consumption does not affect the nominal interest rate; this seems particularly relevant if the nominal interest rate is pinned at zero. In the model without capital, I show that an increase in government consumption causes an increase in private consumption—so the government consumption multiplier is bigger than 1—if and only if consumption and leisure are substitutes. However, even in that event, an increase in government consumption is always welfare reducing. In the model with capital, I find numerically that an increase in government consumption crowds out private investment and tends to reduce private consumption. Again, this is welfare reducing. This is true whether wages are rigid or flexible.

Finally, I should include a disclaimer. I view this paper as being about models, not about the real world. The fact that the models predict that an increase in government spending can be contractionary and welfare reducing does not mean that this is necessarily the case in the real world. But if it is not, then this finding should be viewed as a critique of the models. The models that I study here are admittedly simple and far more stylized that the usual quantitative New Keynesian models (Smets and Wouters, 2003; Christiano, Eichenbaum, and Evans, 2005). The virtue of this is that it highlights the essential mechanisms in those models. But of course the bells and whistles in a more fully-fleshed model may hide or even overturn some of these conclusions. It is therefore best to view this paper as an effort to improve our understanding of the realism and empirical relevance of the nature of price rigidities in these models.

The remainder of the paper consists of three sections. I first describe the model without capital, then the model with capital, and finally briefly conclude by summarizing the paper's main message.

2 No Capital

I consider an economy with a representative household, a representative final goods producer, heterogeneous intermediate goods producers, and a government. Households supply labor to intermediate goods producers and choose how much to consume and how much to save. Each intermediate goods producers hires workers to produce its differentiated intermediate good, which it then sells to the final goods producers. The final goods producers combine the intermediate goods into a final good which is then sold to households and the government. The government also subsidizes the sale of intermediate goods in order to undo the monopoly distortion in the intermediate goods section and finances its purchases and subsidies through a lump-sum tax on households. I start by describing the economic environment in more detail.

2.1 Economic Environment

Household members are infinitely-lived and discount the future with factor β_t between periods $t-1$ and t. Let $\beta^t \equiv \prod_{s=1}^{t} \beta_s$ denote the cumulative discount factor through period t (with $\beta^0 = 1$) and assume $\lim_{t\to\infty} \beta^t = 0$. The household's period utility function is increasing in its consumption c_t and decreasing in its labor supply h_t, with functional form

$$\frac{c_t^{1-\sigma}\left(1+(\sigma-1)\frac{\gamma\varepsilon}{1+\varepsilon}h_t^{\frac{1+\varepsilon}{\varepsilon}}\right)^{\sigma}-1}{1-\sigma},$$

if $\sigma \neq 1$ and

$$\log c_t - \frac{\gamma\varepsilon}{1+\varepsilon}h_t^{\frac{1+\varepsilon}{\varepsilon}}$$

if $\sigma = 1$. These preferences are characterized by three parameters: $\gamma > 0$ determines the disutility of work; $\varepsilon > 0$ is the Frisch elasticity of labor supply; and $\sigma > 0$ determines the substitutability between consumption and leisure; in particular, if $\sigma > 1$, the marginal utility of consumption is increasing in hours worked. These preferences are the most general ones consistent with two requirements: balanced growth and a constant Frisch elasticity of labor supply. The household maximizes its lifetime utility subject to a single lifetime budget constraint.

A typical intermediate goods producer $j \in [0, 1]$ is the monopoly supplier of good j. The producer uses labor $h_{j,t}$ to produce $y_{j,t} \equiv h_{j,t}$ of good j in period t, which is then sold to the representative final goods producer at a price $p_{j,t}$. The government subsidizes the sale of the final good, so the intermediate goods producer receives $(1 + \nu)p_{j,t}$ for each unit sold; this subsidy undoes the monopoly distortion in the economy.[1] The intermediate goods producer pays workers a wage W_t and maximizes the present value of its profits.

The final goods producer in turn combines all the varieties of intermediate goods to produce a final good using a constant elasticity of substitution production function,

$$Y = \left(\int_0^1 y_j^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}}, \tag{1}$$

where $\theta > 1$ is the elasticity of substitution between different intermediate goods. The final good is used for private and government consumption and is sold at a price of P_t. The final goods producers maximize profits and in equilibrium earn zero profits.

The government levies a lump-sum tax on households to fund its consumption and the production subsidies. Ricardian equivalence holds in this economy, so the timing of taxation is unimportant. To ensure that the economy with flexible prices achieves a Pareto optimum, it sets the production subsidy at $\nu = 1/(\theta - 1)$.

Let q_0^t denote the time 0 price of a unit of the numeraire good at time t, so $i_{t+1} \equiv q_0^t/q_0^{t+1} - 1$ is the nominal interest rate between periods t and $t + 1$. This is the key intertemporal price in the model. I now describe in detail how each economic actor behaves taking prices as given.

[1] While this assumption may be unrealistic, it is standard in the New Keynesian literature because otherwise there would be an incentive to use monetary policy to undo the monopoly distortion, a prediction that seems at odds with how monetary policy is conducted in practice.

2.2 Households

A typical household with initial assets B_0 chooses a path for consumption, $\{c_t\}$, and for labor supply $\{h_t\}$, to maximize its lifetime utility

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-\sigma} \left(1 + (\sigma - 1) \frac{\gamma\varepsilon}{1+\varepsilon} h_t^{\frac{1+\varepsilon}{\varepsilon}}\right)^{\sigma} - 1}{1 - \sigma} \right),$$

subject to a single lifetime budget constraint

$$\sum_{t=0}^{\infty} q_0^t \left(P_t c_t - W_t h_t\right) = B_0 - \tau,$$

where τ is the present value of lump-sum taxes which are used to finance government consumption and production subsidies. Any equilibrium allocation must satisfy

$$c_t \geq 0 \text{ and } 1 + (\sigma - 1) \frac{\gamma\varepsilon}{1+\varepsilon} h_t^{\frac{1+\varepsilon}{\varepsilon}} \geq 0 \tag{2}$$

so the level of utility is well-defined.

The solution to the household's problem is characterized by two equations. First is the Euler equation,

$$\frac{u_{c,t}}{u_{c,t+1}} = \beta_{t+1} \frac{q_0^t P_t}{q_0^{t+1} P_{t+1}}, \tag{3}$$

where $u_{c,t}$ is the marginal utility of consumption:

$$u_{c,t} \equiv \left(\frac{c_t}{1 + (\sigma - 1) \frac{\gamma\varepsilon}{1+\varepsilon} h_t^{\frac{1+\varepsilon}{\varepsilon}}} \right)^{-\sigma}. \tag{4}$$

Second, the household equates the marginal rate of substitution between consumption and leisure to the real wage,

$$\gamma\sigma u_{c,t}^{-\frac{1}{\sigma}} h_t^{\frac{1}{\varepsilon}} = W_t / P_t \tag{5}$$

This, combined with the household budget constraint, completely describes the household's behavior.

