Non-Clearing Goods Markets and the Capacity-Utilization Phillips Curve

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Abstract

Is the Phillips curve dead? I propose a simple New-Keynesian framework with goods market search-and-matching to link inflation and monetary policy to the capacity utilization rate. This approach allows to include active aggregate demand and goods market characteristics. I can derive a "Capacity Utilization New-Keynesian Phillips Curve" with a slope that depends on the level of goods market search-and-matching frictions. It decreases in markets where aggregate demand becomes more important for market matching. The model can replicate the joint behavior of capacity utilization and macroeconomic aggregates reasonably well. The goods market search-and-matching modeling approach allows to include a large variety of household and goods market matching characteristics like demographics, sentiment, or labor market status and breaks it down to one parameter.

Keywords: Search-and-Matching, Capacity Utilization, Phillips Curve

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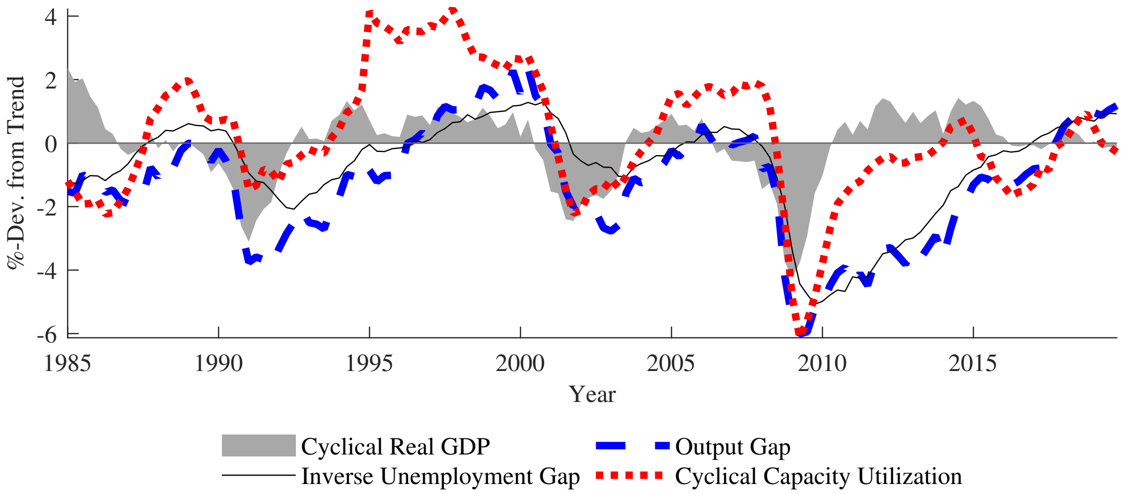
1. Introduction

Is the Phillips (1958) curve dead? With recent episodes of *"missing disinflation"* during the Great Recession, *"missing inflation"* during its aftermath, and ongoing low inflation in most advanced economies ever since, this question has got a lot of attention in the literature recently. Understanding the determinants of inflation is important for policy makers and central banks. Precise inflation forecasts are central to conducting successful monetary policy (see e.g. Orphanides and van Norden (2005)). The Phillips curve has always been a debatted construct. But, with the recent decline in its slope (see e.g. Hooper et al. (2019)), it has become more important to understand why the Phillips curve has changed.
Several explanations of the decline in the slope of the Phillips curve have been put forward in the literature. A non-exhausting list of reasons contains anchored inflation expectations (Bernanke (2007)), non-linearities and asymmetric behavior (Lindé and Trabandt (2019); Hooper et al. (2019)), domestic factors as e.g. financial frictions (Gilchrist and Zakrajšek (2015); Lieberknecht (2019)), global factors as e.g. commodity prices, oil prices, and global slack (Forbes (2019)), and challenges in measuring economic slack (Albuquerque and Baumann (2017)). I am focusing on the challenges in measuring economic slack.
Common measures of economic slack are the output gap and the unemployment gap. They measure realized GDP and unemployment relative to their long-run potential. Both are used as determinants of the Phillips curve to calculate and forecast inflation. Both measures are theoretical constructs though. While we observe GDP and unemployment, we cannot observe potential GDP and the natural rate of unemployment. Therefore, their estimation is at the center stage of the calculation of the output and unemployment gaps. This process is prone to mismeasurement and constant revisisons, which in turn leads to bad forecasts of inflation and bad monetary policy (see e.g. Orphanides and van Norden (2002, 2005); Barbarino et al. (2020)). Therefore, it is worthwhile to explore other measures of economic slack that are less prone to mismeasurement.

Figure 1 shows quarterly data on different measures of economic slack for the United States from 1985q1 to 2019q4. Capacity utilization is based on survey data and its definition

Figure 1: Measures of Economic Slack



NOTE: Data is quarterly for the U.S. from 1985q1 to 2019q4. The grey area shows real GDP percentage fluctuations from a one-sided HP filter trend. The dashed blue curve shows the output gap. The solid black line shows the inverse of the unemployment gap. The dotted red curve shows cyclical deviations of aggregate capacity utilization as calculated by the author. See appendix Appendix D for further details.

is closely connected to the output gap definition, as it measures realized GDP relative to available production capacity. An advantage of the capacity utilization data is that is readily available and shows lower variation in its revisions (see e.g. Orphanides and van Norden (2002)). Both the output gap (inverse unemployment gap) and capacity utilization are highly procyclical and correlated with each other. At the same time there are differences. First, the capacity utilization survey data shows a methodological break in 1995, which accounts for the strong increase. Second, capacity utilization shows the same deep recession around 2008 as the output gap, but shows a significantly faster recovery following the Great Recession. This pattern matches the *"missing inflation"* puzzle. From 2016 onwards, capacity utilization and the output gap again move alongside each other. The close connection of capacity utilization and the output gap, both in definition and in the data, and the potential explanatory power of capacity utilization for the recent inflationary behavior lead to the following questions:

1. *How can we implement non-clearing goods markets, both in steady-state and over the business cycle, in a monetary macroeconomic model?*

2. *What impact do non-clearing goods markets have on the slope of the Phillips curve?*

In this paper, I use search-and-matching (SAM) theory to implement non-clearing goods markets in an otherwise textbook New-Keynesian model. I derive a "Capacity Utilization New-Keynesian Phillips Curve" from the model framework. I analyze the determinants of non-clearing goods markets and show their impact on the slope of the Phillips curve. I use model simulations to show whether the model can explain the joint behavior of capacity utilization and inflation in the data.

This paper is closely connected to the New-Keynesian literature analyzing inflation and monetary policy as e.g. Ireland (2004); Christiano et al. (2005). The literature analyzing capital or labor utilization and inflation as e.g. McAdam and Willman (2013); Kuhn and George (2019) is similar, but different, as goods markets are always clearing and there is no direct role of aggregate demand in determining economic slack. A second strand of literature connected to this paper analyzes the relationship between capacity utilization and inflation. Most of those papers are empirical and written in the late 90's, as e.g. Garner et al. (1994); Finn (1996); Emery and Chang (1997); Corrado and Mattey (1997). As non-clearing goods markets and idle capacity are absent from New-Keynesian models, I use the "dis-equilibrium" approach in an equilibrium framework an in Michaillat and Saez (2015); Petrosky-Nadeau and Wasmer (2015); Kaplan and Menzio (2016); Bai et al. (2017), where goods markets can create excess demand and supply following an active aggregate demand margin. This appraoch is part of a recent resurgence of search-and-matching (SAM) on the goods market following the original literature around Diamond (1971, 1984, 1993).

The New-Keynesian model with goods market SAM nests the textbook New-Keynesian model and links variable capacity utilization to inflation and the output gap. The "Capacity Utilization Phillips Curve" shows a decreasing slope in goods market frictions. The slope of aggregate demand decreases in goods market frictions as well, yet its impact is quantitatively negelectable. Those results are in line with the results of Del Negro et al. (2020), who show that a decrease in the slope is at the core of the "missing deflation" puzzle. Consumer characteristics like demography, employment status, or income drive goods market frictions and can be summarized into a single parameter in the model. Capacity utilization is driven by both the labor and the goods market. It acts as an amplification mechanism between input and output. The model can explain the second moments of capacity utilization and macroeconomic aggregates reasonably well, but has difficulties matching both goods and labor markets at the same time.

The rest of the paper is organized as follows. Section 2 develops the theoretical model. Section 3 analyzes the model dynamimcs. Section 4 derives a three-equation output gap version of the model, and shows the impact of goods market SAM on inflation. Section 5 shows whether the model can replicate the joint behavior of capacity utilization and macroeconomic aggregates. Section 6 concludes.

2. Model Setup: Aggregate Demand and Capacity Utilization

The model is based on a textbook New Keynesian model as e.g. Ireland (2004). Main features include monopolistic competition à la Dixit and Stiglitz (1977) and sticky prices à la Rotemberg (1982). The novel feature of the paper is search-and-matching (SAM) on the goods market à la Michaillat and Saez (2015); Bai et al. (2017). This approachs allows to model explicitly active aggregate demand, non-clearing goods markets, and capacity utilization. It follows a "dis-equilibrium" optimizing framework in an equilibrium model where goods markets can run hot and cold.

2.1. Goods Markets Setup

Households and firms meet on goods markets determined by search-and-matching. Supply and demand match according to a Cobb-Douglas matching function. Imperfect matching leads to excess demand or excess supply of goods, both in the steady-state and over the business cycle. Both states of the market are an equlibrium process, as search costs are always equalized to the expected benefits of a trade. There is a continuum $i \in (0, 1)$ of differentiated consumption goods $C_t(i)$, following the Dixit and Stiglitz (1977) monopolistic competition framework. The goods markets are segmented along the varieties of the differentiated consumption goods, as search is directed following Moen (1997). Households exert active costly search effort $D_t(i)$ for each variety i and each firm i supplies idle production capacity $S_t(i)$. Each customer relationship trades one unit of the consumption good. Customer relationships for variety i form according to

$$C_t(i) \quad = \quad \psi_t D_t(i)^{\gamma} S_t(i)^{1-\gamma}, \tag{1}$$

where $0 < \gamma \leq 1$ is the demand elasticity of goods market matching. It determines the impact of active aggregate demand on goods market matching. $\psi_t > 0$ is the goods market matching efficiency. It fluctuates following an exogenous goods market mismatch shock. Each firm produces exactly one variety of the differentiated good. The probability of a household to find a good i is given by $f_t(i) = \psi_t \left(\frac{D_t(i)}{S_t(i)}\right)^{\gamma-1}$. The probability of a firm i to sell a unit of its good is given by $q_t(i) = \psi_t \left(\frac{D_t(i)}{S_t(i)}\right)^{\gamma}$. Goods market tightness for variety i is given by demand relative to supply, $x_t(i) = \frac{D_t(i)}{S_t(i)}$. It is an indicator of excess demand in the economy.

Definition of household search costs. The novel part in the paper is household search effort for consumption goods $D_t(i)$ and therefore justifies some discussion. It serves as search cost in this model, symmetric to vacancy costs in the labor SAM literature. There are broadly speaking two definitions of search costs in the literature. First, a narrow definition of costs associated with the search process. Second, a broader definition additionally including all costs associated with the process of acquiring a good. The discussion in the labor SAM literature differs between vacancy costs, and vacancy and training costs (see e.g. Merz and Yashiv (2007)).

The natural approach to search-and-matching frictions is asymmetric information and the process of acquiring the information. Petrosky-Nadeau et al. (2016) analyze the American time-use survey and find, that time spent researching goods and its cyclicality are rather limited. Bai et al. (2020) analyze the tradeoff between the decrease in information costs following digitization of markets, and the congestion effect in the search process following an increase in competitors. They show that although the costs of accessing information has decreased, the increase in differentiated goods has increased costs associated with picking the best quality brand. This process is related to Pytka (2018), who analyzes the impact

of searching and bargaining for lower prices as they are heterogenous across stores. As the comparison of prices takes time, stores have some market power in setting their prices. Although Petrosky-Nadeau et al. (2016) find no signifcant cyclicality in time spent researching for goods, they find that the time spent shopping for goods is large and procyclical. It also varies across income groups, employment status, and demography. The time spent shopping for goods is connected to the process of buying goods you know where to buy and for which price. Time spent shopping therefore can also include some sort of consumer sentiment.
There are different margins associated with the goods market SAM process. As I aggregate over all of them when introducing one search friction, I take the broad approach in defining search costs in this paper. I follow Petrongolo and Pissarides (2001) and take the goods market matchinig function as a "black box" aggregating different margins associated with the market matching process.

Definition of firm available production capacity.

2.2. Households

There are infinitely many households on the unit interval. Each household searches for and consumes differentiated consumption goods and supplies hours to the labor market. Each household maximizes his intertemporal utility

$$\mathbb{V}_t \quad = \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[log\left(C_t - \mu_D D_t\right) - \mu_H \frac{H_t^{1+\nu_H}}{1+\nu_H} \right],$$

where $H_t = \int_0^1 H_t(i)di$ is total hours supplied. $0 \leq \beta < 1$ is the period discount rate. $\mu_D > 0$ is the level of search disutility. $\mu_H > 0$ is the labor supply disutility, and $\nu_H > 0$ is the inverse of the Frisch labor supply elasticity. The utility function follows Greenwood et al. (1988) preferences in consumption and search effort[1].
Each household divides his aggregate shopping effort into $D_t = \int_0^1 \frac{D_t(i)^{1+\nu_D}}{1+\nu_D} di$, where $\nu_D > 0$

[1]Any wealth effects between consumption and household search effort cancel out. This is a necessary condition to obtain a balanced growth path.

is the inverse of the search effort supply elasticity[2]. Customer relationships for variety i form according to (1). As there are infinitely many households, the goods finding probability for variety i, $f_t(i)$, is exogenous. Therefore, a single household does not have any impact on aggregate market tightness. Each households likes to consume a large variety of differentiated goods. His aggreagte consumption bundle is determined by a Dixit and Stiglitz (1977) index given by

$$C_t = \left(\int_0^1 C_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}},$$

where $1 \leq \epsilon \leq \infty$ determines the elasticity of substitution between two varieties of consumption goods. Each household follows his intertemporal budget constraint

$$B_t = (1 + r_{t-1})\, B_{t-1} + \int_0^1 W_t(i) H_t(i) di - \int_0^1 P_t(i) C_t(i) di - Tax_t + Div_t,$$

where B_t are one-period nominal bonds, which pay the nominal interest rate r_t. Labor income is given by $\int_0^1 W_t(i)H_t(i)di$, where $W_t(i)$ is the nominal wage paid by firm i. Consumption expenses are given by $\int_0^1 P_t(i)C_t(i)di$, where $P_t(i)$ is the price for consumption good i. Tax_t are lump-sum taxes charged by the government to pay for the subsidies to offset steady-state monopolistic competition effects. Div_t are firm dividends paid to the households by a mutual fund. I assume that each household owns an equal share of the mutual fund.