2.3 Final Goods Producers

The representative final good producer chooses a bundle of inputs $\{y_{j,t}\}$ in period t to maximize its static profits

$$P_t \left(\int_0^1 y_{j,t}^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}} - \int_0^1 y_{j,t} p_{j,t} dj,$$

where $p_{j,t}$ is the nominal price of good j in period t. Profit maximization implies that the demand for good j depends on its relative price and on aggregate demand,

$$y_{j,t} = Y_t \left(\frac{P_t}{p_{j,t}} \right)^{\theta} \tag{6}$$

where Y_t is total output in period t, defined in equation (1). Since the final goods producer earns zero profit, the price of the final good must be

$$P_t = \left(\int_0^1 p_{j,t}^{1-\theta} dj \right)^{\frac{1}{1-\theta}} .$$

It follows that P_t is also the ideal price index.

2.4 Intermediate Goods Producers

The producer of good j chooses a price $p_{j,t}$ and output $y_{j,t}$ to maximize its static profits

$$\tfrac{\theta}{\theta-1} p_{j,t} y_{j,t} - W_t y_{j,t},$$

including the production subsidy $\nu = 1/(\theta - 1)$, subject to the constraint that $p_{j,t}$ is consistent with the demand from final goods producers, given in equation (6):

$$p_{j,t} = P_t \left(\frac{Y_t}{y_{j,t}} \right)^{\frac{1}{\theta}} .$$

The first order condition of this problem imposes that the marginal revenue product is equal to the real wage,

$$\left(\frac{Y_t}{y_{j,t}} \right)^{\frac{1}{\theta}} = W_t / P_t. \tag{7}$$

In equilibrium, all producers set the same price, $p_{j,t} = P_t$, and produce the same output, $y_{j,t} = Y_t$. This implies that the real wage is equal to 1.

2.5 Market Clearing

Output is used for private and government consumption. Since all intermediate goods firms use the same inputs, this implies

$$y_t = c_t + g_t, \tag{8}$$

where g_t is government consumption. In addition, since equation (7) implies the real wage is 1 and since hours worked is equal to output, the labor supply equation (5) reduces to

$$\gamma\sigma u_{c,t}^{-\frac{1}{\sigma}} y_t^{\frac{1}{\varepsilon}} = 1 \tag{9}$$

Eliminate $u_{c,t}$ using the definition of the marginal utility of consumption in equation (4), hours using the production technology $y_t = h_t$, and consumption using the market clearing condition (8):

$$\frac{\gamma\sigma(y_t - g_t)}{y_t^{-\frac{1}{\varepsilon}} + (\sigma - 1)\frac{\gamma\varepsilon}{1+\varepsilon} y_t} = 1. \tag{10}$$

Under condition (2), the left hand side of this expression is increasing in y_t and decreasing in g_t and so this uniquely defines output and employment $y_t = h_t$ as an increasing function of government consumption g_t. The same condition ensures that consumption $c_t = y_t - g_t$ is decreasing in government consumption. With zero government consumption, I can solve this equation explicitly to obtain the level of consumption, income, and hours worked:

$$c_t = h_t = y_t = \left(\frac{1+\varepsilon}{(\sigma+\varepsilon)\gamma}\right)^{\frac{\varepsilon}{1+\varepsilon}} \equiv c^* \tag{11}$$

With positive government consumption, private consumption is lower and output is higher.

Note that these outcomes are completely static. They do not depend on the future path of government consumption, nor on the discount factor. This is because the model has no state variable and no technology for transferring resources over time. Nevertheless, one can recover the nominal interest rate from the household Euler equation (3), and this does depend on the discount factor. For example, if government consumption is the same in periods t and $t+1$, the marginal utility of consumption is constant, and so the gross nominal interest rate is

$$\frac{q_0^t}{q_0^{t+1}} = \frac{P_{t+1}}{\beta_{t+1} P_t}.$$

Of course, only relative prices are determined in equilibrium. I find it useful to fix the final good as numeraire, $P_t = 1$ for all t. This implies that the price of all intermediate goods is fixed at 1 as well. In this case, or more generally with zero inflation, the gross nominal interest is bigger than 1 if and only if the discount factor is smaller than 1.

2.6 Nominal Interest Rate Policy

In the remainder of this section, I assume that the price of the intermediate and final goods are fixed at $p_{j,t} = P_t = 1$, but prior to some date $T > 0$, the nominal interest rate is not set at a level that clears the market. Instead, assume there is some arbitrary sequence $\{i_{t+1}\}$ for the nominal interest rate, which in turn pins down the growth rate of intertemporal prices: $q_0^t/q_0^{t+1} = i_{t+1} + 1$ for $t \in \{0, \ldots, T-1\}$. After T, the nominal interest rate distortion is eliminated, or equivalently prices are perfectly flexible. For example, it might be the case that the discount factor exceeds unity, $\beta_{t+1} > 1$ for $t = \{0, 1, \ldots, T-1\}$, in which case equilibrium with constant government consumption implies the nominal interest rate is negative, $i_{t+1} = \beta_{t+1}^{-1} - 1 < 0$. Thinking of the model as representing the cashless limit of a monetary economy, the zero bound on nominal interest rates makes this impossible, and so instead we have $i_{t+1} = 0$.

With the nominal interest rate fixed, some other market must not clear. Following the New Keynesian literature, I assume that intermediate goods producers supply however much output is demanded at the price $p_{j,t} = 1$. In other words, they are constrained by demand. Note that if the nominal interest rate distortion is sufficiently small, the intermediate goods producers will continue to earn a profit, and so prefer producing rather than shutting down, but they are not profit maximizing.

With production constrained by demand, the real wage is not necessarily equal to 1. That is, equation (7) need not hold. However, since households still choose how much labor to supply, equation (5) continues to hold, as does the resource constraint (8). In summary, an equilibrium is described by two equations. First, the household Euler equation implies

$$\frac{u_{c,t}}{u_{c,t+1}} = \beta_{t+1}(1 + i_{t+1}). \tag{12}$$

For a given path of the nominal interest rate between dates 1 and T, this equation, together with the requirement that the economy returns to its undistorted equilibrium after date T, so equation (10) holds, pins down the path of the marginal utility of consumption. Second, labor market clearing implies

$$\gamma \sigma u_{c,t}^{-\frac{1}{\sigma}} h_t^{\frac{1}{\varepsilon}} = W_t, \tag{13}$$

which determines the nominal and real wage.

For a given path of the wage, equation (13) pins down consumption and hours, and so the household's problem has a unique solution. If $\sigma \leq 1$, the resulting equilibrium is unique. But if $\sigma > 1$, there can be zero, one, or many paths for consumption and hours consistent with equilibrium as defined here. To understand why, use the expression for the marginal utility of consumption (4) and the conditions $y_t = h_t = c_t + g_t$ to determine c_t and h_t given $u_{c,t}$. Two problems may arise. First, if $\sigma > 1$, there is a limit to how low the marginal utility of consumption can get. Increasing consumption requires working more hours, which raises the marginal utility of consumption. As a result, it is straightforward to prove that the marginal utility of consumption always exceeds $\left((1+\varepsilon)(\gamma(\sigma-1))^{\varepsilon}\right)^{\sigma/(1+\varepsilon)}$. There is no equilibrium if the path of nominal interest rates dictates that marginal utility should be lower than this. This means that this path of the nominal interest rate cannot be implemented by any monetary policy rule.

Second, if $\sigma > 1$ and $\varepsilon \in (0, \infty)$, any value of marginal utility that is feasible can be attained in two different ways, with low consumption and hours or with high consumption and hours. These two different outcomes imply two different paths for the real wage, but both are consistent with equilibrium. Since $u(c,h) = (1-\sigma)cu_c(c,h)$, it is always the case that the outcome with lower consumption and hours offers higher utility, but there does not appear to be any reason why the economy will be in this equilibrium. During the periods before date T, the economy can also move back and forth between these two outcomes.

To be concrete, suppose government consumption is constant, so $u_{c,t}$ would be constant and the nominal interest rate would be equal to the inverse of the discount factor in the absence of interest rate distortions. Now suppose that the government artificially raises the nominal interest rate between dates 1 and T, so $\beta_{t+1}(1+i_{t+1}) > 1$. To be consistent with equation (12), marginal utility must be high and decreasing during this time, reaching its normal value only at date T. If $\sigma \leq 1$, the marginal utility of consumption is decreasing in consumption and in hours, and so it follows that consumption is low and increasing when the nominal interest rate is too high, and consumption rises to its normal value at date T. If $\sigma > 1$, there typically will be zero or many paths of consumption and hours consistent with the desired path of marginal utility. Along one path, consumption is low and increasing, along another path it is high and decreasing, and along still other paths it jumps between the first two paths either stochastically or deterministically.[2]

To be clear, if an equilibrium exists, individual behavior is uniquely determined. Given a path of consumption and hours, the path of the wage is determined from equation (13). And given this path of nominal wages and interest rates, there is a unique optimal choice of consumption and hours for each individual, and that choice is consistent with the equilibrium path for the marginal utility of consumption. But in general there are multiple equilibria.

It is worth thinking about how individuals perceive a "depressed" economy with $\beta_1 i_1 > 1$ and $\beta_t(1+i_t) = 1$ for all $t > 1$. For simplicity, I focus here on the case where consumption

[2]Many monetary economists would argue that high nominal interest rates depress output and so only the first path is reasonable. But as a matter of economic theory, it is unclear why the economy is on this path.

and leisure are separable, $\sigma = 1$, and so the equilibrium is unique. Facing a high interest rate between periods 0 and 1, all individuals would like to consume more at date 1 than at date 0. This depresses all of their demands for date 0 output and raises their demand for date 1 output. With low demand for date 0 output, production and income falls until the economy achieves the desired slope in the consumption profile without changing future consumption and output. Intermediate goods producers would like to sell more at the fixed price, or alternatively they would like to cut their price, but this is impossible. Nevertheless, they earn profits in this depressed environment, with an elevated profit rate but lower total profits.

With $\sigma > 1$, the logic of a depressed economy is the same, except that one needs to recognize the possibility that the economy can jump to an outcome with high consumption and hours and a high marginal utility of consumption. In this case, intermediate goods producers wish they could raise their price and reduce output, but again this is impossible.

2.7 Government Consumption

I next consider the impact of an increase in government consumption with a fixed path of the nominal interest rate. Following Christiano, Eichenbaum, and Rebelo (forthcoming), I show that an increase in government consumption causes a more-than-proportional increase in output—the government consumption multiplier is bigger than one—only if the substitution parameter σ is bigger than 1.[3] But even in this case, if the economy is in the equilibrium with high consumption and hours, the government consumption multiplier is negative. I then consider the welfare implications of this increase in government consumption and show that it is welfare enhancing if and only if the government consumption multiplier is negative.

To start, note from equation (12) that the path of government consumption prior to date T does not affect the path of the marginal utility of consumption $u_{c,t}$. If $\sigma = 1$, this immediately implies that government consumption does not affect consumption, i.e. the government consumption multiplier is 1. Otherwise, substituting the market clearing condition $y_t = h_t = c_t + g_t$ into equation (4) implies

$$u_{c,t} = \left(\frac{c_t}{1 + (\sigma - 1)\frac{\gamma\varepsilon}{1+\varepsilon}(c_t + g_t)^{\frac{1+\varepsilon}{\varepsilon}}} \right)^{-\sigma}.$$

Evaluating at $g_t = 0$, an increase in consumption raises the marginal utility of consumption

[3] See also and Bilbiie (2011) and Monacelli and Perotti (2008).

if and only if $\sigma > 1$ and

$$c_t < \left(\frac{1+\varepsilon}{(\sigma-1)\gamma}\right)^{\frac{\varepsilon}{1+\varepsilon}} \equiv \bar{c}.$$

Levels of $c_t > \bar{c}$ correspond to the equilibrium with high consumption and hours, while lower levels of consumption $c_t < \bar{c}$ correspond to the equilibrium with low consumption and hours. Next, implicitly differentiate the marginal utility of consumption to get the responsiveness of consumption to government consumption, evaluated again at $g_t = 0$. This gives

$$\left.\frac{dc_t}{dg_t}\right|_{g_t=0} = \frac{1}{\frac{1}{(\sigma-1)\gamma c_t^{\frac{1+\varepsilon}{\varepsilon}}} - \frac{1}{1+\varepsilon}},$$

which is positive only if $\sigma > 1$ and $c_t < \bar{c}$. For example, when evaluated at the undistorted level of consumption, $c_t = c^*$ defined in equation (11), I obtain $\left.\frac{dc_t}{dg_t}\right|_{g_t=0} = \sigma - 1$.

To summarize, an increase in government consumption starting from $g_t = 0$ causes a more-than-proportionate increase in output if and only if $\sigma > 1$ and the economy is in the equilibrium with a low level of consumption and output. On the other hand, if $\sigma > 1$ and the economy is in the other equilibrium, I find that $\frac{\partial c_t}{\partial g_t} < -(1+\varepsilon)$. An increase in government consumption reduces private consumption more than proportionately, and therefore reduces output and hours worked.[4]

It is also interesting to calculate the welfare consequences of an increase in government consumption in this simple model. I focus on the pure Keynesian argument for government consumption, that it is expansionary, and so ignore any other potential direct welfare benefits from this activity. To start, I assume that, if there are multiple equilibria associated with the path of nominal interest rates, an increase in government consumption does not shift the equilibrium. Using $h_t = c_t + g_t$ and recognizing that the marginal utility of consumption is unaffected by government consumption, I obtain

$$\left.\frac{du(c_t, c_t + g_t)}{dg_t}\right|_{g_t=0} = (u_{c,t} + u_{h,t}) \left.\frac{dc_t}{dg_t}\right|_{g_t=0} + u_{h,t} = \frac{\gamma u_{c,t}}{\frac{(\sigma-1)\gamma}{1+\varepsilon} - c^{-\frac{1+\varepsilon}{\varepsilon}}}$$