2.3. Firms

There are infinitely many firms on the unit interval. Each firm produces a unique variety of the consumption good and supplies its idle production capacity $S_t(i)$ to the goods market. Each firm employs labor and capital in a Cobb-Douglas production capacity function, $Y_t(i) = A_t H_t(i)^{1-\alpha} \bar{K}_t^{\alpha}$, where A_t is an exogenous technology process. I assume that capital

[2] In contrast to the labor supply elasticity, the search effort supply elasticity applies to each variety i. This captures both the non-linearity of search effort disutility in aggregate and for each individual good. It also lets firms address the non-linearity in their pricing behavior, a feature present in the literature, e.g. Bai et al. (2017); Pytka (2018).

is an exogenous and fixed variable. Each firm i maximizes its profits by

$$\Pi_t = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{0,t} \left[P_t(i) C_t(i) - W_t(i) H_t(i) \right],$$

where $\beta_{0,t}$ is the period discount rate of the firm[3]. Idle production capacity is given by

$$\left(1 + c_{P,t}(i)\right) S_t(i) = Y_t(i), \tag{2}$$

where $c_{P,t}(i) = \frac{\kappa}{2} \left(\frac{P_t(i)}{P_{t-1}(i)} - \bar{\pi} \right)^2$ are convex Rotemberg (1982) price adjustment costs determined by $\kappa \geq 0$. Price adjustment costs are proportional to production capacity, as it is also costly to adjust prices for unsold goods. Customer relationships form according to (1). Each firm can control the market of its variety, as it has the monopoly over this variety of the consumption good. A firm controls the market outcome for its variety i by jointly determining available production capacity $S_t(i)$ and the goods price $P_t(i)$ such that firm profits are maximized.

The price setting mechanism of a firm follows Michaillat and Saez (2014), which is a combination of directed search[4] by Moen (1997) and convex Rotemberg (1982) price adjustment costs. The firm takes the household consumption demand function into account when setting its supply and price. Household consumption demand[5] is given by

$$\frac{P_t(i)}{P_t(j)} = \frac{\left(\frac{C_t}{C_t(i)}\right)^{\frac{1}{\epsilon}} - \frac{\mu_D}{\psi_t} D_t(i)^{\nu_D} \left(\frac{D_t(i)}{S_t(i)}\right)^{1-\gamma}}{\left(\frac{C_t}{C_t(j)}\right)^{\frac{1}{\epsilon}} - \frac{\mu_D}{\psi_t} D_t(j)^{\nu_D} \left(\frac{D_t(j)}{S_t(j)}\right)^{1-\gamma}}, \tag{3}$$

where the relative price of any two varieties i and j depends on their ratio of marginal utility of consumption net of the respective search disutility. Different marginal search disutilities or different goods market tightnesses between the two varieties can therefore lead to different prices, aside from the impact of monopolistic competition and imperfect substitutability.

[3] It is equal to the houehold stochastic discount rate as all firms are owned by the household mutual fund.

[4] A common alternative pricing mechanism in the search-and-matching literature is Nash bargaining. The results are equal to the approach used here when the Hosios (1990) condition is fulfilled.

[5] The household consumption demand function follows from household optimization of consumption allocation across varierties given by the first-order condition of marginal utility.

Each firm maximizes its profits by optimally setting the tradeoff between price and goods selling probability, which in turn sets marginal household search effort. In contrast to the cited goods market SAM literature, each firm has a monopoly over its variety i, hence the goods market is segmented for each variety. It follows that each firm does not take selling probability $q_t(i)$ as given, but can influence it. Firm decisions depend on a nexus of search frictions and monopoly power.

2.4. General Equilibrium

To close the model, I define a monetary policy rule and the exogenous processes. The central bank follows a Taylor (1993)-type rule and sets the nominal interest rate according to

$$\frac{1+r_t}{1+r} = \left(\frac{1+r_{t-1}}{1+r}\right)^{i_r} \left[\left(\frac{\pi_t}{\pi}\right)^{i_\pi} \left(\frac{C_t}{C}\right)^{i_{gdp}} \left(\frac{cu_t}{cu}\right)^{i_{cu}}\right]^{1-i_r} M_t, \tag{4}$$

where r is the target nominal interest rate, $i_r \geq 0$ determines policy inertia, and $i_\pi, i_{gdp}, i_{cu} \geq 0$ are coefficients. M_t is a monetary policy shock. All exogenous shocks, except the monetary policy shock, follow an AR(1) proces given by

$$X_t = X^{1-\rho_X} X_{t-1}^{\rho_X} \varepsilon_{X,t}, \quad \varepsilon_{X,t} \sim \mathcal{N}(\Sigma_X, \sigma_X^2)$$

where $0 \leq \rho_X < 1$ determines the autocorrelation of the shock, and $\varepsilon_{X,t}$ is a white noise random process around a normal distribution with mean Σ_X and standard deviation σ_X.

2.5. Linking Capacity Utilization to the Model

Goods market tightness created by goods market SAM and capacity utilization are different concepts. The two measures deviate in their definition of the labor market. Goods market tightness is measured at current total hours worked. Capacity utilization is measured at long-run stable total hours worked. To connect the data and the model, I follow the definition of the survey-based production capacity measure given by the Federal Reserve[6]. It

[6]In the literature, as e.g. Bauer et al. (1988) show, there are two definitions of capacity utilization. One describes full capacity utilization as the point where marginal cost equal marginal revenue. It is called the cost-based measure of capacity utilization. The other describes full capacity as the point where technically no more goods can be produced without increasing input factors. It is called the engineering-based measure of capacity utilization. This paper applies the second definition.

states:

> *"The Federal Reserve Board's capacity indexes attempt to capture the concept of sustainable maximum output — the greatest level of output a plant can maintain within the framework of a realistic work schedule, after factoring in normal downtime and assuming sufficient availability of inputs to operate the capital in place."*

It follows, that production capacity is defined at the current capital stock and at *full* employment in normal times, which includes the current stock of employees, but no deviations in hours per employee. Hence, any short-time or overtime work of an employee is not measured as part of the production capacity. In the model, we do not differentiate between the stock of employees and hours per employee. Hence, production capacity is given by

$$F\left(A_t, \bar{H}_t, K_t\right) \quad = \quad A_t \bar{H}_t^{1-\alpha} K_t^{\alpha},$$

where $\bar{H}_t$ is total hours worked within the framework of a realistic work schedule. As the number of workers fluctuates over the business cycle, capacity utilization in the model has a bias compared to its data counterpart. In this paper, I accept this bias in order to derive a parsimonious three-equation model. The capacity utilization rate is given by

$$cu_t \quad = \quad \frac{C_t}{F\left(A_t, \bar{H}_t, K_t\right)} \quad = \quad \frac{q_t}{1 + c_{P,t}} \left(\frac{H_t}{\bar{H}_t}\right)^{1-\alpha}, \tag{5}$$

where I use the goods market clearing condition () and the production capacity function () to substitute for real GDP. The capacity utilization rate is determined by the goods selling probability, price adjusmtent costs, and the difference between current total hours worked and total hours worked at full employment in normal times. Following the definition of Morin and Stevens (2004); Michaillat and Saez (2015), I define full employment as a slow moving variable equal to the steady-state over the business cycle, $\bar{H}_t = H$.

An *important result* from (5) is, that capacity utilization as a measure of economic slack can be stated without knowing the level or growth of technology, as it cancels out. It is part of both real GDP and capacity and has the same impact on both variables. Therefore, capacity utilization determines the share of potential GDP being used without relying on estimates of technology or total factor productivity necessary to calculate potential GDP. It is a survey-based approach and (5) states its theoretical connection.

2.6. Calibration

I calibrate the model to replicate the business cycle behavior of the U.S. economy between 1985q1 and 2019q4. Time is in quarters. A full overview of the parameterization, its sources, and calculations can be found in appendix Appendix D.

Goods Market. The steady-state capacity utilization rate is set to 86%, which is a weighted average of industry and service sector capacity utilization. I assume that $f = q$, as there is no data on the goods finding probability. The demand elasticity with respect to goods market matching γ is set to 0.11. The value represents the lower end of the interval estimated by Bai et al. (2017). The convex price adjustment costs parameter κ is set to replicate a Phillips curve slope of 0.1, which follows from firms adjusting their prices every three quarters on average. I set the substitutability of differentiated goods parmeter ϵ to 6, which represents a steady-state markup of 20%.

Labor Market. I normalize the labor supply disutility level by $\mu_H = 1$. The inverse of the Frisch labor supply elasticity ν_H is set to one. The capital elasticity with respect to production capacity α is set to 0. This creates a linear production capacity function in total hours worked.

Monetary Policy. The period discount rate β is 0.9925, which represents a risk-free interst rate of 3% p.a. in a zero inflation steady-state. The Taylor (1993)-type rule coefficients are in line with the business cycle literature. I set $i_R = 0.8$, $i_\pi = 1.5$, $i_{gdp} = 0$, and $i_{cu} = 0$. Hence, monetary policy follows inflation targeting in the default calibration.

Shock processes. The autocorrelation of the technology shock it is set to $\rho_A = 0.95$. For the other shocks, it is set to 0.8. The standard deviations of the white-noise processes are set to commonly used values in the literature. The technology shock standard deviation is set to $\sigma_A = 0.0045$. The monetary policy shock standard deviation is set to $\sigma_M = 0.0024$. The cost-push and the SAM shock standard deviations are set such that the economy matches the standard deviation of GDP in the data and such that they create approximately 5% of GDP fluctuations, respectively.

3. Model Dynamics

What impact do non-clearing goods markets and costly search effort have on the decisions of households and firms? Their decision rules are given by the first order conditions of the optimizing problems. In this section, I derive the intertemporal decision rules and show the differences to a textbook New-Keynesian model. I assume that all firms have the same technology and hence the same decision space. I therefore drop the firm index i and present the dynamic system by a representative household and a representative firm. I linearize the system around its non-stochastic steady state. All variables with a hat represent percentage deviations from their non-stochastic steady-states. All derivations are postponed to the appendix Appendix A.

3.1. The Non-Stochastic Steady-State Economy

What is the long-run impact of goods market SAM on the model economy? I derive the non-stochastic steady-state at zero inflation. Aside from the impact of monopolistic competition, the economy is constrained efficient following the directed search approach of Moen (1997). The non-stochastic steady-state of the economy is given by

$$mc = \frac{1}{1+\frac{1+\nu_D}{(\epsilon-1)(1+\nu_D-\gamma)}}, \tag{6}$$

$$H = \left(\frac{1-\frac{\gamma}{1+\nu_D}\frac{\epsilon-1}{\epsilon}}{1-\frac{\gamma}{(1+\nu_D)^2}\frac{\epsilon-1}{\epsilon}}\frac{(1+\nu_D)(1-\gamma)}{1+\nu_D-\gamma}\frac{1-\alpha}{\mu_H}mc\right)^{\frac{1}{1+\nu_H}}, \tag{7}$$

$$cu = \left(\frac{\frac{\gamma}{1+\nu_D}\frac{\epsilon-1}{\epsilon}\frac{\psi^{\frac{1+\nu_D}{\gamma}}}{\mu_D}}{H^{\nu_D(1-\alpha)}}\right)^{\frac{1}{\nu_D+(1+\nu_D)\frac{1-\gamma}{\gamma}}}, \tag{8}$$

$$C = H^{1-\alpha}cu, \tag{9}$$

where (6) describes real marginal costs, (7) describes the labor market, (8) describes the goods market, and (9) describes the resource constraint of the economy. The labor market determines total hours worked, the goods market determines capacity utilization, and the combination of goods and labor market outcome determines real GDP. It is therefore a direct result of the combination of slack on both labor and goods markets.

Proposition 1. *If search and matching on the goods market is completely supply driven, $\gamma = 0$, its impact on the steady-state of the economy reduces to the impact of matching efficiency, ψ, a technology parameter.*[7]

Proof. See appendix Appendix E.1. □

The model is a model of aggregate demand. Without an active role for aggregate demand, as specified in proposition 1, the model reduces to a textbook New-Keynesian model with market matching technology ψ, which we can normalize to one. It is therefore not the introduction of goods market frictions that makes the difference compared to a textbook New-Keynesian model, but the explicit role of aggregate demand as a productive input factor, given by $\gamma > 0$. As (6) to (9) show, aggregate demand has a direct and significant impact on each part of the steady-state economy.

Real marginal costs increase in ϵ. As goods become better substitutes, real markups decrease and real marginal costs increase. Adding to the textbook New-Keynesian model, the impact of goods market SAM acts as a amplification mechanism on ϵ. As aggregate demand becomes a more important part of goods matching, $\gamma \rightarrow 1$, steady-state real marginal costs decrease. Hence, firm markups increase in goods market frictions. They increase further as search disutility becomes non-linear, $\nu_D > 0$. Firms can charge higher prices and thus higher markups as larger goods market frictions indicate higher marginal household search costs. The price elasticity of household search costs increases and households accept higher prices and higher firm markups to decrease their search costs. Goods market SAM therefore creates an additional channel for firm markups in combination with monopolistic competition.

Steady-state total hours worked are driven by two goods market SAM channels. First, household labor supply elasticity decreases in ν_D. Expanding consumption becomes increas-

[7] If the one-sided matching function has decreasing returns to scale, the matching elasticity further defines steady-state real GDP and labor allocation. With linear one-sided matching, this impact drops out.

ingly expensive, hence expanding labor supply does not lead to the same increase in utility. This is shown by the first term in the bracket of (7). Second, increasing ν_D increases the impact of real marginal costs on the labor market. This is shown by the second term in (7). The two channels work in opposite directions on total hours worked. It depends on the calibration to determine which of the two channels is quantitatively larger.

Steady-state capacity utilization as given by (8) increases in goods market efficiency ψ, and in the search effort matching elasticity γ. It decreases in the market power of monopolistically competitive firms $\epsilon \to 1$ and in the household search disutility level μ_D. The impact of total hours worked depends on the inverse of the search effort supply elasticity ν_D. Competitive markets and an efficient matching technology are therefore essential for high capacity utilization in the steady-state. Even with efficient markets, market power can have a lasting effect on capacity utilization. It creates an additional wedge between real and potential GDP, besides the goods market SAM frictions. Firms will accept lower capacity utilization in order to charge higher prices. Monopolistic competition in a model with non-clearing goods markets therefore does not only reduce realized GDP due to higher prices, it also increases the gap between realized and potential GDP as it decreases steady-state capacity utilization rates.

Real GDP as a summary statistic of the economy is determined by labor and goods market slack. Total hours worked define the level of production capacity and capacity utilization defines how efficiently it is used. As most economies show consistently idle capacity, its determinants are important determinants for real GDP. Besides the long-run impact of non-clearing goods markets on real GDP, it is the short-run tradeoff between sticky prices and goods market frictions that drives capacity utilization over the business cycle. How non-clearing goods markets impact price setting in a sticky prices framework is the topic of the following sections.

3.2. The Euler Equation, Total Hours Worked, and Real GDP

The representative household maximizes his intertemporal welfare by optimizing his consumption allocation across periods. It is given by the intertemporal consumption Euler equation

$$\mathbb{E}_t\hat{C}_{t+1} - \hat{C}_t = \hat{r}_t - \mathbb{E}_t\hat{\pi}_{t+1} - \Phi\left(\hat{g}'_{D,t+1} - \hat{g}'_{D,t}\right), \tag{10}$$

where the real interest rate $(\hat{r}_t - \mathbb{E}_t\hat{\pi}_{t+1})$, and the growth rate of marginal household search costs $\left(\hat{g}'_{D,t+1} - \hat{g}'_{D,t}\right)$ - the novel feature of the paper - are its determinants. The impact of the growth rate of marginal household search costs on intertemporal consumption allocation is determined by $\Phi = \left(\frac{1}{g'_D} - 1\right)^{-1} - \left(\frac{1+\nu_D}{g'_D} - 1\right)^{-1}$. It increases in ν_D and disappears for $\nu_D = 0$. Therefore, marginal household search costs only have a distinct impact on the Euler equation as long as they are non-linear in search effort D_t. Otherwise, they are proportional to consumption and do not influence intertemporal consumption allocation.