It is straightforward to verify that an increase in government consumption reduces welfare if $\sigma \leq 1$ or if $\sigma > 1$ and $c_t < \bar{c}$, while it raises welfare if $\sigma > 1$ and $c_t > \bar{c}$. That is, an increase in government consumption is welfare enhancing if and only if it reduces output. The same logic holds if the increase in government consumption shifts the equilibrium, because the equilibrium with lower consumption always attains higher welfare. If an increase in

[4] This observation does not appear to be in Christiano, Eichenbaum, and Rebelo (forthcoming), perhaps because they linearize the model economy near the steady state and so focus only on equilibria near undistorted outcome, which has $c_t < \bar{c}$.

government consumption discretely reduces private consumption and output, it is welfare enhancing. In conclusion, while this simple sticky price model explains why government consumption can be expansionary, it does not explain why government consumption can be welfare enhancing when the government consumption multiplier exceeds unity. Rather it predicts the opposite.[5]

2.8 Nominal Wage Rigidity

A rigid nominal interest rate distorts the real wage W_t/P_t. In general, it can be too high or too low, depending on the product $u_{c,t}^{-\frac{1}{\sigma}} h_t^{\frac{1}{\varepsilon}}$. To be concrete, suppose $\beta_{t+1}(1+i_{t+1}) > 1$ for all $t \in \{1, \ldots, T\}$, so $u_{c,t}$ is a decreasing sequence prior to date t. If $\sigma = 1$ and $g = 0$, this implies that consumption and labor supply are increasing between dates 0 and T. That is, the economy is depressed by the interest rate distortion and so equation (13) implies that the real wage is too low, $W_t < P_t = 1$.

Now suppose there is also a nominal wage rigidity, so this cannot happen. I assume that if the wage is too high, households are constrained from supplying as much labor as they would like. The model is otherwise unchanged. With a nominal wage rigidity and a fixed nominal interest rate, the household Euler equation still yields equation (12), pinning down the path of marginal utility, but equation (13) no longer holds. It is straightforward to verify that this rigidity does not affect the path of consumption, output, or hours worked, but simply causes unemployment. Households wish they could supply more labor at the prevailing wage. Moreover, after date T, when the nominal wage rigidity no longer binds, the equilibrium wage returns to $W_t = 1$ and so there are no lingering effects of the nominal wage rigidity. In short, the interaction of wage and price rigidities does not seem particularly interesting in this simple economy.

3 Capital

I now extend the model by introducing capital. I assume that a typical intermediate goods producer $j \in [0,1]$ uses capital $k_{j,t}$ and labor $h_{j,t}$ to produce $y_{j,t} \equiv A k_{j,t}^{\alpha} h_{j,t}^{1-\alpha}$ of good j in period t, which is then sold to the representative final goods producer at a price $p_{j,t}$. As before, the government subsidizes the sale of the final good, so the intermediate goods

[5] Woodford (2011) and the references within it argues that the government consumption multiplier can exceed unity and government consumption can be welfare enhancing because higher government consumption can raise inflation and therefore reduce the real interest rate even if the nominal interest rate is fixed. This possibility is absent from the fixed price economy that I look at here. In practice, the link between government consumption and inflation seems tenuous in the data, although I am unaware of any recent paper evaluating this link.

producer receives $(1+\nu)p_{j,t}$ for each unit sold, where $\nu = 1/(\theta-1)$. The parameter $\alpha \in (0,1)$ is the capital share of income. The intermediate goods producer owns its capital stock and pays workers a wage W_t. A fraction δ of the capital depreciates in production, and the intermediate goods producer purchases more capital at price P_t from the final goods producers for use in the following period. The intermediate goods producer maximizes the present value of its profits.

The final goods producer's problem is unchanged, except now the final good is used for private and government consumption as well as for investment. Similarly the household problem is unchanged. I therefore turn directly to the intermediate goods producers' problem.

I focus here on a model with no adjustment costs in capital. The results that follow therefore result in extreme investment dynamics. At the opposite extreme, with no feasible adjustment in capital, the results would mirror those in an economy without capital. On the other hand, with adjustment costs one would expect to see somewhat intermediate results, at the cost of more complex formulae and dynamics. I therefore believe this extreme case offers a useful benchmark for understanding the implications of price and wage rigidities.

3.1 Intermediate Goods Producers

The producer of good j chooses a path for labor $\{h_{j,t}\}$ and capital $\{k_{j,t+1}\}$ to maximize the present value of profits,

$$\sum_{t=0}^{\infty} q_0^t \big(\tfrac{\theta}{\theta-1} p_{j,t} y_{j,t} - P_t\big(k_{j,t+1} - (1-\delta)k_{j,t}\big) - W_t h_{j,t}\big)$$

where

$$y_{j,t} = A k_{j,t}^{\alpha} h_{j,t}^{1-\alpha},$$

is the firm's output, and $p_{j,t}$ is consistent with the demand from final goods producers, given in equation (6):

$$p_{j,t} = P_t \left(\frac{Y_t}{y_{j,t}}\right)^{\frac{1}{\theta}}.$$

Note that $k_{j,t+1} - (1-\delta)k_{j,t}$ represents the firm's investment, purchased from final goods producers at a price P_t.

The intermediate goods producers profit maximization problem yields two first order conditions. First, the marginal revenue product of labor is equal to the wage:

$$(1-\alpha)\left(\frac{Y_t}{y_{j,t}}\right)^{\frac{1}{\theta}}\left(\frac{y_{j,t}}{h_{j,t}}\right) = W_t/P_t. \tag{14}$$

Second, the gross marginal revenue product of capital is equal to the gross real interest rate

$$\alpha\left(\frac{Y_{t+1}}{y_{j,t+1}}\right)^{\frac{1}{\theta}}\left(\frac{y_{j,t+1}}{k_{j,t+1}}\right) + 1 - \delta = \frac{q_0^t P_t}{q_0^{t+1} P_{t+1}}. \tag{15}$$

In equilibrium, all producers use the same capital in every period and so set the same price, $p_{j,t} = P_t$, and produce the same output, $y_{j,t} = Y_t$.[6] This simplifies the previous two equations slightly.

3.2 Market Clearing

Output is used for consumption, investment, and government consumption. Since all intermediate goods firms use the same inputs, this implies

$$k_{t+1} = Ak_t^{\alpha} h_t^{1-\alpha} + (1-\delta)k_t - c_t - g_t. \tag{16}$$

In addition, eliminate the wage between the labor supply equation (5) and the labor demand equation (14):

$$\gamma\sigma u_{c,t}^{-\frac{1}{\sigma}} h_t^{\frac{1}{\varepsilon}} = (1-\alpha)A\left(\frac{k_t}{h_t}\right)^{\alpha} \tag{17}$$

Similarly eliminate the real interest rate between the household Euler equation (3) and the firm's investment equation (15) to get an expression for the growth rate of the marginal product of capital.

$$\frac{u_{c,t}}{u_{c,t+1}} = \beta_{t+1}\left(\alpha A\left(\frac{k_{t+1}}{h_{t+1}}\right)^{\alpha-1} + 1 - \delta\right). \tag{18}$$

Together with the definition of $u_{c,t}$ in (4), this is a complete system of equations that describes the dynamics of capital, labor, and consumption. Moreover, one can verify that the system is saddle-path stable for an arbitrary initial capital stock.