Marginal household search costs define the disutility created by the search effort necessary to buy an additional consumption good. Fluctuations in marginal household search costs are determined by

$$\hat{g}'_{D,t} = \nu_D\hat{C}_t + (1+\nu_D)\frac{1-\gamma}{\gamma}\hat{q}_t - \frac{1+\nu_D}{\gamma}\hat{\psi}_t, \tag{11}$$

where the level of consumption, the goods selling probability, and the goods market mismatch shock are its determinants. The main driver of marginal household search costs is the goods selling probability $\hat{q}_t$. If goods markets become tight, each household has to exert additional search effort to match one consumption good. The overall costs of buying one consumption good increase in marginal search costs. To match the increase in marginal search costs, marginal consumption utility has to increase. This leads to a drop in consumption, ceteris paribus.

Real marginal costs of the firm are given by

$$\hat{mc}_t = \frac{1}{1+(\epsilon-1)\left(1-\frac{\gamma}{1+\nu_D}\right)}\hat{g}'_{D,t}, \tag{12}$$

where marginal household search costs are its driver. Firm markups are defined as the inverse of real marginal costs. Marginal costs increase in tight goods markets as the tradeoff between goods prices and goods selling probability intensifies. As household search costs are high, firms pass through part of their markups to attract additional customers[8]. This channel vanishes in perfectly competitive markets, $\epsilon \to \infty$, as there is no price competiton and prices equal marginal costs. For monopolistic competition, the impact of marginal household search costs on marginal costs increases in γ, as goods markets become more demand-driven. Goods market SAM therefore acts as an amplifier of monopolistic competition in driving real marginal costs over the business cycle. It is therefore important to take goods market SAM into account when estimating the market power parameter ϵ. As capacity utilization is highly volatile in the data, this model attributes a significant share of marginal costs fluctuations to the impact of non-clearing goods markets.

An increase in total hours worked increases production capacity. Firms will only employ additional hours when capacity utilization is high. This tradeoff puts total hours worked in the center of capacity utilization analysis. Fluctuations in total hours are given by

$$\hat{H}_t = \frac{1}{1+\nu_H}\left[\hat{mc}_t - \Phi \hat{g}'_{D,t}\right],$$

where the Frisch labor supply elasticity ν_H determines the impact of fluctuations in marginal costs and marginal household search costs. An increase in marginal costs leads to an increase in total hours worked. Firms employ additional labor in tight goods markets to increase production capacity in order to attract additional customers. On the household side, non-linear search disutility leads to a lower labor supply in tight goods markets, as marginal consumption utility decreases. Both the marginal costs and the marginal consumption channel depend on marginal household search costs. For the default calibration, the first channel outweighs the second and total hours increase in goods market tightness.

The resource constraint (1) determines the connection between input factors, the production capacity function $\hat{Y}_t$, and realized output. In this model consumption is equal to real GDP and given by

$$\hat{C}_t = \hat{q}_t + \hat{A}_t + (1-\alpha)\hat{H}_t, \tag{13}$$

[8] A micro-founded approach of this mechanism with heterogenous firms is given by Paciello et al. (2019).

where technology and total hours worked define the production capacity of the economy. The goods selling probability $\hat{q}_t$ defines the level of efficiency of using the production capacity. It thus creates an additional wedge between input and output. Aggregate demand in the form of active household search becomes an input factor in the production function. As e.g. Bai et al. (2017) show, any shock that has an impact on aggregate demand can therefore look like a supply shock. Because goods selling probabilities are hard to observe, I use (5) to link the data to the model. The linearized equation is given by

$$\hat{cu}_t \quad = \quad \hat{q}_t + (1-\alpha)\,\hat{H}_t, \tag{14}$$

where capacity utilization incorporates fluctuations in total hours worked as the definition determines capacity utilization at full employment in normal times. Hence, real GDP fluctuations are the sum of technology and capacity utilization fluctuations in this model. Non-clearing goods markets have a distinct impact on the intertemporal consumption allocation, labor allocation, and real GDP. They determine the cyclical efficiency of goods markets. As capacity utilization is highly volatile in the data, it is important to include it in business cycle analysis.

3.3. The Capacity Utilization New-Keynesian Phillips Curve

Each firm sets the price for its variety of the consumption good. The price setting behavior of a firm is defined by the tradeoff between goods prices and goods selling probability. As prices are sticky, the tradeoff only adjusts gradually to its optimal point. The New-Keynesian Phillips curve

$$\hat{\pi}_t \quad = \quad \frac{1}{\kappa}\left(\underbrace{\frac{1}{1-\gamma}\frac{\epsilon}{\epsilon-1}}_{\text{HH SAM Channel}} - \underbrace{\frac{1}{1-\gamma}\frac{1}{\epsilon-1}}_{\text{Firm MC Channel}}\right)\hat{g}'_{D,t} + \hat{\xi}_t + \beta\mathbb{E}_t\hat{\pi}_{t+1}, \tag{15}$$

is forward-looking and describes the gradual adjustment of goods prices and goods selling probabilities. The slack variable is given by marginal household search costs and determined by two channels. First, the household SAM channel describes the tradeoff between goods prices and household search costs. It is the novel feature of the Phillips curve in this framework. Second, the firm marginal costs channel describes the tradeoff between markups and the customer base. It is also present in a textbook New-Keynesian model. I add a cost-push shock $\hat{\xi}_t$ that describes any nominal movement in inflation that is not explained by the slack variable. Inflation increases as marginal household search costs increase. Goods markets become tighter and households have to exert more effort to find a consumption good. They will trade off higher prices for lower search costs. As prices are sticky, the adjustment takes time. The impact of marginal household search costs on inflation is determined by price adjustment costs κ, and the demand elasticity of goods market matching γ. It decreases in κ and increases in γ. The impact of monopolistic competition ϵ is negatively proportional for both channels in this setup and therefore cancels out.

Proposition 2. *Reformulating the New-Keynesian Phillips curve with real marginal costs as the slackness variable results in a textbook New-Keynesian Phillips curve formulation.*

Proof. I substitute (12) in (15). The resulting Phillips curve is given by

$$\hat{\pi}_t \quad = \quad \frac{1 + (\epsilon - 1)\left(1 - \frac{\gamma}{1+\nu_D}\right)}{\kappa\,(1-\gamma)} \hat{mc}_t + \hat{\xi}_t + \beta \mathbb{E}_t \hat{\pi}_{t+1}, \tag{16}$$

which is forward-looking and increases in real marginal costs. Its impact depends on monopolistic competition ϵ, price adjustment costs κ, and the goods market SAM parameters γ and ν_D. □

Adding goods market SAM changes the transition processes of the model economy. But we can derive a New-Keynesian Phillips curve that is symmetrical to the textbook setup, as proposition 2 shows. The estimates of the slope of the Phillips curve as e.g. in Galı and Gertler (1999) therefore also apply to the model in this paper, although the decomposition of the slope into its parameters differs. This has an impact on κ as the residual parameter of the slope of the Phillips curve.

Both marginal household search costs and real marginal costs are difficult to observe. As Galı and Gertler (1999) discuss, there are only proxies for real marginal costs. In order to get a New-Keynesian Phillips curve that is driven by observables, I use the definition of capacity utilization given in (14) to substitute for the slack variable. The *Capacity Utilization New-Keynesian Phillips Curve* is then given by

$$\hat{\pi}_t = \frac{1}{\kappa\left(1-\gamma\right)\left(\varphi+\Omega\right)}\hat{cu}_t + \hat{\Theta}_t + \beta\mathbb{E}_t\hat{\pi}_{t+1} \tag{17}$$

where inflation increases in capacity utilization. The tradeoff between capacity utilization and inflation follows the tradeoff of households to minimize the overall costs of consumption goods consisting of goods prices and search costs. When goods markets are tight, capacity utilization is high and householdd will trade higher prices for lower search costs. Firms increase their prices acknowleding the demand curve (3) of the household. Markets are efficient as search is directed à la Moen (1997). Therefore, firms minimize the composite price for the households when maximizing their profits.

The impact of capacity utilization on inflation can be divided into a labor market channel summarized by φ, a goods market channel summarized by Ω, and price adjustment costs κ. Both φ and Ω are composite parameters defined by

$$\begin{aligned}\varphi &= \frac{1-\alpha}{1+\nu_H}\left[\frac{1}{1+\frac{(\epsilon-1)(1+\nu_D-\gamma)}{1+\nu_D}}-\Phi\right],\\ \Omega &= \frac{1-\nu_D\varphi}{\nu_D+\left(1+\nu_D\right)\frac{1-\gamma}{\gamma}},\end{aligned}$$

where the impact of labor markets on inflation, φ, decreases in ϵ and increases in the household search effort channel Φ. If differentiated goods are greater complements, labor demand is more elastic. Firms pass through a larger share of their markups to employ additional labor in tight goods markets and attract additional customers. This increases φ. As firms pass-through a larger share of their markups as capacity utilization increases, their increase in prices is smaller as the slope of the Phillips curve decreases. The household search effort channel Φ works in the opposite direction. With greater non-linearity in search disutility ν_D, the elasticity of marginal consumption utility increases. Households demand higher real wages as capacity utilization increases. This leads to an increase in φ and an increase in the slope of the Phillips curve. For linear disutility in search effort, $\nu_D = 0$, the household search effort channel vanishes.

The impact of goods market frictions on inflation is given by Ω. If goods markets are supply-driven, $\gamma \rightarrow 0$, Ω decreases and the slope of the Phillips curve increases, indicating lower goods market frictions. In the limiting case of $\Omega = 0$, the Phillips curve reduces to a textbook New-Keynesian Phillips curve. We find a similar impact if ν_D increases. If goods markets become more demand-driven, $\gamma \rightarrow 1$, Ω increases and the slope of the Phillips curve decreases. For demand-driven markets the tradeoff between household search costs and goods prices becomes less elastic as aggregate demand becomes a more important input factor. Higher prices cannot lower household search costs significantly. The dominance of the goods price in determining the market outcome decreases. An increase in capacity utilization therefore leads to a smaller increase in inflation compared to supply-driven goods markets, as the impact of firms on goods market matching decreases.

The composite exogenous shock term $\hat{\Theta}_t$ of the "Capacity Utilization New-Keynesian Phillips Curve" includes demand-pull and cost-push shocks. It therefore puts demand-pull shocks more to the center of inflation analysis, as aggregate demand becomes an active input factor of the goods market. The composite shock term is given by

$$\hat{\Theta}_t \quad = \quad \hat{\xi}_t + \frac{1}{\kappa\left(1-\gamma\right)} \frac{1}{1+\left(1+\nu_D\right)\frac{1-\gamma}{\gamma}\varphi} \left[\nu_D \hat{A}_t - \frac{1+\nu_D}{\gamma}\hat{\psi}_t\right].$$

With non-linear search effort, $\nu_D > 0$, technology shocks can shift the Phillips curve as household search disutility disproportionally increases compared to the increase in production capacity. During a technology boom prices drop less as households are weary to increase their search effort and therefore pay higher goods prices. Goods market mismatch shocks $\hat{\psi}_t$, which represent aggregate demand and goods market efficiency shocks, lead to a drop in inflation which is not warranted by the Phillips curve. This can be an increase in household search effort given by μ_D, or a reallocation of consumption towards more efficient goods markets. For example, Pytka (2018) shows in a similar framework that single households spend less time shopping than the unemployed or retirees. Any deviation in those margins can lead to a demand-pull shock to the Phillips curve where GDP increases while inflation decreases. Ultimatively those shocks represent some form of household heterogeneity or goods market characteristic not modeled explicitly here. Therefore, the Phillips curve shows both demand and supply shift variables, compared to supply shift variables in the textbook New-Keynesian model. This highlights the importance of active aggregate demand in a goods market SAM framework.

Overall, the Phillips curve presented in this section is based on non-clearing goods markets and the tradeoff between goods prices and household search costs. Although non-clearing goods markets is a clear deviation from the textbook model, I can derive a New-Keynesian Phillips curve, driven by marginal costs, that is symmetrical to the literature. The decomposition of the Phillips curve slope parameters changes though with the introduction of goods market SAM. I derive a "Capacity Utilization New-Keynesian Phillips Curve" that nests the textbook New-Keynesian Phillips curve. Its slope depends on the level of goods market frictions defined by γ. As γ increases, goods markets become more demand-driven and the slope of the Phillips curve decreases. This section shows the importance of household and goods market characteristics in determining the slope of the Phillips curve and offers a theoretical explanation for the results of Del Negro et al. (2020) and the "missing inflation" puzzle.

4. The Nested Three-Equation Output Gap Model

The output gap model is defined as the difference between the sticky price model and the flexible price model. Linearized fluctuations of the gap variables around the non-stochastic steady-state are shown by a tilde over the variable, e.g. $\tilde{x}$. The output gap model can be readily deduced from the dynamic system of the sticky price model. The model in this paper can be represented as a three equation New-Keynesian model

$$\mathbb{E}_t\tilde{C}_{t+1} = \underbrace{\frac{1}{1-\frac{\Phi}{\varphi+\Omega}}}_{\text{Euler SAM wedge}} \left(\hat{r}_t - \hat{r}_t^N - \mathbb{E}_t\hat{\pi}_{t+1}\right) + \tilde{C}_t, \tag{18}$$

$$\hat{\pi}_t = \frac{\epsilon}{\kappa}\frac{1+\nu_H}{1-\alpha}\underbrace{\frac{\frac{1-\alpha}{1+\nu_H}}{\epsilon\left(1-\gamma\right)\left(\varphi+\Omega\right)}}_{\text{Phillips SAM wedge}}\tilde{C}_t + \hat{\xi}_t + \beta\mathbb{E}_t\hat{\pi}_{t+1}, \tag{19}$$

$$\hat{r}_t = i_r\hat{r}_{t-1} + (1-i_r)\left[i_\pi\hat{\pi}_t + i_{gdp}\hat{C}_t\right] + \hat{M}_t, \tag{20}$$

where (18) is the Euler (dynamic IS) equation, (19) is the New-Keynesian Phillips curve, and (20) is a Taylor (1993)-type rule. Fluctuations in the natural interest rate are given by

$$\hat{r}_t^N = \frac{(-1)(1+\nu_D)}{\nu_D \gamma + (1+\nu_D)(1-\gamma)} \Big((1-\gamma)(1-\rho_A)\hat{A}_t + (1-\rho_\psi)\hat{\psi}_t \Big),$$

which is driven by exogenous processes. The goods market mismatch shock is an additional driver of the natural interest rate. It therefore is a real shock and has an impact on the flexible price model.

Proposition 3. *The New-Keynesian model with goods market SAM presented in this paper reduces to a textbook New-Keynesian model if $\gamma = 0$ and $\psi = 1$. The textbook New-Keynesian model is therefore a nested version of the model presented here. The demand elasticity γ of the goods matching function determines the weight of active aggregate demand - the novel feature - for business cycle fluctuations.*

Proof. See appendix Appendix E.2. □

Corollary 1. *Given proposition 3, the difference between the textbook New-Keynesian model and the model presented here can be summarized by "SAM-wedges" in the Euler equation as shown in (18) and the Phillips curve as shown in (19). Further, goods market SAM allows for different shocks in the decomposition of fluctuations in the natural interets rate $\hat{r}_t^N$. The "SAM wedges" show up in the equations as follows*

$$\text{Euler SAM wedge} := \frac{1}{1 - \frac{\Phi}{\varphi + \Omega}}, \tag{21}$$

$$\text{Phillips SAM wedge} := \frac{\frac{1-\alpha}{1+\nu_H}}{\epsilon(1-\gamma)(\varphi+\Omega)}. \tag{22}$$

The Euler SAM wedge describes the impact of SAM frictions on the slope of the Euler equation and hence on the household side of the economy. The slope describes the impact of the interest rate gap - the real rate net of the natural rate - on the growth rate of the output gap. A larger Euler SAM wedge leads to a stronger increase in the growth rate of the output gap as the interest rate gap increases. The Phillips SAM wedge describes the impact of SAM frictions on the slope of the Phillips curve and hence on the firm side of the economy. The slope describes the impact of the output gap on inflation. A larger Phillips SAM wedge leads to a stronger increase in inflation as the output gap increases.

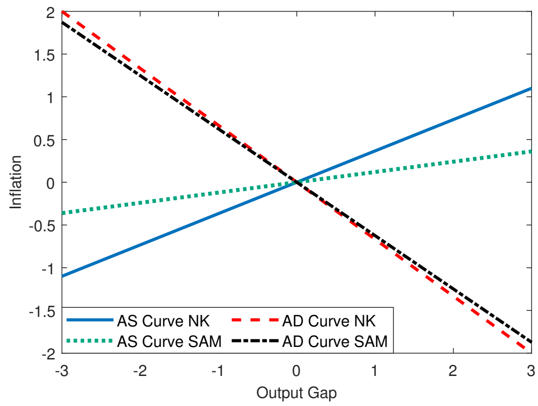
Both the Euler SAM wedge and the Phillips SAM wedge are driven by the impact of goods market SAM on labor markets φ, and on goods markets Ω. The Euler SAM wedge is generally above one and increases in both φ and Ω. The Phillips SAM wedge is generally below one and decreases in both φ and Ω. Larger goods market frictions therefore lead to a stronger impact of the interest rate gap on output gap growth and a weaker impact of the output gap on inflation. Goods market SAM therefore flattens the output gap Phillips curve through both the aggregate demand and the aggregate supply channel. Both channels are in line with the findings of Del Negro et al. (2020).

We can derive a simplified and tractable model to get some intuition on the impact of the "SAM wedges" on the economy. I assume that the model has two periods, the short-run and the long-run. The model is long-run neutral, hence all variables return to their steady-state in the second period, $\tilde{C}_{t+1} = \hat{\pi}_{t+1} = 0$. With two periods there is also no history dependence, hence $\hat{r}_{t-1} = 0$. The simplified and tractable model represents an AS-AD model, where the Phillips curve is the aggregate supply (AS) equation and the monetary policy rule substituted into the Euler equation is the aggregate demand (AD) equation.

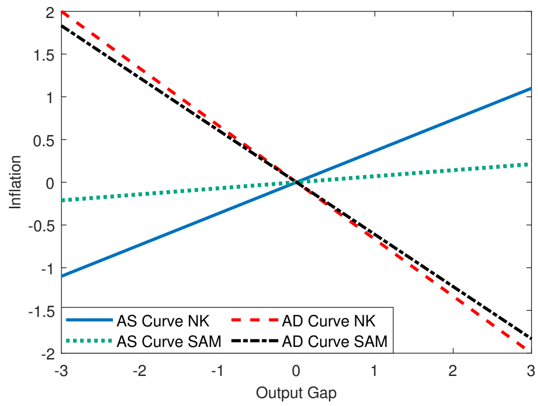
Figure 2 shows the AS and AD curves with and without goods market SAM. The left-hand figure shows $\gamma = 0.11$, the right-hand figure shows $\gamma = 0.23$. Goods market frictions have a significant impact on the slope of the AS curve. The slope decreases in γ leading to a smaller response of inflation to fluctuations in the output gap. The tradeoff between household search costs and goods prices becomes less elastic as aggregate demand becomes a more important input factor. As γ increases, price changes must become larger to trade off changes in search costs. Non-linear search disutility ν_D has the opposite effect on inflation as figure F.7 in appendix Appendix F shows. The impact of γ on the slope of the Phillips curve cleary dominates quantitatively though.

The impact of goods market frictions on the AD curve is less significant and heavily depends on ν_D. The slope of the AD curve is equal across models for $\nu_D = 0$. The "Euler SAM wedge"

Figure 2: AS-AD Model Economy with and without Goods Market SAM



(a) AS-AD model for $\gamma = 0.11$



(b) AS-AD model for $\gamma = 0.23$

NOTE: The figure shows a two-period long-run neutral AS-AD model derived from the three-equation output gap model. The AD curve shows the household side of the economy. The AS curve shows the firm side of the economy. Subfigure 2a shows the case of low goods market frictions. Subfigure 2b shows the case of high goods market frictions.

increases in both γ and ν_D, which decreases the slope of the AD curve. Aggregate demand becomes less elastic with respect to inflation as goods market frictions increase. This follows from the greater impact of household search costs on the overall price of consumption. The impact of goods market SAM on aggregate demand therefore supports the lower elasticity of inflation with respect to the output gap. The impact of goods market SAM on the AS curve quantitatively clearly dominates the impact on the AD curve though.

The results of the tractable AS-AD model are replicated by the full dynamic model. Table 1 shows the standard deviation and relative standard deviations of inflation for varying values of γ while keeping all other parameters fixed. The standard deviation of inflation decreases by up to 33%, as we introduce goods market SAM to the model. The relative standard deviation with respect to GDP shows a decrease of up to 49%, the relative standard deviation with respect to the output gap by up to 57%, and the relative standard deviation with respect to capacity utilization by up to 59%. All three relative standard deviations show, that the standard deviation of inflation decreases faster than the standard deviation of the economic slack variables. Hence, inflation reduces in γ even if economic activity does not change. These simulation results clearly support the decrease in the slope of the Phillips curve as γ increases.

Table 1: Goods market SAM on inflation fluctuations

	$std(\pi)$	$\frac{std(\pi)}{std(GDP)}$	$\frac{std(\pi)}{std(GDP_{Gap})}$	$\frac{std(\pi)}{std(cu)}$
$\gamma \approx 0$	0.40%	0.35	0.44	0.49
$\gamma = 0.11$	0.31%	0.23	0.31	0.26
$\gamma = 0.23$	0.27%	0.18	0.19	0.20

NOTE: The second moments are computed by simulating the model economy with the default calibration for 20000 periods with 20 repetitions. All variables are de-trended using a one-sided HP filter.

If we assume that we know the slope of the Phillips curve instead, introducing goods market frictions changes the price adjustment costs parameter κ, as it is normally calculated as a residual in Rotemberg (1982)-style Phillips curves. Setting the Phillips curve slope to 0.1, as in the default calibration, κ can become rather large for the setup without goods market SAM. This point is shown by e.g. Ireland (2004). For the default calibration and $\gamma = 0$, the price adjustment costs parameter is $\kappa = 120$. This implies costs of 0.6% of GDP for a $1\% - point$ deviation of inflation and costs of 2.4% of GDP for a $2\% - point$ deviation of inflation. For $\gamma = 0.11$, the price adjustment costs parameter reduces to $\kappa = 57$, which is an average reduction of 53%. This implies price adjustment cost of 0.29% of GDP for a $1\% - point$ deviation of inflation and cost of 1.14% of GDP for a $2\% - point$ deviation of inflation. For $\gamma = 0.23$, the price adjustment costs parameter reduces further to $\kappa = 37$, which is an average reduction of 69%. This implies price adjustment cost of 0.19% of GDP for a $1\% - point$ deviation of inflation and cost of 0.74% of GDP for a $2\% - point$ deviation of inflation. The model framework therefore can produce the same level of price stickiness with lower levels of price adjustment costs. Varying other model parameters changes the impact of γ and ν_D on the "SAM wedges". Details can be found in appendix Appendix F.

Introducing goods market SAM leads to a three-equation New-Keynesian model that nests the textbook model. It changes the slopes of both the Euler equation and the Phillips curve. While the impact on the "Euler SAM wedge" and the AD curve is limited, goods market frictions have a significant impact on the "Phillips SAM wedge" and the AS curve. We can either achieve the same price stickiness with a lower price stickiness parameter κ, or the slope of the Phillips curve decreases. The first point is useful from a general model fit perspective, as the large κ necessary to reproduce empricially plausible slopes of the Phillips curve in New-Keynesian models is unrealistically high. The second point is interesting from the point of view of recent episodes of missing inflation. As γ is a black box of goods market frictions and household heterogeneity, it is a parsimonious way of modeling the impact of an increase in goods market frictions on the slope of the Phillips curve. The goods market SAM approach therefore opens up the possibility to include further household and goods market features that can have an impact on the Phillips curve. In this section, I have shown that the impact of goods market SAM on the Phillips curve is valid for both the "Capacity Utilization Phillips Curve" and the overall output gap model.

5. Business Cycle Fluctuations of the Model Economy

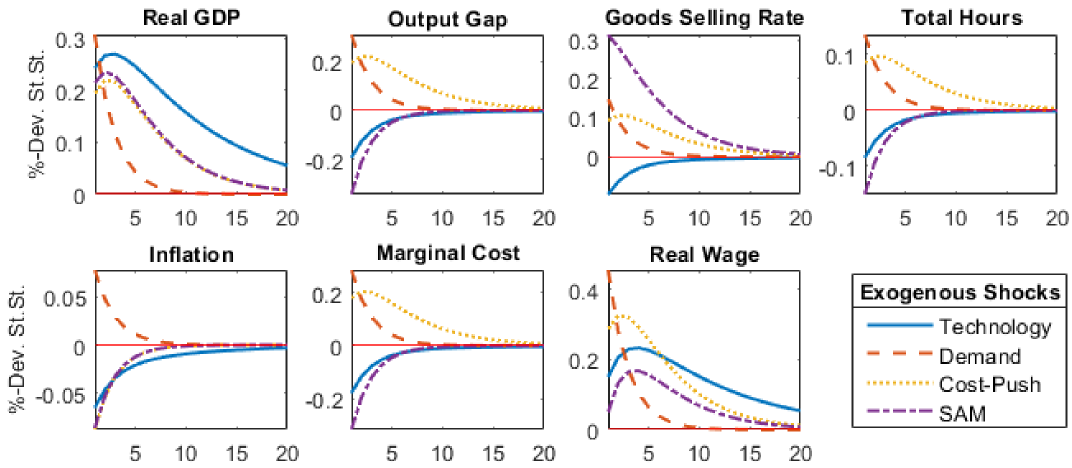
Non-clearing goods markets act as an amplifictaion mechanism of business cycle shocks. Varying capacity utilization leads to varying costs of production. In this section, I analyze the impact of the different shocks to the model economy. I analyze whether the model can account for the second moments of capacity utilization and macroeconomic aggregates in the data. As a robustness exercise, I show the impact of varying goods markets matching elasticities on the transmission mechanisms of the model economy.

5.1. Non-Clearing Goods Markets and Market Mismatch

How do non-clearing goods markets influence the transmission of business cycle shocks onto the economy? Figure 3 shows the impulse response functions to the four shocks of the model economy - technology, demand, cost-push, and search and matching. All figures show expansionary impulse responses.

All shocks except the demand shock create a hump-shaped response of real GDP. This follows from policy inertia in the Taylor-type rule. Goods market SAM does not add to this. The technology shock is the only shock with a countercyclical goods selling rate, as it is the only

Figure 3: Procyclical Impulse Response Functions of the Default Model



NOTE: The figure shows impulse response functions to the shocks of the model economy with default calibration. The standard deviations of the exogenous shocks are chosen for visible representation in a single figure. The blue curve shows the IRFs to a technology shock. The dashed orange curves show the IRFs to a demand shock (monetary policy shock). The dotted yellow curves show the IRFs to a cost-push shock. The purple dashed-dotted curves show the IRFs to a SAM shock, given by the matching efficiency shock. All figures show expansionary impulse responses. Impulse responses are measured as percentage deviations from the non-stochastic steady-state.

shock that directly increases production capacity. The other shocks show a procyclical goods selling rate as the means of expansion. If demand shocks can look like supply shocks, the impulse response of the goods selling rate allows to differentiate between the two shocks. This is along the lines of Bai et al. (2017).

Marginal costs and inflation are mainly driven by the tradeoff between goods prices and household search costs. The tradeoff can be described by goods market tightness. Hence, marginal costs and inflation are the result of frictions on both the labor and goods market. Total hours worked and real wages are highly cyclical in the model economy, as is common in a textbook New-Keynesian model without wage inertia. The endogenous goods selling rate and its impact on average costs of production amplify labor market fluctuations.

An *expansionary technology shock* increases production capacity for any given amount of input factors. Better technology decreases marginal costs of firms, which in turn decrease goods prices to attract additional customers. Lower prices increase aggregate demand by increasing household search effort. Higher production capacity and higher aggregate demand lead to an increase in consumption and real GDP. As prices are sticky, they only fall gradually, slowing the increase in additional aggregate demand. Production capacity increases faster than aggregate demand, leading to a drop in the goods selling rate and the output gap. Total hours worked drop as a reaction of the firms to the lower goods selling rate. With better technology though, real wages increase simultaneously. Adding non-clearing goods markets therefore adds additional frictions to the pass-through of technology to real GDP.

An *expansionary demand shock* increases contemporaneous consumption by decreasing the nominal interest rate. Households shift aggregate demand towards today and supply more search effort. Additional aggregate demand leads to an increase in the goods selling rate. Consumption and real GDP increase. Tighter goods markets lead to higher goods prices, as households will pay higher prices to balance rising search costs. As prices are sticky, they will only increase gradually, leading to a positive output gap. With a higher goods selling rate, marginal labor productivity increases, which leads to higher labor demand. Firms must offer higher real wages in order to attract additional labor. Higher real wages lead to an increase in marginal costs as there is no efficiency increase to offset it. Firms pass through part of their markup in order to attract additional customers. Adding non-clearing goods markets adds active aggregate demand by household search effort.

An *expansionary cost-push shock* decreases goods prices exogenously by decreasing firm markups, which shows up as an increase in marginal costs. Lower prices attract additional aggregate demand by increasing household search effort, which in turn increases the goods selling rate. The output gap increases as production capacity is constant. Consumption and real GDP increase. Total hours worked increase as a higher goods selling rate increases marginal labor productivity and thus labor demand. To employ additional labor, the firms must pay higher real wages. For the cost-push shock, fluctuations in goods market tightness both dampen labor demand and amplify real wage fluctuations at the same time. Adding non-clearing goods markets allows to distinguish technology and cost-push shocks, as the impulse response of the goods selling rate allows to differentiate.

Adding goods market SAM adds more than just non-clearing goods markets. As Merz

(1995); Andolfatto (1996) show for the labor market, adding goods market SAM defines margins that drive market behavior. Market characteristics drive the impulse response of single goods markets. The matching function is a "black-box" representing those market characteristics, as Petrongolo and Pissarides (2001) show. The matching function can change with market characteristics, both in the long-run due to fundamentals in markets, and in the short-run due to frictional elements. As the mismatch literature for the labor market shows (see e.g. Petrongolo and Pissarides (2001); Barnichon and Figura (2015); Diamond and Şahin (2016)), an aggregate matching function and its paramters can fluctuate over the business cycle due to e.g. dispersion or composition effects when aggregating different sub-markets. I implement the short-run frictional elements to the matching function with the SAM shock in form of a matching efficiency shock. As the shock to matching technology, it represents any deviation of matching in the data from the aggregate Cobb-Douglas matching function. It also represents aggregate demand shocks, as search effort is an active input factor into matching[9].