Now consider the effect of a temporary change in the discount factor β. The model is no longer static and so this affects equilibrium outcomes even in the absence of any nominal rigidities. For example, if β_t is unusually high for $t \in \{1, \dots, T\}$, individuals choose to postpone consumption and leisure, which boosts output and investment. Even after the

[6] If the initial capital holdings are not equal across periods, this will not be the case in period 0 but it will hold in all subsequent periods. I ignore this caveat in what follows.

discount factor has returned to normal, individuals continue to enjoy the benefits of the earlier investment and so the economy only gradually settles back to the steady state.

3.3 Nominal Interest Rate Policy

Once again, suppose that the government distorts the nominal interest rate $i_{t+1} = q_0^t/q_0^{t+1} - 1$. If prices were flexible, this would be offset by a proportional change in the growth of the price level P^{t+1}/P_t, leaving the real interest rate $q_0^t P_t / q_0^{t+1} P^{t+1}$ unchanged. But with price rigidities, $p_{j,t} = P_t = 1$, this is impossible and so the change in the nominal interest rate has real effects.

Distortions in the nominal interest rate do not change either the household or final final goods producers' problems. As before, I assume, however, that intermediate goods producers are restricted from supplying as much output as they would like to at the fixed price. Instead, they maximize profits taking as given the demand for their good $y_{j,t}$ and the prices $p_{j,t} = P_t = 1$. This is equivalent to a cost minimization problem,

$$\min_{k_{j,t+1},h_{j,t}} \sum_{t=0}^{\infty} q_0^t \big(k_{j,t+1} - (1-\delta)k_{j,t} + W_t h_{j,t}\big) \text{ subject to } A k_{j,t}^{\alpha} h_{j,t}^{1-\alpha} = y_{j,t}.$$

The solution to this problem is

$$\frac{W_t h_t}{1-\alpha} = \frac{(i_t + \delta)k_t}{\alpha}, \tag{19}$$

where $i_t + \delta$ is the user cost of capital in this zero inflation environment. In particular, in a demand constrained economy, the wage is not necessarily equal to the marginal product of labor and the user cost of capital is not necessarily equal to the marginal product of capital; however, the ratio of the wage to the user cost is the ratio of the two marginal products, which just depends on the capital-labor ratio with a Cobb-Douglas production function.

To proceed, equating labor supply from equation (5) to labor demand from equation (19) gives

$$\gamma \sigma u_{c,t}^{-\frac{1}{\sigma}} h_t^{\frac{1}{\varepsilon}} = \frac{(1-\alpha)(i_t+\delta)k_t}{\alpha h_t}. \tag{20}$$

The market clearing condition (16) is unchanged, as is the household Euler equation (3), repeated here in the special case with $P_t = 1$:

$$\frac{u_{c,t}}{u_{c,t+1}} = \beta_{t+1}(1 + i_{t+1}). \tag{21}$$

This is again a complete system of equations describing the dynamics of capital, labor, and consumption for a given path of the nominal interest rate.

I again consider a temporary distortion to the nominal interest rate i_t for all $t \in \{1, \dots, T\}$. After this date, the nominal interest rate takes on its natural value, as in the market clearing (or flexible price) model. In the model without capital, this assumption pinned down the marginal utility of consumption in period T and so equation (21) determined the entire sequence for marginal utility. But with capital, the distortion to the nominal interest rate generally affects the capital stock and so changes marginal utility even after the distortion is completed. This argument also changes the logic of the government consumption multiplier. To the extent that government consumption affects private investment, it will also affect the path of marginal utility even with a fixed nominal interest rate. The earlier discussion about why the government consumption multiplier may exceed 1 therefore no longer applies.

To analyze the model, I proceed numerically, but I start by providing intuition for my main finding: a reduction in the nominal interest rate leads to a collapse in investment unless labor supply is extremely inelastic. To understand why, observe first that the user cost of capital is very sensitive to the nominal interest rate when prices are rigid. This is because in steady state, the nominal interest rate is the inverse of the discount factor minus one, $i_t = \beta^{-1} - 1$, and in practice $\beta^{-1} - 1$ and δ are roughly of the same magnitude. A reduction in the nominal interest rate from $\beta^{-1} - 1$ to zero therefore cuts the user cost of capital $i_t + \delta$ in half.

Normally one's intuition is that a reduction in the user cost of capital should spur investment. But that is not the case in this model, where production and hence the incentive to invest are constrained by demand. Instead, look at equation (20). A short-lived reduction in the nominal interest rate should not affect the the marginal utility of consumption $u_{c,t}$, nor can it affect the initial capital stock k_t. If labor supply is infinitely elastic, $\varepsilon = \infty$, it follows that a reduction in the nominal interest rate must cause a proportional decline in labor input h_t. That is, if the user cost of capital falls in half, then labor input must fall in half as well. If labor supply is inelastic, the effect on hours is reduced, and instead the reduction in nominal interest rates also pushes down the equilibrium wage. But unless the elasticity of labor supply is extremely low, the impact on hours worked is substantial.

With fewer hours worked, output is lower. With a labor share of $1 - \alpha = 0.67$, a fifty percent decline in hours worked corresponds to a 34 percent reduction in output. This must correspond to the decline in aggregate demand. If $\sigma = 1$, so consumption and leisure are separable, constant marginal utility implies constant consumption, and so the entire decline in demand is absorbed by a decrease in investment. If $\sigma > 1$, the reduction in hours worked pushes down consumption and so typically both consumption and investment decline. In any case, the model does not appear to easily generate expansionary effects from a reduction in nominal interest rates.

To explore these claims more fully, I calibrate the model. I think of a time period as representing a month and set the monthly discount factor at $\beta_t = 0.996$; later I consider the impact of an increase in the discount factor. I set the capital share at $\alpha = 0.33$. I fix the depreciation rate at $\delta = 0.0046$, which implies a steady-state capital to annual output ratio of 3.2. The elasticity of substitution θ is unimportant for model outcomes. I look at the case of additively separable preferences, $\sigma = 1$, and again later consider consumption-leisure substitutability. I set the Frisch elasticity of labor supply at $\varepsilon = 1$. Finally, I fix the disutility of work at $\gamma = 0.813$, which normalizes the steady state labor supply to 1 but otherwise does not affect my results.

I assume that the economy is in steady state at time 0. Then the government announces that it will fix the nominal interest rate at $i_t = 0$ in period $t = 1$; thereafter the nominal interest rate returns to the market-clearing level, or equivalently prices are flexible. Starting from steady state, the reduction in the nominal interest rate reduces the user cost of capital from $\beta^{-1} - 1 + \delta = 0.0086$ to 0.0046 in month 1 and so has a substantial effect on employment and output that month.