An *expansionary SAM shock* leads to a higher matching rate given the available production capacity. It therefore eases the matching friction and increases the goods selling rate. Less production capacity is idle and consumption and real GDP increase. The increase in the goods selling rate does not increase prices though, as the goods market tightness decreases due to higher market efficiency. Lower frictions on the goods market ease the tradeoff between prices and search costs as the marginal search effort decreases. Therefore, households will not accept higher prices, but rather increase their search effort. This leads to falling prices while real GDP increases. As prices are sticky, they only fall gradually. The output gap is negative as aggregate demand falls short of the potential aggregate demand without sticky prices. With monopolistic competition, firm markups increase as marginal costs decrease with a higher goods selling rate. Total hours decrease as less production capacity has to be supplied to create the same amount of goods matching. The higher goods selling rate at the same time leads to an increase in marginal labor productivity, which increases real wages.

[9] If we model shocks to $\hat{\mu}_{D,t}$ explicity, the IRFs show an identical cyclical behavior.

Hence, real wages increase while total hours fall. Adding non-clearing goods markets adds the possibility of analyzing goods market mismatch in a parsimonious way. As the matching function and the SAM shock are a "black box", the interpretations are manyfold. There are some examples in the literature showing how to map and interpret the SAM shock from microfoundations.

An exogenous increase in household search effort reduces matching frictions and can therefore be represented by the SAM shock. The additional search effort can be used to search for more consumption goods or to search for a better price. Pytka (2018) examines these patterns and builds a microfounded model that explains why older and richer households spend more effort searching for goods. This pattern is shown by differences in μ_D. Shocks to this parameter are equivalent to the SAM shock. Lower search effort disutility leads to higher real GDP and lower goods prices. Another example is the change in the "dependency-ratio" as shown by Goodhart and Pradhan (2020). As the society ages, the ratio of aggregate demand to production capacity increases. Average goods market tightness increases, which leads to an increase in the responsiveness of inflation in the presented goods market SAM framework. If aggregate supply increases relative to aggregate demand, as has been the case over the last 30 years globally, the responsiveness of inflation to economic slack decreases. This is in line with the decrease in the slope of the Phillips curve since 1990. Both examples shows how income heterogeneity and demographics can have an impact on inflation is a goods market SAM framework.

Another example of an expansionary goods market efficiency shock is the shift in composition over the business cycle. If market matching efficiency differs across sectors, then fluctuations in the composition of the sectors can lead to fluctuations in matching efficiency. Similar mismatch shocks can be found in the labor SAM literature, where for example the composition of short-term and long-term unemployed has an impact on the aggregate labor matching function (see e.g. Barnichon and Figura (2015)). For the goods markets, Baqaee et al. (2021) show how heterogenous firms and endogenous markups can lead to an endogenous increase in productivity over the business cycle. More productive firms with larger markups increase their market share over the business cycle, which directly leads to an increase in both productivity and markups, although both variables on the firm level do not change. This is directly related to the market efficiency shock presented here. In the data, capacity utilization and value-added are both more cyclical for the manufacturing than the service sector. Hence, the service sector decreases its share of GDP over the business cycle, leading to an increase in aggregate capacity utilization fluctuations. The goods matching efficiency shock captures the aggregate effects of this composition effect. An increase in matching efficiency increases capacity utilization and decreases average costs per unit in the model. The tradeoff between prices and search costs improves for the households, which leads to a drop in firm markups. This impact directly links the goods market SAM framework to the results of Baqaee et al. (2021).

Overall, adding goods market SAM reduces the initial impact of technology shocks, allows for demand shocks with an active impact on the efficiency of an economy, and enables us to differentiate between technology and cost-push shocks due to the different response in the goods selling rate. It allows for adding SAM shocks which represent goods market mismatch in a parsimonious way and therefore enables us to analyze the impact of heterogeneity in active household search behavior and goods market charracteristics. But can the model also replicate the second moments of aggregate data representing non-clearing goods markets?

5.2. Determinants of Capacity Utilization

Capacity utilization is driven by both fluctuations in goods selling rate and total hours worked as shown by (5). Any deviation from long-run full employment can therefore create fluctuations in capacity utilization as well. I use (14) to decompose capacity utilization data into its components for the US and the EU. In this section, I analyze whether the model is able to match the second moments of capacity utilization and macroeconomic aggregates in the data.

First, I use aggregate data on real GDP, capacity utilization, total hours worked, hours per employee, and the GDP deflator for the US the EU. The construction of goods market tightness is based on the model. Its construction is shown in appendix Appendix G. The second moments of the EU data can be found in appendix Appendix G. Generally, they are close to the US second moments. Table 2 shows the second moments for US data.

Table 2: US data second moments

	RStd	Correlations				
		GDP	cu	H	q	π
GDP	1.00	1	0.71	0.89	0.52	0.42
cu	0.80	–	1	0.75	0.87	0.47
H	1.37	–	–	1	0.45	0.34
q	0.59	–	–	–	1	0.48
π	0.16	–	–	–	–	1

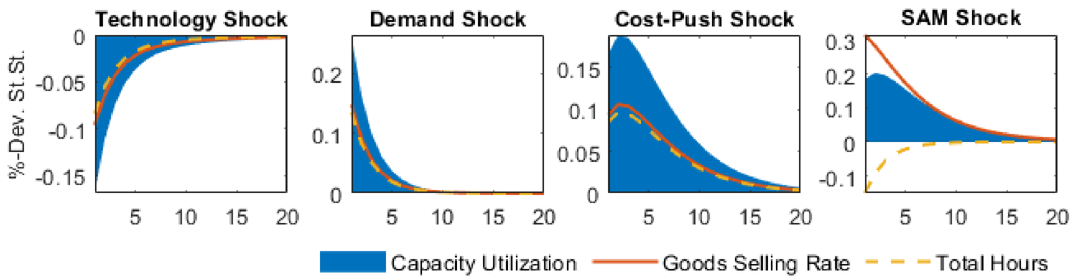
NOTE: The data is retrived from the FRED database of the FED St. Louis. Time is in quarters and covers 1985q1 to 2019q4. All time series are de-trended using a one-sided HP filter. Further details can be found in appendix Appendix D.

Both capacity utilization and total hours worked are highly cyclical and positively correlated with GDP and each other. The relative standard deviation of the goods market tightness is significantly lower and about half as volatile as GDP. It is highly positively correlated with capacity utilization, but shows a lower but positive correlation of about 0.5 with GDP and total hours worked. Hence, capacity utilization is closely related to GDP and driven by both goods and labor markets in the data. Yet, it is not the case that goods and labor markets always push in the same direction. Inflation data shows that its volatility is significantly lower than the volatility of GDP. It is positively correlated with GDP, the goods market, and the labor market. Yet, the correlation is rather weak with all values below 0.5.

The data highlights two points of capacity utilization data. First, fluctuations in hours worked are not sufficient to explain fluctuations in capacity utilization. There is an additional margin describing variable utilization of productive capacity on the goods market. Second, in order to give a good description of capacity utilization fluctuations one needs to take labor markets and its features into account.

Figure 4 shows the impulse response functions of capacity utilization, the goods selling rate, and total hours for all shocks of the model economy. The impulse response of capacity utilization decomposes into the goods selling rate and hours worked. For all shocks, both goods and labor markets play an important role in determining capacity utilization.

Figure 4: Impulse Response Functions for the Determiannts of Capacity Utilization



NOTE: The figure shows impulse response functions to the shocks of the model economy with default calibration. All shocks are expansionary. The blue areas show the impulse response of capacity utilization. It is the sum of the impulse responses of the goods selling rate shown by the solid orange curves and the impulse responses of total hours shown by the dashed yellow curves.

The impulse response to an expansionary technology shock shows a drop in capacity utilization. Both the goods selling rate and hours worked decrease and hence add up to the decrease in capacity utilization. As prices only gradually decrease due to sticky prices, the new production capacity is only gradually matched. With a larger share of production capacity being idle, firms decrease their employed hours. Sticky prices therefore has a double role in decreasing capacity utilization after an expansionary technology shock.

The impulse response to an expansionary demand shock shows a significant increase in capacity utilization. Both the goods selling rate and hours worked increase and hence add up to the increase in capacity utilization. With the increase in the goods selling rate, firms start to employ more hours. The labor market response therefore follows the goods market responses and acts as an multiplier on the impulse response of capacity utilization to the initial shock. As prices only gradually increase due to stiky prices, the increase in aggregate demand only slowly fades. With flexible prices the price level would jump at the initial period counteracting any change in capacity utilization and hours worked. The impulse responses to an expansionary cost-push shock shows the same pattern as to an expansionary demand shock.

The impulse response to an expansionary SAM shock shows an increase in capacity utilization. While the goods selling rate increases by construction, improved efficiency decreases labor demand at the same time. As prices only gradually decrease due to sticky prices, the improved market efficiency only gradually increases the amount of matches. Firms then decrease their labor demand as less production capacity is needed to realize the same amount of production. With a drop in hours worked, capacity utilization does not increase as much as the goods selling rate. The impulse response shows why it is important to keep track of the labor market when analyzing capacity utilization of the goods market. The negative correlation between hours worked and capacity utilization is a feature that distinguishes the SAM shock from the other shocks in the model. This allows to differentiate between those shocks in the data.

An increase in goods market frictions to e.g. $\gamma = 0.23$ leads to an increase in the fluctuations of the goods selling rate for all shocks, except the SAM shock. As goods markets become more frictional, the utilization margin becomes more important. For the SAM shock, households use the additional matching efficiency to reduce their search costs. For the other shocks affecting either demand or supply, a more inelastic search margin leads to stronger fluctuations in the goods selling rate. This pattern at the same time decreases the fluctuations of total hours as the goods selling rate determines average costs and labor productivity. An increase in the non-linearity of search disutility ν_D leads to the opposite response of the economy. Labor markets become more important for fluctuations in capacity utilization as aggregate demand becomes less elastic. The impulse response functions for either change in parameter can be found in figures G.10 and G.11 in appendix Appendix G.

Table 3: Default model second moments

	$RStd$	*Correlations*					
		GDP	cu	H	q	π	mc
GDP	1.00	1	0.82	0.70	0.77	0.50	0.70
cu	0.75	–	1	0.86	0.94	0.71	0.86
H	0.39	–	–	1	0.63	0.85	1.00
q	0.50	–	–	–	1	0.50	0.63
π	0.23	–	–	–	–	1	0.85
mc	0.82	–	–	–	–	–	1

NOTE: The second moments are computed by simulating the model economy for 20000 periods with 20 repetitions. I de-trend all results with a one-sided HP filter to be methodologically consistent with the data computations. $RStd$ describes the standard deviation of a variable relative to GDP, hence $RStd = \frac{std(Variable)}{std(GDP)}$. $Correlations$ shows the contemporaneous correlation of different model variables.

Can the parsimonious model replicate key second moments of capacity utilization and macroeconomic aggregates? I compare the second moments for the US given in table 2 to the model second moments given in table 3. For this first exercise, I use the default calibration given in section 2.6.

The model is able to replicate the relative standard deviations of the goods selling rate and inflation. The relative standard deviation of total hours worked falls short of its data counterpart. For hours worked this is a known feature of the class of small-scale New-Keynesian models. The relative standard deviation of capacity utilization matches the data well. Although total hours as one of its determinants in the model does not match the data, it comes close to the relative standard deviation of hours per employee. As we model capacity utilization at total hours instead of hours per employee in the model, the too low relative standard deviation in total hours and the bias in the definition cancel each other out. Marginal costs are highly cyclical in the model and highly positively correlated to total hours, capacity utilization, and inflation.

The model can match the positive correlation of capacity utilization and GDP well but shows a too high correlation of the goods selling rate with GDP. It matches the high positive correlations of hours worked and inflation with GDP. The correlations of capacity utilization with hours worked, the goods selling rate, and inflation are all too high but not far of their data counterparts. Hence, the model can replicate the joint behavior of capacity utilization and its determinants. The correlation of total hours and the goods selling rate fits the data well, while the correlation of total hours and inflation misses the data. It is significantly lower in the data, indicating that total hours and marginal costs are too tightly correlated in the model, which is also shown by their correlation of one. The correlation of the goods selling rate and inflation is close to the data.

If we assume that goods markets are more demand-driven by setting $\gamma = 0.23$ while keeping $\bar{cu} = 0.86$, the relative standard deviations of capacity utilization and the goods selling rate increase, while they decrease for total hours and marginal costs. Demand-driven markets therefore decrease the variability of firm markups in the model framework. The correlations of goods market variables increase slightly, but the general picture does not change. The correlation of inflation with all other variables decreases, which improves the data fit except for the correlation with the goods selling rate, which is slightly worse of. The non-linearity of search disutility ν_D shows no significant impact for empirically plausible values. Further, in such an exercise there is always uncertainty of the shock composition, as they are parameterized instead of estimated. If we drop the SAM shock, as it is the new shock in such a framework, the correlations of total hours and inflation with GDP increase. At the same time the correlation between total hours and the goods selling rate becomes one, which is far off the data. The SAM shock is the only driving force in the model that leads to an increase in capacity utilization while total hours decrease. The results for varying both γ and neglecting the SAM shock can be found in table G.9 in appendix Appendix G.

To summarize, the model with the default calibration does a good job in explaining capacity utilization and the goods selling rate. It misses to explain total hours and its connection to the goods market and inflation. Varying the impact of aggregate demand does not improve the short-commings of the default calibration. In the next section, I introduce frictional labor markets in order to try to improve the labor market fit.

Overall, the dynamic model can describe the behavior of capacity utilization, the goods selling rate, and macroeconomic aggregates reasonably well. This section showed, that it is important to have a detailed description of both the goods and the labor market, if we want to match capacity utilization second moments from the data. The parsimonious model framework has issues creating enough fluctuation on the labor market. Adding sticky wages improves the fit of the labor market but at the cost of the fit of the goods market. In order to resolve this tradeoff, we likely need a more detailed labor market in the model.

6. Discussion and Concluding Remarks

This paper is set up to include non-clearing goods markets in a textbook New-Keynesian model to take on the challenges in measuring economic slack in a theoretical macro model. For this purpose, I set up a model that explicitly models active aggregate demand by introducing goods market search-and-matching frictions. The modeling approach adds a second price margin - household search costs - to the goods market and creates a tradeoff between goods prices and household search costs. Taken together with sticky price adjustment, this tradeoff is central to the paper. I show that the capacity utilization margin can be naturally derived from goods market tightness and be implemented in the model. It allows for idle production capacity, both in the steady-state and over the business cycle. The model can be reduced to a common three-equation New-Keynesian model, although the transmission channels are different. This property allows for direct comparison with the textbook New-Keynesian model as it is nested by the model framework in this paper.

As a second task, I analyze the impact on non-clearing goods markets on the slope of the New-Keynesian Phillips curve and the business cycle properties of the model. I show that the model replicates the second moments of capacity utilization and main macroeconomic aggregates reasonably well. As capacity utilization is driven by both goods and labor markets, it requires realistic labor market features to match second moments in the data. Cyclical capacity utilization acts as an amplification mechanism between input and output of an economy. The demand elasticity with respect to goods market matching is an important determinant of the slope of the Phillips curve. It determines the impact of aggregate demand on the model economy and summarizes goods market characteristics and household heterogeneity. High search costs lead to strong inflation increases as households trade prices for search costs. A large impact of aggregate demand on matching leads to weaker inflation responses as the goods price as a feature of the supply side has less impact on matching. The Phillips curve shows demand-pull and cost-push shocks as exogenous drivers of inflation. The model therefore offers a modeling approach that can include a large variety of household and goods market features and gives a theoretical, yet parsimonious, explanation of the "missing deflation" puzzle at the same time.

This paper is meant as a starting point for goods market search-and-matching in monetary macro models. As a precise description of the labor market is a necessary feature to describe capacity utilization data, future research should include labor market search-and-matching and a hours per worker margin. This paper adss an active role of aggregate demand on the goods market. This feature opens up the possibility to analyze different margins of search behavior and market matching. Future research should include micro founded features like advertising, long-term contracts, inventories, or multi-good trades per match. Overall, this paper shows the importance of non-clearing goods markets and capacity utilization for monetary policy models and offers a starting point for further analysis.

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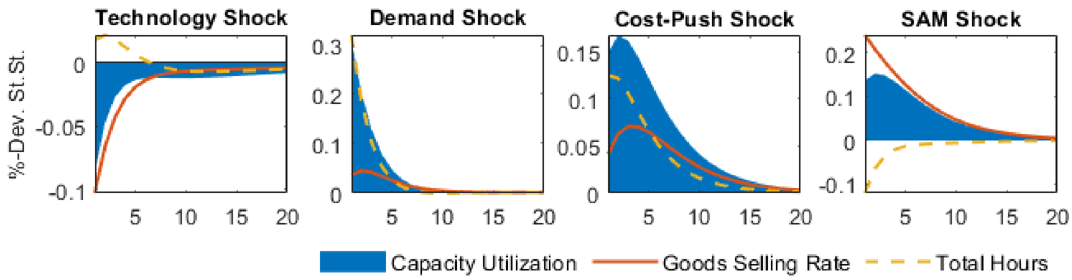
Appendix A. Frictional Labor Markets and Capacity Utilization

I introduce sticky wages along the lines of Erceg et al. (2000) to create labor market inertia. I calibrate the substitution elasticity of differentiated labor supply $\eta = 21$ as e.g. in Christiano et al. (2005). The nominal wage adjustment costs parameter is set to $\kappa_W = 120$, following the price adjustment costs parameter without SAM frictions as shown in section 4. The expanded model equations can be found in appendix Appendix A.

Figure A.5: Impulse Response Functions for the Determinants of Capacity Utilization



NOTE: The figure shows impulse response functions to the shocks of the model economy with the sticky wages calibration ($\kappa_W = 120, \eta = 21$). All shocks are expansionary. The blue areas show the impulse response of capacity utilization. It is the sum of the impulse responses of the goods selling rate shown by the solid orange curves and the impulse responses of total hours shown by the dashed yellow curves.

Figure A.5 shows the impulse response functions of capacity utilization, the goods selling rate, and total hours for all shocks of the model economy calibrated with sticky wages. The impulse response of capacity utilization decomposes into the goods selling rate and total hours. Both labor and goods markets have their role in determining capacity utilization. Compared to the default calibration without sticky wages given in figure 4 though, it depends on the shock whether the goods selling rate or total hours are the main driving force of capacity utilization.

The impulse responses to an expansionary technology shock shows a drop in capacity utilization. Total hours increase contrary to the default calibration, as wages are sticky. Higher total hours create higher production capacity, leading to a stronger drop in the goods selling rate. The combination of an increase in total hours and a strong decrease in the goods selling rate lead to a drop in capacity utilization which is smaller than the drop in the goods selling rate.

The impulse response to an expansionary demand shock shows an increase in capacity utilization. Total hours increase stronger compared to the default calibration, as households increase their labor supply following the aggregate demand shock, but real wages only decrease gradually. The higher consumption demand of households is met by a higher production capacity, leading to a weaker response of the goods selling rate. The combination of a stronger labor market response and a weaker goods market response leads to a stronger increase in capacity utilization after an expansionary demand shock. The impact of sticky wages on the cost-push shock follows the same pattern as the demand shock.

The impulse response to an expansionary SAM shock shows no significant differences for the sticky wage calibration compared to the default calibration. As the SAM shock affects market technology, it affects both the demand and supply side almost equally. The impulse responses to a SAM shock in a sticky wages environment show slightly weaker deviations in both total hours and the goods selling rate.

If goods markets become more demand-driven by setting $\gamma = 0.23$, the fluctuations of the goods selling rate become larger for all shocks, except for the SAM shock. This pattern increases the total hours response of the technology shock and decreases it for all other shocks. The utilization margin has a larger impact on labor productivity. An increase in the non-linearity of search disutility ν_D has no significant quantitative impact on the economy. The impulse response functions for either change in parameter can be found in figures G.12 and G.13 in appendix Appendix G. Overall, sticky wages lead to an increase in total hours for expansionary shocks compared to the default calibration. Whether this has a positive or negative impact on the goods selling rate depends on the shock.

Table A.4: Sticky wages model second moments

	RStd	Correlations					
		GDP	cu	H	q	π	mc
GDP	1.00	1	0.86	0.84	0.44	0.36	0.37
cu	0.77	–	1	0.92	0.61	0.57	0.57
H	0.73	–	–	1	0.25	0.65	0.63
q	0.31	–	–	–	1	0.08	0.15
π	0.16	–	–	–	–	1	0.69
mc	0.40	–	–	–	–	–	1

NOTE: The second moments are computed by simulating the model economy with sticky wages ($\kappa_W = 120, \eta = 21$) for 20000 periods with 20 repetitions. I de-trend all results with a one-sided HP filter to be methodologically consistent with the data computations. *RStd* describes the standard deviation of a variable relative to GDP, hence $RStd = \frac{std(Variable)}{std(GDP)}$. *Correlations* shows the contemporaneous correlation of different model variables.

Adding sticky wages improves the relative standard deviation of total hours at the cost of the relative standard deviation of the goods selling rate. A frictional labor market reduces goods market fluctuations as production capacity cannot adjust instantaneously anymore. Higher supply in recessions and lower supply in expansions dampens the impact of aggregate demand on the goods market. The relative standard deviation of capacity utilization is close to the default model, as the decrease in goods market fluctuations is made up by the increase in labor market fluctuations. Labor becomes a more important determinant of capacity utilization. The relative standard deviation of inflation improves as slower adjustment of labor costs leads to slower adjustment of prices.

Adding sticky wages improves the data fit of all correlations with GDP. It reduces espeically the high positive correlation of GDP with the goods selling rate to values around 0.5. The correlation of capacity utilization with total hours increases while the correlation with the goods selling rate decreases. The data fit decreases as the impact of the labor market compared to the goods market on capacity utilization increases. This also leads to a drop of the correlation between the goods selling rate and total hours below its data counterpart. Therefore, sticky wages lead to a disconnect between the supply side of goods markets and goods market matching. The impact of the goods selling rate and average production costs on total hours deteriorates - a feature not present in the data. The correlation of total hours with inflation improves as it decreases, yet at the cost of a worse fit of the goods selling rate and inflation as it decreases further. Sticky wages therefore increase the fit of the labor market at the cost of the fit of the goods market with capacity utilization. Increasing goods market frictions by increasing $\gamma = 0.23$ while keeping $\bar{cu} = 0.86$ improves the fit of the goods markets at the cost of the fit of labor market relative standard deviation. The correlations between total hours worked and the goods selling rate and inflation move closer to their data counterpart. Further, the fit of inflation to the data decreases generally as well. The correlation of the goods selling rate and inflation shows an almost acyclical behavior - a feature contrary to the high positive correlation in the data. If we drop the SAM shock, the model with sticky wages does not create much fluctuation in the goods selling rate anymore. Hence, sticky wages counteract the goods market SAM channel in this model. As in the default model, dropping the SAM shock leads to an improvement of fit for inflation. Hence, the SAM shock pattern of decreasing inflation while GDP and capacity utilization increase is not in line with the second moments of inflation - at least in this model setup. The results for varying both γ and neglecting the SAM shock can be found in table G.10 in appendix Appendix G.

ONLINE APPENDIX

Appendix A. Model Derivations

Appendix A.1. Goods Market Setup

The goods market is differentiated along the lines of each goods variety i. Each household[10] j buys every good i. Each variety is produced by a single firm. Goods market matching on each market follows

$$C_t(i,j) = (1-\delta_C)\, C_{t-1}(i,j) + \psi_t D_t(i,j)^{\gamma} S_t(i,j)^{1-\gamma}. \tag{A.1}$$

The matching probabilities of households and firms are respectively given by

$$f_t(i,j) = \frac{\psi_t D_t(i,j)^{\gamma} S_t(i,j)^{1-\gamma}}{D_t(i,j)} = \psi_t x_t(i,j)^{\gamma-1}, \tag{A.2}$$

$$q_t(i,j) = \frac{\psi_t D_t(i,j)^{\gamma} S_t(i,j)^{1-\gamma}}{S_t(i,j)} = \psi_t x_t(i,j)^{\gamma}, \tag{A.3}$$

$$x_t(i,j) = \frac{D_t(i,j)}{S_t(i,j)} = \frac{q_t(i,j)}{f_t(i,j)}. \tag{A.4}$$

Appendix A.2. Optimization Problem: Labor Union

$$\begin{aligned}\mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{0,t} \Bigg\{ & \left[W_t \left(\int_0^1 H_{G,t}(i)di + H_{K,t} \right) - \int_0^1 W_t(j) H_t(j) dj \right] \\ & - \Gamma_{1,t} \left[H_t - \left(\int_0^1 H_t(j)^{\frac{\eta-1}{\eta}} dj \right)^{\frac{\eta}{\eta-1}} \right] \\ & - \Gamma_{2,t} \left[H_t - \int_0^1 H_{G,t}(i)di - H_{K,t} \right] \Bigg\}\end{aligned}$$

First-order condition:.

$$\frac{W_t(j)}{W_t} = \left(\frac{H_t}{H_t(j)} \right)^{\frac{1}{\eta}} \tag{A.5}$$

[10] The differentiation of households is necessary for the sticky wages setup usedd in the monetary policy analysis. Otherwise it drops out.

Appendix A.3. Optimization Problem: Households of type j

The Lagrange maximization problem (MAX: $C_t(j)$, $C_t(i,j)$, $D_t(j)$, $D_t(i,j)$, $B_t(j)$, $H_t(j)$, $H_t(i,j)$, $W_t(i,,j)$) of each household is given by

$$
\begin{aligned}
\mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Bigg\{ & \left[\frac{1}{1-\sigma} \left(C_t(j) - \frac{\mu_D}{1+\nu_D} D_t(j) \right)^{1-\sigma} - \frac{\mu_H}{1+\nu_H} H_t(j)^{1+\nu_H} \right] \\
& - \lambda_{1,t} \Bigg[B_t(j) - (1+r_{t-1}) B_{t-1}(j) - W_t(j) H_t(j) + \int_0^1 P_t(i,j) C_t(i,j) di \\
& \qquad + \frac{\kappa_W}{2} \left(\frac{W_t(j)}{W_{t-1}(j)} - 1 \right)^2 W_t(j) H_t(j) + Tax_t(j) - \Pi_{G,t} \Bigg] \\
& - \lambda_{2,t} \left[C_t(i,j) - (1-\delta_C) C_{t-1}(i,j) - f_t(i,j) D_t(i,j) \right] \\
& - \lambda_{3,t} \left[C_t(j) - \left(\int_0^1 C_t(i,j)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \right] \\
& - \lambda_{4,t} \left[D_t(j) - \int_0^1 D_t(i,j)^{1+\nu_D} di \right] \\
& - \lambda_{5,t} \left[H_t(j) - \left(\frac{W_t}{W_t(j)} \right)^{\eta} H_t \right] \Bigg\},
\end{aligned}
$$

where it is assumed that the no-Ponzi scheme condition $\lim_{T\to\infty} \mathbb{E}_t B_T(j) \geq 0$ holds. The labor demand equation (last constraint, $\lambda_{5,t}$) of differentiated labor follows from the firm labor cost minimization problem (A.5).

First-Order Conditions:.

$$
\mathcal{L}_{C_t(j)}: \quad \lambda_{3,t} = \left(C_t(j) - \frac{\mu_D}{1+\nu_D} D_t(j) \right)^{-\sigma} \tag{A.6}
$$

$$
\mathcal{L}_{C_t(i,j)}: \quad \lambda_{1,t} P_t(i,j) = \left(\frac{C_t(j)}{C_t(i,j)} \right)^{\frac{1}{\epsilon}} \lambda_{3,t} - \lambda_{2,t} + \beta (1-\delta_C) \mathbb{E}_t \lambda_{2,t+1} \tag{A.7}
$$

$$
\mathcal{L}_{D_t(j)}: \quad \lambda_{4,t} = (-1) \frac{\mu_D}{1+\nu_D} \left(C_t(j) - \frac{\mu_D}{1+\nu_D} D_t(j) \right)^{-\sigma} \tag{A.8}
$$

$$
\mathcal{L}_{D_t(i,j)}: \quad \lambda_{2,t} = (-1)(1+\nu_D) \frac{D_t(i,j)^{\nu_D}}{f_t(i,j)} \lambda_{4,t} \tag{A.9}
$$

$$
\mathcal{L}_{B_t(j)}: \quad \lambda_{1,t} = \beta (1+r_t) \mathbb{E}_t \lambda_{1,t+1} \tag{A.10}
$$

$$
\mathcal{L}_{H_t(j)}: \quad \mu_H H_t(j)^{\nu_H} = \lambda_{5,t} - \lambda_{1,t} W_t(j) \left[1 - c_{W,t}(j) \right] \tag{A.11}
$$

$$
\begin{aligned}
\mathcal{L}_{W_t(j)}: \quad \lambda_{5,t} = \lambda_{1,t} \frac{W_t(j)}{\eta} \Bigg[& 1 - c_{W,t}(j) - c'_{W,t}(j) \\
& + \beta \mathbb{E}_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} \frac{H_{t+1}(j)}{H_t(j)} \frac{W_{t+1}(j)}{W_t(j)} c'_{W,t+1}(j) \Bigg],
\end{aligned} \tag{A.12}
$$

where $c_{W,t}(j) = \frac{\kappa_W}{2}\left(\frac{W_t(j)}{W_{t-1}(j)} - 1\right)^2$ and $c'_{W,t}(j) = \kappa_W\left(\frac{W_t(j)}{W_{t-1}(j)} - 1\right)$. Define $\lambda_{1,t}P_t(j) = muc_t(j)$ and substitute into (A.10) to get the consumption Euler equation

$$muc_t(j) = \beta\mathbb{E}_t\frac{1+r_t}{1+\pi_{t+1}(j)}muc_{t+1}(j), \tag{A.13}$$

where $1+\pi_{t+1}(j) = \frac{P_{t+1}(j)}{P_t(j)}$. Define $\mathbb{U}_{C,t}(j) = \lambda_{3,t}$, $\mathbb{U}_{D,t}(i,j) = \lambda_{2,t}$, and substitute (A.9) in (A.8) for the search disutility equation

$$\begin{aligned}\mathbb{U}_{D,t}(i,j) &= \mu_D\frac{D_t(i,j)^{\nu_D}}{f_t(i,j)}\mathbb{U}_{C,t}(j),\\ &= g'_{D,t}(i,j)\mathbb{U}_{C,t}(j).\end{aligned} \tag{A.14}$$

Substitute (A.7) in (A.8) for the marginal utility equation

$$muc_t(j)\frac{P_t(i,j)}{P_t(j)} = \left(\frac{C_t(j)}{C_t(i,j)}\right)^{\frac{1}{\epsilon}}\mathbb{U}_{C,t}(j) - \mathbb{U}_{D,t}(i,j) + \beta\left(1-\delta_C\right)\mathbb{E}_t\mathbb{U}_{D,t+1}(i,j). \tag{A.15}$$

Labor supply of the household can be derived by substituting (A.11) in (A.12)

$$\begin{aligned}\frac{\mu_H H_t(j)^{\nu_H}}{muc_t(j)}\frac{P_t(j)}{P_t(i,j)} &= \frac{w_t(j)}{\eta}\Big[\left(1-c_{W,t}(j)\right)(\eta-1) + c'_{W,t}(j)\\ &\quad -\mathbb{E}_t\frac{1+\pi_{W,t+1}(j)}{1+r_t}\frac{H_{t+1}(j)}{H_t(j)}c'_{W,t+1}(j)\Big],\end{aligned} \tag{A.16}$$

where $w_t(j) = \frac{W_t(j)}{P_t(j)}$, $(1+\pi_{W,t+1}(j)) = (1+\pi_{t+1}(j))\frac{w_{t+1}(j)}{w_t(j)}$, and $\beta\frac{\lambda_{1,t+1}}{\lambda_{1,t}} = \frac{1}{1+r_t}$.