Anticipating the low nominal interest rate, individuals increase their consumption in period 0 by 0.4 log points above steady state. This reduction in the marginal utility of consumption pushes hours worked down by 0.2 log points and output down by 0.1 log points. It follows that investment must fall, and it does by 2.6 log points. Of course, one month of slightly low investment has a negligible impact on the capital stock.

Outcomes get more interesting in period 1, when the user cost of capital falls in half. Labor input plummets by 31.5 log points and output crashes by 21.1 log points. Consumption essentially returns to trend, and so this entirely reflects a decline in investment, which actually becomes slightly negative, with some of the existing capital being converted back into consumption.

With flexible prices returning in period 2, the user cost of capital returns back to a more normal value and labor demand recovers, falling to just 0.1 log points below steady state. But the month without investment is enough to push the capital stock down by 0.5 log points, with long-lasting consequences. Output is depressed by 0.2 log points and consumption by 0.3 log points, with only a slow recovery towards more normal values.

Next suppose the low nominal interest rate policy remains in effect for 12 months. This does not much change the basic conclusion. During that year, labor input is depressed by an average of 32.4 log points and output by 22.7 log points, while consumption is down by 1.1 log points and investment is negative. By the end of this episode, the capital stock is down by 6.1 log points. In the first year of recovery, labor input is up by 1.0 log points, output is

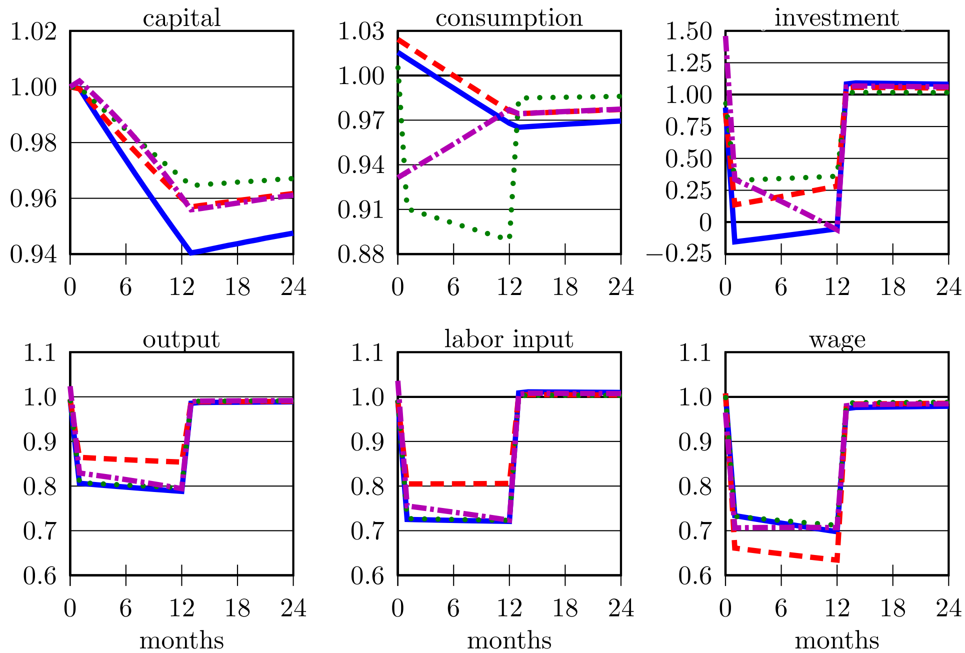

Figure 1: The impact of a reduction in the nominal interest rate to $i_t = 0$ from $t = 1$ to $t = 12$, sticky price economy. All figures are expressed relative to steady state with an undistorted interest rate. The solid blue line shows the benchmark model. The dashed red line shows the economy with less elastic labor supply, $\varepsilon = 0.5$. The dotted green line shows the economy where consumption and leisure are substitutes, $\sigma = 2$. The dash-dotted purple line shows the economy with a discount factor shock, $\beta_t = 1.004$ for $t \in \{1, \ldots, 12\}$.

down by 1.2 log points, consumption is down by 3.3 log points, and investment is up by 8.2 log points relative to steady state. These are standard transitional dynamics for an economy rebuilding its capital stock. The solid blue line in Figure 1 shows these results.

Figure 1 also shows how some variants of the calibrated model behave. The dashed red line shows that if labor supply is less elastic ($\varepsilon = 0.5$ instead of 1), labor input, output, and investment fall by less during the low interest rate policy period, while wages absorb more of the shock. The dotted green line shows that if consumption and leisure are substitutes ($\sigma = 2$ rather than $\sigma = 1$) then consumption falls sharply during the low interest rate period, tracking the behavior of the labor input.[7] This moderates the investment response. Finally, the dash-dotted purple line shows that if the low interest rate period is also a period with a high discount factor ($\beta_t = 1.004$ rather than 0.996), consumption rises and investment falls but the model's behavior is otherwise unchanged.

The finding that labor input, investment, and output collapse when the nominal interest

[7] In contrast to the model without capital, the model with capital has a unique equilibrium even when $\sigma > 1$.

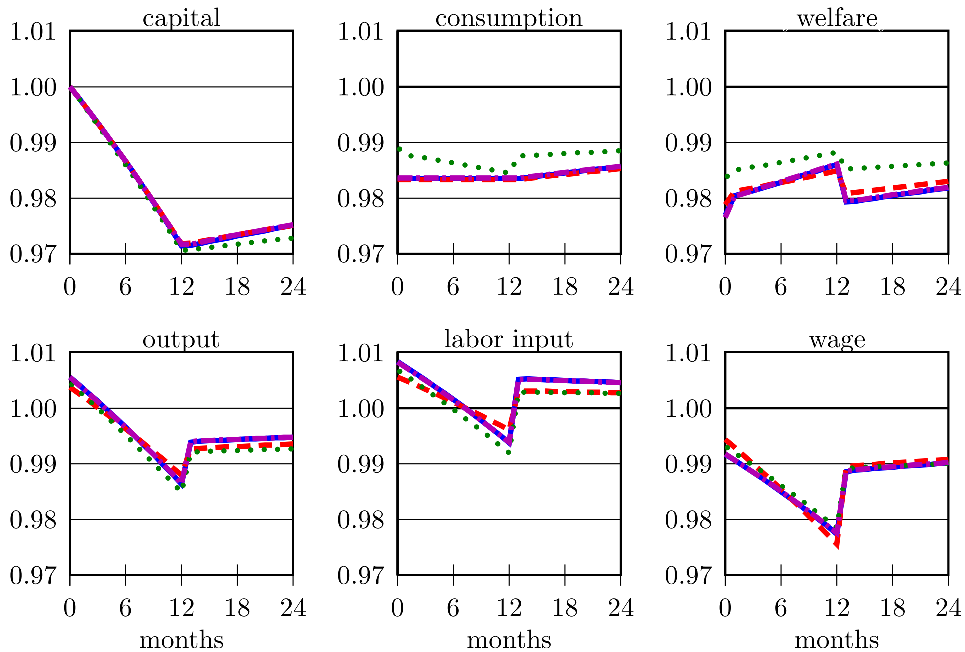

Figure 2: The impact of an increase in government consumption g_t from $t = 0$ to $t = 11$, sticky price economy with nominal interest rate pinned at $i_t = 0$ from $t = 1$ to $t = 12$. All figures are expressed relative to the economy without government consumption. The solid blue line shows the benchmark model. The dashed red line shows the economy with less elastic labor supply, $\varepsilon = 0.5$. The dotted green line shows the economy where consumption and leisure are substitutes, $\sigma = 2$. The dash-dotted purple line shows the economy with a discount factor shock, $\beta_t = 1.004$ for $t \in \{1, \ldots, 12\}$.

rate is pushed down to $i_t = 0$ appears to be a robust conclusion of this model. Of course, one can imagine variants on the model that would move away from such an extreme collapse. In general, one would expect that various types of adjustment costs will moderate the economy's response (Christiano, Eichenbaum, and Evans, 2005), but the basic forces at work in this model will continue to operate with adjustment costs.

3.4 Government Consumption

I next turn to the impact of government consumption. In the model without capital, an increase in government consumption did not affect the path of the marginal utility of consumption, a critical piece of the proof that the government consumption multiplier can exceed 1. In the model with capital, government consumption affects investment and so an increase in government consumption will typically affect the path of marginal utility. Intuitively, government consumption crowds out private investment and so lowers the capital stock. Since households are poorer, consumption falls and the multiplier is typically less than 1.

To show this, I assume that the government raises g_t from zero to ten percent of steady state output between dates $t = 0$ and $t = 11$. It also keeps the nominal interest rate fixed at $i_{t+1} = 0$. I compare the economy with the fiscal stimulus to the economy without the fiscal stimulus, focusing on the same four parameterizations of the model. Figure 2 shows that the increase in government consumption reduces the capital stock almost three percent in all variants of the model. Although it initially raises labor input and output, the increase in government consumption always crowds out private consumption by one or two percent. This is true even if consumption and leisure are substitutes. In short, the government consumption multiplier is always negative in this model and remains negative thereafter.

To assess whether the fiscal expansion is desirable, I measure welfare as the amount of consumption required to achieve the equilibrium level of flow utility if labor supply were fixed at the steady state level. I find that a ten percentage point increase in government consumption reduces welfare by one or two percent in all of the experiments. Thus the model with capital reaffirms the conclusion that an increase in government consumption is unlikely to be desirable even if the nominal interest rate is trapped at zero, although now this holds even when the government consumption multiplier is negative.

3.5 Rigid Wage

Finally, I consider the interaction between nominal price and nominal wage rigidities in the model with capital. Observe from the last panel in Figure 1 that the equilibrium wage always lies below the steady state wage, both during the year when the nominal interest rate is distorted and during the subsequent year(s) of recovery. During the first year, this reflects movements down workers' labor supply curve: a lower real wage induces workers to reduce their labor supply, consistent with the reduction in firms' labor demand. In the second year, this reflects the wealth effect from a loss in the capital stock. When the capital stock is below steady state, labor demand falls because the marginal product of labor would otherwise be low and labor supply increases because of the loss in household wealth. Equilibrium again requires a reduction in the wage.

This section asks what happens if the wage cannot fall due to some nominal wage rigidity. I continue to assume that the price level is fixed at $P_t = 1$ and now impose that the nominal wage is also fixed at the steady state level,

$$W^* = \left(\frac{\alpha^\alpha (1-\alpha)^{1-\alpha} A}{\left(\beta^{-1} - 1 + \delta\right)^\alpha} \right)^{\frac{1}{1-\alpha}} .$$

When the government cuts the nominal interest rate, this fixed wage exceeds the equilibrium wage and so labor supply exceeds labor demand. I assume that employment is determined by labor demand, with each worker only able to supply a fraction of the labor he would like to offer. It follows that the wage rigidity does not change either the intermediate or final goods' producers problems, but it does take workers off of their labor supply curve.

I distinguish between two cases. First, suppose that the nominal interest rate is fixed at a level such that firms are demand constrained. Equilibrium is described by three equations: the resource constraint (16) is unchanged,

$$k_{t+1} = Ak_t^\alpha h_t^{1-\alpha} + (1-\delta)k_t - c_t - g_t;$$

the Euler equation comes only from the household problem, as in equation (21),

$$\frac{u_{c,t}}{u_{c,t+1}} = \beta_{t+1}(1+i_{t+1});$$

and firms optimally trade off the use of capital and labor when meeting their production quota, as in equation (19), which under a fixed wage W^* gives

$$h_t = \left(\frac{i_t+\delta}{\beta^{-1}-1+\delta}\right)\left(\frac{\beta^{-1}-1+\delta}{\alpha A}\right)^{\frac{1}{1-\alpha}} k_t.$$

Given an initial value for marginal utility and a path for the nominal interest rate, these equations can be solved forward to compute consumption and output.

Second, suppose that the nominal interest rate adjusts so that the goods market clears. In this case too, equilibrium is described by three equations: an unchanged resource constraint (16),

$$k_{t+1} = Ak_t^\alpha h_t^{1-\alpha} + (1-\delta)k_t - c_t - g_t;$$

the standard Euler equation (18),

$$\frac{u_{c,t}}{u_{c,t+1}} = \beta_{t+1}\left(\alpha A\left(\frac{k_{t+1}}{h_{t+1}}\right)^{\alpha-1} + 1 - \delta\right);$$

and the requirement that intermediate goods producing firms hire workers until the wage is equal to the marginal product of labor, so equation (14) holds. With a fixed wage $W_t = W^*$, this last requirement pins down the capital-labor ratio

$$h_t = \left(\frac{\beta^{-1}-1+\delta}{\alpha A}\right)^{\frac{1}{1-\alpha}} k_t.$$

Substituting this into the Euler equation then implies $u_{c,t} = u_{c,t+1}$, at least if the discount factor between periods t and $t + 1$ is equal to the steady state discount factor. That is, consumption and hours are constant. Finally, the resource pins down the level of consumption and hours consistent with a constant capital stock.

Now suppose that the government cuts the nominal interest rate between dates 1 and T. After date T, the goods market is undistorted, although the wage rigidity remains. To find an equilibrium, I posit an initial level for marginal utility and solve the model forward until date T. I then check if the marginal utility of consumption at date T, $u_{c,T}$, and the capital stock, k_T, are consistent with the economy remaining at this point forever. Finally, I verify that the marginal rate of substitution between consumption and leisure (MRS) is smaller than the wage throughout the adjustment process. If so, I have found the equilibrium.

Note that the economy remains permanently depressed even after the nominal interest rate distortion is removed. The result that an otherwise competitive economy with a completely rigid wage cannot rebuild its capital stock after an adverse event that destroys some of it is contained in Shimer (2011).