Household Consumption Demand Equation. For any two varieties of differentiated goods (i,l), we can reformulate (A.15) such that

$$\frac{P_t(i,j)}{P_t(l,j)} = \frac{\left(\frac{C_t(i,j)}{C_t(j)}\right)^{\frac{-1}{\epsilon}}\mathbb{U}_{C,t}(j) - g'_{D,t}(i,j)\mathbb{U}_{C,t}(j) + \beta\left(1-\delta_C\right)\mathbb{E}_t g'_{D,t+1}(i,j)\mathbb{U}_{C,t+1}(j)}{\left(\frac{C_t(l,j)}{C_t(j)}\right)^{\frac{-1}{\epsilon}}\mathbb{U}_{C,t}(j) - g'_{D,t}(l,j)\mathbb{U}_{C,t}(j) + \beta\left(1-\delta_C\right)\mathbb{E}_t g'_{D,t+1}(l,j)\mathbb{U}_{C,t+1}(j)}.$$

Appendix A.4. Optimization Problem: Goods firms of type i

The Lagrange maximization problem (MAX: $C_t(i,j)$, $S_t(i,j)$, $D_t(i,j)$, $P_t(i,j)$, $H_t(i)$) of each firm is given by

$$
\begin{aligned}
\mathcal{L} \quad = & \\
& \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{0,t} \Bigg\{ \left[\int_0^1 P_t(i,j) C_t(i,j) dj - W_t(i) H_{G,t}(i) - P_{I,t} I_{G,t}(i) \right] \\
& - \phi_{1,t} \Bigg[\int_0^1 \left(1 + \frac{\kappa}{2} \left(\frac{P_t(i,j)}{P_{t-1}(i,j)} - 1 \right)^2 \right) S_t(i,j) dj - A_t H_{G,t}(i)^{1-\alpha_G} \left(e_{G,t}(i) K_{G,t-1}(i) \right)^{\alpha_G} \\
& \qquad + (1-\delta_C) \int_0^1 C_t(i,j) dj - (1-\delta_I) \left(1 - \int_0^1 \psi_{t-1} D_{t-1}(i,j)^{\gamma} S_{t-1}(i,j)^{-\gamma} dj \right) \int_0^1 S_{t-1}(i,j) dj \Bigg] \\
& - \phi_{2,t} \left[\int_0^1 C_t(i,j) dj - (1-\delta_C) \int_0^1 C_{t-1}(i,j) dj - \psi_t \int_0^1 D_t(i,j)^{\gamma} S_t(i,j)^{1-\gamma} dj \right] \\
& - \phi_{3,t} \Bigg[\int_0^1 P_t(i,j) \frac{muc_t(j)}{P_t(j)} dj - \int_0^1 \left(\frac{C_t(i,j)}{C_t(j)} \right)^{-\frac{1}{\epsilon}} \mathbb{U}_{C,t}(j) dj \\
& \qquad + \int_0^1 \frac{\mu_D}{\psi_t} S_t(i,j)^{\gamma-1} D_t(i,j)^{1-\gamma+\nu_D} \mathbb{U}_{C,t}(j) dj - \int_0^1 \beta \left(1-\delta_C \right) \mathbb{U}_{D,t+1}(i,j) \Bigg] \\
& - \phi_{4,t} \left[K_{G,t} - \left(1 - \delta_{G1} - \delta_{G2} e_{G,t}(i)^{1+\phi_G} \right) K_{G,t-1}(i) - I_{G,t}(i) \left(1 - \frac{\kappa_G}{2} \left(\frac{I_{G,t}(i)}{I_{G,t-1}(i)} - 1 \right)^2 \right) \right] \Bigg\},
\end{aligned}
$$

where the second to last constraint states the household consumption demand constraint derived in (A.15) and aggregated over all households.

First-order conditions.

$$\mathcal{L}_{C_t(i,j)}: \quad \phi_{2,t} = P_t(i,j) - \frac{1}{\epsilon}\left(\frac{C_t(j)}{C_t(i,j)}\right)^{\frac{1}{\epsilon}} \frac{\mathbb{U}_{C,t}(j)}{C_t(i,j)}\phi_{3,t} + \mathbb{E}_t\beta_{t,t+1}\left(1-\delta_C\right)\left(\phi_{2,t+1}-\phi_{1,t+1}\right) \tag{A.17}$$

$$\begin{aligned}\mathcal{L}_{S_t(i,j)}: \quad \phi_{1,t}\left(1+c_{P,t}(i,j)\right) = {}& \phi_{2,t}\left(1-\gamma\right) q_t(i,j) + \phi_{3,t}\left(1-\gamma\right) g'_{D,t}(i,j) S_t(i,j)^{-1}\mathbb{U}_{C,t}(j) \\ & + \mathbb{E}_t\beta_{t,t+1}\left(1-\delta_I\right)\left(1-\left(1-\gamma\right) q_t(i,j)\right)\phi_{1,t+1}\end{aligned} \tag{A.18}$$

$$\mathcal{L}_{D_t(i,j)}: \quad \phi_{3,t} = \frac{\gamma}{1-\gamma+\nu_D}\frac{f_t(i)D_t(i,j)}{\mathbb{U}_{C,t}(j)}\frac{1}{g'_{D,t}(i,j)}\left[\phi_{2,t} - \mathbb{E}_t\beta_{t,t+1}\left(1-\delta_I\right)\phi_{1,t+1}\right] \tag{A.19}$$

$$\begin{aligned}\mathcal{L}_{P_t(i,j)}: \quad C_t(i,j) = {}& \phi_{1,t}S_t(i,j)\frac{c'_{P,t}(i,j)}{P_t(i,j)} + \phi_{3,t}\frac{muc_t(j)}{P_t(j)} \\ & - \mathbb{E}_t\beta_{t,t+1}\phi_{1,t+1}S_{t+1}(i,j)\frac{c'_{P,t+1}(i,j)}{P_{t+1}(i,j)}\frac{P_{t+1}(i,j)}{P_t(i,j)}\end{aligned} \tag{A.20}$$

$$\mathcal{L}_{H_t(i)}: \quad W_t(i) = \phi_{1,t}\left(1-\alpha_G\right)\frac{Y_{G,t}(i)}{H_{G,t}(i)}, \tag{A.21}$$

$$\mathcal{L}_{I_{G,t}(i)}: \quad P_{I,t} = \phi_{4,t}\left[1 - g_{IG,t}(i) - g'_{IG,t}(i)\right] + \mathbb{E}_t\beta_{t,t+1}\phi_{4,t+1}g'_{IG,t+1}(i)\frac{I_{G,t+1}(i)}{I_{G,t}(i)} \tag{A.22}$$

$$\mathcal{L}_{K_{G,t}(i)}: \quad \phi_{4,t} = \mathbb{E}_t\beta_{t,t+1}\left[\alpha_G\frac{Y_{G,t+1}(i)}{K_{G,t}(i)}\phi_{1,t+1} + \left(1-\delta_{G1}-\delta_{G2}e_{G,t+1}(i)^{1+\phi_G}\right)\phi_{4,t+1}\right] \tag{A.23}$$

$$\mathcal{L}_{e_{G,t}(i)}: \quad \phi_{1,t}\alpha_G\frac{Y_{G,t}(i)}{K_{G,t-1}(i)} = \phi_{4,t}\delta_{G2}\left(1+\phi_G\right)e_{G,t}(i)^{1+\phi_G} \tag{A.24}$$

where $c_{P,t}(i,j) = \frac{\kappa}{2}\left(\frac{P_t(i,j)}{P_{t-1}(i,j)}-1\right)^2$, $c'_{P,t}(i,j) = \kappa\left(\frac{P_t(i,j)}{P_{t-1}(i,j)}-1\right)$, $Y_{G,t}(i) = A_tH_{G,t}(i)^{1-\alpha_G}\left(e_{G,t}(i)K_{G,t-1}(i)\right)^{\alpha_G}$, $g_{IG,t}(i) = \frac{\kappa_G}{2}\left(\frac{I_{G,t}(i)}{I_{G,t-1}(i)}-1\right)^2$, and $g'_{IG,t}(i) = \kappa_G\left(\frac{I_{G,t}(i)}{I_{G,t-1}(i)}-1\right)\frac{I_{G,t}(i)}{I_{G,t-1}(i)}$. I use (A.19) to substitute for $\phi_{3,t}$ in (A.17), (A.18), and (A.20)

$$\begin{aligned}
\frac{\phi_{1,t}}{P_t(i)} &= \frac{1}{1+c_{P,t}(i,j)}\left\{\frac{\phi_{2,t}}{P_t(i)}(1-\gamma)\,q_t(i,j)\left(1+\frac{\gamma}{1-\gamma+\nu_D}\right)\right. \\
&+\mathbb{E}_t\beta_{t,t+1}(1-\delta_I)\left(1-(1-\gamma)\,q_t(i,j)\right)\frac{P_{t+1}(i)}{P_t(i)}\frac{\phi_{1,t+1}}{P_{t+1}(i)} \\
&\left.-\,\mathbb{E}_t\beta_{t,t+1}(1-\delta_I)\frac{f_t(i)D_t(i,j)}{S_t(i,j)}(1-\gamma)\frac{\gamma}{1-\gamma+\nu_D}\frac{P_{t+1}(i)}{P_t(i)}\frac{\phi_{1,t+1}}{P_{t+1}(i)}\right\}
\end{aligned} \tag{A.25}$$

$$\begin{aligned}
\frac{\phi_{2,t}}{P_t(i)} &= \frac{P_t(i,j)}{P_t(i)}+\mathbb{E}_t\beta_{t,t+1}\frac{P_{t+1}(i)}{P_t(i)}(1-\delta_C)\left(\frac{\phi_{2,t+1}}{P_{t+1}(i)}-\frac{\phi_{1,t+1}}{P_{t+1}(i)}\right) \\
&-\frac{1}{\epsilon}\frac{\left(\frac{C_t(i)}{C_t(i,j)}\right)^{\frac{1}{\epsilon}}}{g'_{D,t}(i,j)}\frac{\gamma}{1-\gamma+\nu_D}\frac{f_t(i)D_t(i,j)}{C_t(i,j)}\left[\frac{\phi_{2,t}}{P_t(i)}-\mathbb{E}_t\beta_{t,t+1}\frac{P_{t+1}(i)}{P_t(i)}(1-\delta_I)\frac{\phi_{1,t+1}}{P_{t+1}(i)}\right]
\end{aligned} \tag{A.26}$$

$$\begin{aligned}
C_t(i,j) &= \frac{\phi_{1,t}}{P_t(i,j)}S_t(i,j)c'_{P,t}(i,j)-\mathbb{E}_t\beta_{t,t+1}\frac{\phi_{1,t+1}}{P_{t+1}(i,j)}S_{t+1}(i,j)c'_{P,t+1}(i,j)\frac{P_{t+1}(i,j)}{P_t(i,j)} \\
&+\frac{P_t(i,j)}{P_t(j)}\frac{\gamma}{1-\gamma+\nu_D}\frac{f_t(i)D_t(i,j)}{\mathbb{U}_{C,t}(j)}\frac{muc_t(j)}{g'_{D,t}(i,j)}\left[\frac{\phi_{2,t}}{P_t(i,j)}-\mathbb{E}_t\beta_{t,t+1}\frac{P_{t+1}(i,j)}{P_t(i,j)}(1-\delta_I)\frac{\phi_{1,t+1}}{P_{t+1}(i,j)}\right]
\end{aligned} \tag{A.27}$$

Define $mc_t(i,j)=\frac{\phi_{1,t}}{P_t(i,j)}$, and $pr_t(i,j)=\frac{\phi_{2,t}}{P_t(i)}$, we get

$$\begin{aligned}
mc_t(i,j) &= \frac{1}{1+c_{P,t}(i,j)}\left\{\frac{(1-\gamma)(1+\nu_D)}{1-\gamma+\nu_D}q_t(i,j)pr_t(i,j)\right. \\
&\left.+\,\mathbb{E}_t\frac{1+\pi_{t+1}(i,j)}{1+r_t}(1-\delta_I)\left(1-\frac{(1-\gamma)(1+\nu_D)}{1-\gamma+\nu_D}q_t(i,j)\right)mc_{t+1}(i,j)\right\}
\end{aligned} \tag{A.28}$$

$$\begin{aligned}
pr_t(i,j) &= \frac{1+\mathbb{E}_t\frac{1+\pi_{t+1}(i,j)}{1+r_t}(1-\delta_C)\left(pr_{t+1}(i,j)-mc_{t+1}(i,j)\right)}{1+\frac{1}{\epsilon}\frac{\left(\frac{C_t(i)}{C_t(i,j)}\right)^{\frac{1}{\epsilon}}}{g'_{D,t}(i,j)}\frac{\gamma}{1-\gamma+\nu_D}\frac{q_t(i)S_t(i,j)}{C_t(i,j)}} \\
&+\frac{\frac{1}{\epsilon}\frac{\left(\frac{C_t(i)}{C_t(i,j)}\right)^{\frac{1}{\epsilon}}}{g'_{D,t}(i,j)}\frac{\gamma}{1-\gamma+\nu_D}\frac{q_t(i)S_t(i,j)}{C_t(i,j)}\mathbb{E}_t\frac{1+\pi_{t+1}(i,j)}{1+r_t}(1-\delta_I)\,mc_{t+1}(i,j)}{1+\frac{1}{\epsilon}\frac{\left(\frac{C_t(i)}{C_t(i,j)}\right)^{\frac{1}{\epsilon}}}{g'_{D,t}(i,j)}\frac{\gamma}{1-\gamma+\nu_D}\frac{q_t(i)S_t(i,j)}{C_t(i,j)}}
\end{aligned} \tag{A.29}$$

$$\begin{aligned}
C_t(i,j) &= mc_t(i,j)S_t(i,j)c'_{P,t}(i,j)-\mathbb{E}_t\frac{1+\pi_{t+1}(i,j)}{1+r_t}mc_{t+1}(i,j)S_{t+1}(i,j)c'_{P,t+1}(i,j) \\
&+\frac{P_t(i,j)}{P_t(j)}\frac{\gamma}{1-\gamma+\nu_D}\frac{q_t(i)S_t(i,j)}{\mathbb{U}_{C,t}(j)}\frac{muc_t(j)}{g'_{D,t}(i,j)}\left[pr_t(i,j)-\mathbb{E}_t\frac{1+\pi_{t+1}(i,j)}{1+r_t}(1-\delta_I)\,mc_{t+1}(i,j)\right]
\end{aligned} \tag{A.30}$$