Figure 3 depicts the behavior of capital, consumption, investment, output, labor, and the marginal rate of substitution in the same four variants of the model. Compared with Figure 1, the crash in economic activity is bigger and there is no recovery. This is mainly due to the fact that when wages do not fall, labor must take the full brunt of the decline in the user cost of capital. This further reduces output, including both of its components, consumption and investment. Otherwise the four variations in the model all deliver similar results: a crash in investment while the nominal interest rate is distorted, followed by stagnation after the distortion is removed from the economy.

I also consider the impact of an increase in government spending, equal to ten percent of steady state output, while the economy remains depressed. As in the flexible price economy, this pushes down capital, consumption, output, labor, and the marginal rate of substitution. Moreover, welfare measured in consumption equivalent units is depressed. All these findings mirror the economy without the wage rigidity.

4 Conclusions

One way to summarize the message of this paper is that rigid prices are a powerful mechanism. Their impact qualitatively and quantitatively dwarfs the impact of rigid wages. Whether this is good news for models of price rigidity is an open question. On the one hand, price rigidities have a very important impact on economic outcomes. On the other hand, the

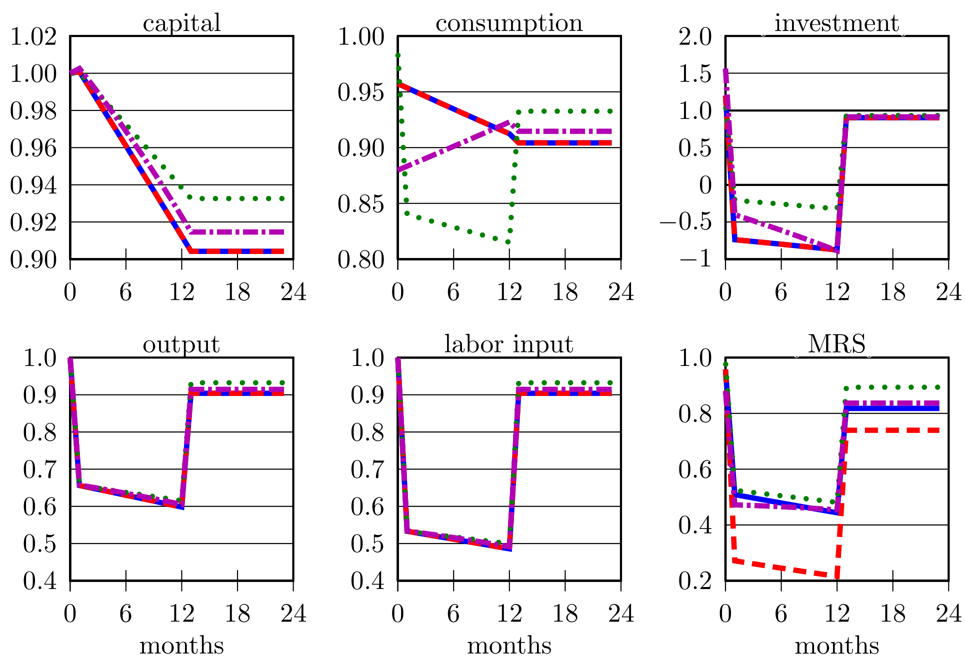

Figure 3: The impact of a reduction in the nominal interest rate to $i_t = 0$ from $t = 1$ to $t = 12$, sticky wage and price economy. All figures are expressed relative to steady state with an undistorted interest rate. The solid blue line shows the benchmark model. The dashed red line shows the economy with less elastic labor supply, $\varepsilon = 0.5$. The dotted green line shows the economy where consumption and leisure are substitutes, $\sigma = 2$. The dash-dotted purple line shows the economy with a discount factor shock, $\beta_t = 1.004$ for $t \in \{1, \ldots, 12\}$.

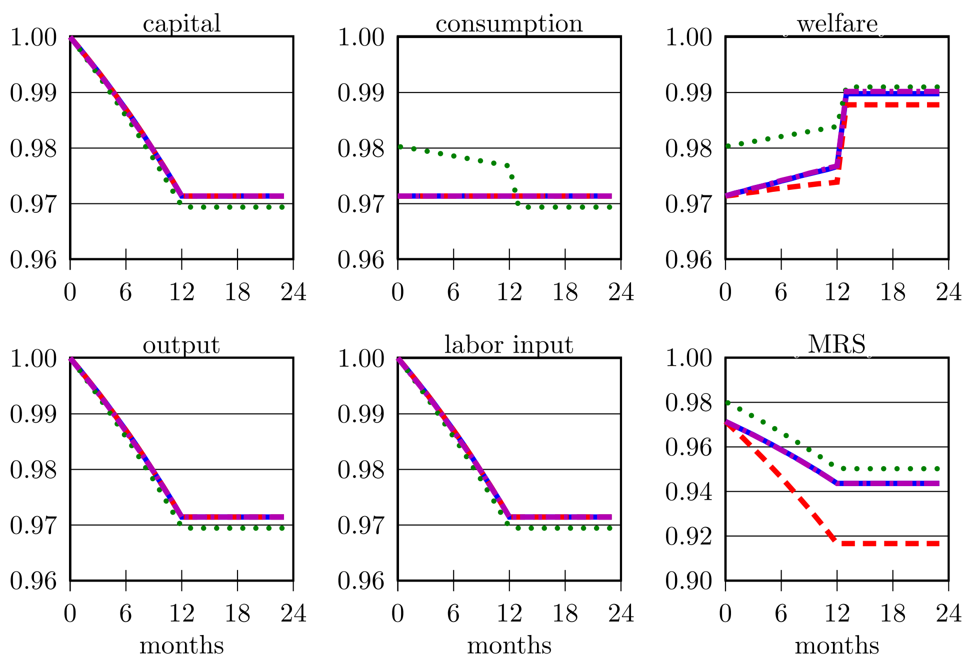

Figure 4: The impact of an increase in government consumption g_t from $t = 0$ to $t = 11$, sticky wage and price economy with nominal interest rate pinned at $i_t = 0$ from $t = 1$ to $t = 12$. All figures are expressed relative to the economy without government consumption. The solid blue line shows the benchmark model. The dashed red line shows the economy with less elastic labor supply, $\varepsilon = 0.5$. The dotted green line shows the economy where consumption and leisure are substitutes, $\sigma = 2$. The dash-dotted purple line shows the economy with a discount factor shock, $\beta_t = 1.004$ for $t \in \{1, \ldots, 12\}$.

impact may be so large and counterintuitive as to be incredible.

This conclusion flies in the face of a large literature which argues for the empirical relevance of rigid prices and New Keynesian macroeconomic models (Smets and Wouters, 2003; Christiano, Eichenbaum, and Evans, 2005). One way to reconcile this paper with that literature is to note that the literature typically adds numerous adjustment costs and frictions to this simple model, all of which act to moderate the direct impact of price rigidities. Whether those additions add microeconomic realism to the models is dubious, but their importance for allowing the model to fit the data is clear.

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