Define $Q_{G,t}(i) = \frac{\phi_{4,t}}{P_t(i)}$

$$
\begin{aligned}
w_t(i) &= (1-\alpha_G)\frac{Y_{G,t}(i)}{H_{G,t}(i)}mc_t(i) && \text{(A.31)}\\
P_{I,t}(i) &= Q_{G,t}(i)\left[1-g_{IG,t}(i)-g'_{IG,t}(i)\right]+\mathbb{E}_t\frac{1+\pi_{t+1}(i)}{1+r_t}g'_{IG,t+1}(i)\frac{I_{G,t+1}(i)}{I_{G,t}(i)}Q_{G,t+1}(i) && \text{(A.32)}\\
Q_{G,t}(i) &= \mathbb{E}_t\frac{1+\pi_{t+1}(i)}{1+r_t}\left[\alpha_G\frac{Y_{G,t+1}(i)}{K_{G,t}(i)}mc_{t+1}(i)+\left(1-\delta_{G1}-\delta_{G2}e_{G,t+1}(i)^{1+\phi_G}\right)Q_{G,t+1}(i)\right] && \text{(A.33)}\\
mc_t(i) &= Q_{G,t}(i)\delta_{G2}\left(1+\phi_G\right)e_{G,t}(i)^{1+\phi_G}\frac{1}{\alpha_G}\frac{K_{G,t-1}(i)}{Y_{G,t}(i)} && \text{(A.34)}
\end{aligned}
$$

where $w_t(i) = \frac{W_t(i)}{P_t(i)}$.

Appendix A.5. Optimization Problem: Capital firms

$$
\begin{aligned}
\mathcal{L} = \mathbb{E}_0\sum_{t=0}^{\infty}\beta_{0,t}\Big\{&\left[P_{I,t}I_{G,t}-W_tH_{K,t}\right]\\
&-\Delta_{1,t}\left[I_{G,t}-A_tA_{K,t}H_{K,t}^{1-\alpha_K}\left(e_{K,t}K_{K,t-1}\right)^{\alpha_K}+I_{K,t}\left(1+\frac{\kappa_K}{2}\left(\frac{I_{K,t}}{I_{K,t-1}}-1\right)^2\right)\right]\\
&-\Delta_{2,t}\left[K_{K,t}-\left(1-\delta_{K1}-\delta_{K2}e_{K,t}^{1+\phi_K}\right)K_{K,t-1}-I_{K,t}\right]\Big\}
\end{aligned}
$$

First-order conditions.

$$
\begin{aligned}
\mathcal{L}_{I_{G,t}}:&\quad P_{I,t} = \Delta_{1,t} && \text{(A.35)}\\
\mathcal{L}_{H_{K;t}}:&\quad W_t = \Delta_{1,t}\left(1-\alpha_K\right)\frac{Y_{K,t}}{H_{K,t}} && \text{(A.36)}\\
\mathcal{L}_{I_{K,t}}:&\quad \Delta_{2,t} = \Delta_{1,t}\left[1+g_{IK,t}+g'_{IK,t}\right]-\mathbb{E}_t\beta_{t,t+1}\Delta_{1,t+1}g'_{IK,t+1}\frac{I_{K,t+1}}{I_{K,t}} && \text{(A.37)}\\
\mathcal{L}_{K_{K,t}}:&\quad \Delta_{2,t} = \mathbb{E}_t\beta_{t,t+1}\left[\Delta_{1,t+1}\alpha_K\frac{Y_{K,t+1}}{K_{K,t}}+\left(1-\delta_{K1}-\delta_{K2}e_{K,t+1}^{1+\phi_K}\right)\Delta_{2,t+1}\right] && \text{(A.38)}\\
\mathcal{L}_{e_{K,t}}:&\quad \Delta_{1,t}\alpha_K\frac{Y_{K,t}}{e_{K,t}} = \Delta_{2,t}\delta_{K2}\left(1+\phi_K\right)e_{K,t}^{\phi_K}K_{K,t-1} && \text{(A.39)}
\end{aligned}
$$

Define ...

$$w_t = P_{I,t}\left(1-\alpha_K\right)\frac{Y_{K,t}}{H_{K,t}} \tag{A.40}$$

$$Q_{K,t} = P_{I,t}\left[1+g_{IK,t}+g'_{IK,t}\right]-\mathbb{E}_t\frac{1+\pi_{t+1}}{1+r_t}g'_{IK,t+1}\frac{I_{K,t+1}}{I_{K,t}}Q_{K,t+1} \tag{A.41}$$

$$Q_{K,t} = \mathbb{E}_t\frac{1+\pi_{t+1}}{1+r_t}\left[P_{I,t+1}\alpha_K\frac{Y_{K,t+1}}{K_{K,t}}+\left(1-\delta_{K1}-\delta_{K2}e_{K,t+1}^{1+\phi_K}\right)Q_{K,t+1}\right] \tag{A.42}$$

$$P_{I,t}\alpha_K\frac{Y_{K,t}}{e_{K,t}} = Q_{K,t}\delta_{K2}\left(1+\phi_K\right)e_{K,t}^{\phi_K}K_{K,t-1} \tag{A.43}$$

Appendix B. Symmetric Model

Appendix B.1. FOCs and Constraints

The FOCs and constraints of the symmetric model follow the assumption that all firms have the same technology and all households the same preferences. We can therefore drop the firm indexes i of differentiated goods and the household indexes j of differentiated labor, as both are given by representative good and labor supply. The system of representative household FOCs (A.13)-(A.16) is given by

$$muc_t = \beta\mathbb{E}_t\frac{1+r_t}{1+\pi_{t+1}}muc_{t+1}, \tag{B.1}$$

$$muc_t = \left(1-g'_{D,t}\right)\mathbb{U}_{C,t}+\beta\left(1-\delta_C\right)\mathbb{E}_t g'_{D,t+1}\mathbb{U}_{C,t+1}, \tag{B.2}$$

$$\frac{\mu_H H_t^{\nu_H}}{muc_t} = \frac{w_t}{\eta}\left[\left(1-c_{W,t}\right)\left(\eta-1\right)+c'_{W,t}-\mathbb{E}_t\frac{1+\pi_{W,t+1}}{1+r_t}\frac{H_{t+1}}{H_t}c'_{W,t+1}\right], \tag{B.3}$$

where $\mathbb{U}_{C,t} = (C_t - g_{D,t})^{-\sigma}$, $g_{D,t} = \frac{\mu_D}{1+\nu_D} D_t^{1+\nu_D}$, and $g'_{D,t} = \frac{\mu_D D_t^{\nu_D}}{f_t}$. The system of representative goods firm FOCs (**??**)-(**??**) is given by

$$pr_t = \frac{1 + \mathbb{E}_t \frac{1+\pi_{t+1}}{1+r_t} \left[(1-\delta_C)(pr_{t+1} - mc_{t+1}) + \frac{1}{\epsilon} \frac{\gamma}{1-\gamma+\nu_D} \frac{q_t S_t}{C_t} \frac{1}{g'_{D,t}} (1-\delta_I) mc_{t+1} \right]}{1 + \frac{1}{\epsilon} \frac{\gamma}{1+\nu_D-\gamma} \frac{q_t S_t}{C_t} \frac{1}{g'_{D,t}}}, \tag{B.4}$$

$$mc_t = \frac{1}{1+c_{P,t}} \left[\frac{(1-\gamma)(1+\nu_D)}{1-\gamma+\nu_D} q_t pr_t + \mathbb{E}_t \frac{1+\pi_{t+1}}{1+r_t} (1-\delta_I) \left(1 - \frac{(1-\gamma)(1+\nu_D)}{1-\gamma+\nu_D} q_t \right) mc_{t+1} \right] \tag{B.5}$$

$$w_t = (1-\alpha_G) \frac{Y_{G,t}}{H_{G,t}} mc_t, \tag{B.6}$$

$$P_{I,t} = Q_{G,t} \left(1 - g_{IG,t} - g'_{IG,t}\right) + \mathbb{E}_t \frac{1+\pi_{t+1}}{1+r_t} g'_{IG,t+1} \frac{I_{G,t+1}}{I_{G,t}} Q_{G,t+1} \tag{B.7}$$

$$Q_{G,t} = \mathbb{E}_t \frac{1+\pi_{t+1}}{1+r_t} \left[\alpha_G \frac{Y_{G,t+1}}{K_{G,t}} mc_{t+1} + \left(1 - \delta_{G1} - \delta_{G2} e_{G,t+1}^{1+\phi_G}\right) Q_{G,t+1} \right] \tag{B.8}$$

$$e_{G,t} = \left[\frac{\alpha_G \frac{Y_{G,t}}{K_{G,t-1}} mc_t}{\delta_{G2} (1+\phi_G) Q_{G,t}} \right]^{\frac{1}{1+\phi_G}} \tag{B.9}$$

$$\begin{aligned} c'_{P,t} = {} & \frac{C_t}{S_t} \frac{1}{mc_t} - \frac{\gamma}{1-\gamma+\nu_D} q_t \frac{muc_t}{\mathbb{U}_{C,t} g'_{D,t}} \left(\frac{pr_t}{mc_t} - \mathbb{E}_t \frac{1+\pi_{t+1}}{1+r_t} (1-\delta_I) \frac{mc_{t+1}}{mc_t} \right) \\ & + \mathbb{E}_t \frac{1+\pi_{t+1}}{1+r_t} \frac{S_{t+1} mc_{t+1}}{S_t mc_t} c'_{P,t+1}. \end{aligned} \tag{B.10}$$

The system of representative capital firm FOCs ()-() is given by

$$w_t = P_{I,t} (1-\alpha_K) \frac{Y_{K,t}}{H_{K,t}}, \tag{B.11}$$

$$Q_{K,t} = P_{I,t} \left[1 + g_{IK,t} + g'_{IK,t}\right] - \mathbb{E}_t \frac{1+\pi_{t+1}}{1+r_t} P_{I,t+1} g'_{IK,t+1} \frac{I_{K,t+1}}{I_{K,t}} \tag{B.12}$$

$$Q_{K,t} = \mathbb{E}_t \frac{1+\pi_{t+1}}{1+r_t} \left[P_{I,t+1} \alpha_K \frac{Y_{K,t+1}}{K_{K,t}} + \left(1 - \delta_{K1} - \delta_{K2} e_{K,t+1}^{1+\phi_K}\right) Q_{K,t+1} \right] \tag{B.13}$$

$$e_{K,t} = \left(\frac{P_{I,t} \alpha_K \frac{Y_{K,t}}{K_{K,t-1}}}{\delta_{K2} (1+\phi_K) Q_{K,t}} \right)^{\frac{1}{1+\phi_K}} \tag{B.14}$$

Goods market matching (A.1)-(A.4) can be stated as

$$D_t = \frac{C_t - (1-\delta_C) C_{t-1}}{f_t} = \frac{C_t - (1-\delta_C) C_{t-1}}{\psi_t^{\frac{1}{\gamma}}} q_t^{\frac{1-\gamma}{\gamma}}, \tag{B.15}$$

$$C_t = (1-\delta_C) C_{t-1} + q_t S_t. \tag{B.16}$$

Labor market clearing is given by

$$H_t = H_{G,t} + H_{K,t}. \tag{B.17}$$

The resource constraint and production function of the goods firm are given by

$$S_t = \frac{1}{1+c_{P,t}}\left(A_t H_{G,t}^{1-\alpha_G}\left(e_{G,t}K_{G,t-1}\right)^{\alpha_G} - (1-\delta_C)\,C_{t-1} + (1-\delta_I)\,(1-q_{t-1})\,S_{t-1}\right), \tag{B.18}$$

$$Y_{G,t} = A_t H_t^{1-\alpha_G}\left(e_{G,t}K_{G,t-1}\right)^{\alpha_G}, \tag{B.19}$$

$$K_{G,t} = \left(1-\delta_{G1}-\delta_{G2}e_{G,t}^{1+\phi_G}\right)K_{G,t-1} + I_{G,t}\left(1-\frac{\kappa_G}{2}\left(\frac{I_{G,t}}{I_{G,t-1}}-1\right)^2\right) \tag{B.20}$$

The resource constraint and production function of the capital firm are given by

$$I_{G,t} = A_t A_{K,t} H_{K,t}^{1-\alpha_K}\left(e_{K,t}K_{K,t-1}\right)^{\alpha_K} - I_{K,t}\left(1+\frac{\kappa_K}{2}\left(\frac{I_{K,t}}{I_{K,t-1}}-1\right)^2\right) \tag{B.21}$$

$$Y_{K,t} = A_t A_{K,t} H_{K,t}^{1-\alpha_K}\left(e_{K,t}K_{K,t-1}\right)^{\alpha_K} \tag{B.22}$$

$$K_{K,t} = \left(1-\delta_{K1}-\delta_{K2}e_{K,t}^{1+\phi_K}\right)K_{K,t} + I_{K,t} \tag{B.23}$$

Appendix B.2. Steady-State

There is no deterministic growth in the steady-state. Therefore, I calculate the steady-state by dropping the time index and summarizing the equations of the model. I assume that the steady-state has zero inflation in prices and wages, hence $\pi = 1$, $\pi_W = 1$. It follows, that $c_P = c'_P = c_W = c'_W = 0$. Solving (B.1) for its steady-state results in

$$r = \frac{1}{\beta} - 1.$$

The definition of capacity utilization (5) in the steady-state is given by

$$cu = q.$$

In a zero inflation steady-state $c_P = c'_P = 0$, the Phillips curve reduces to

$$(1-\gamma+\nu_D)\,\frac{1}{mc} = \gamma\frac{1-g'_D}{g'_D}$$

Plugging the steady-state of (B.4) in and solving for g'_D results in

$$g'_D = \frac{\gamma}{1+\nu_D}\frac{\epsilon-1}{\epsilon}. \tag{B.24}$$

Plugging this solution back into (B.4) results in

$$mc \quad = \quad = \frac{1}{1+\frac{1+\nu_D}{(\epsilon-1)(1-\gamma+\nu_D)}}. \tag{B.25}$$

The resource constraint (B.16) in the steady-state is given by

$$C \quad = \quad q \cdot S \quad = \quad qAH^{1-\alpha}\bar{K}^{\alpha} \quad = \quad qH^{1-\alpha}. \tag{B.26}$$

Using the definition of g'_D and (B.15) determines

$$g'_D \quad = \quad \mu_D \frac{D^{\nu_D}}{f} \quad = \quad \mu_D C^{\nu_D} \left(\frac{q^{1-\gamma}}{\psi}\right)^{\frac{1+\nu_D}{\gamma}}. \tag{B.27}$$

Taking (B.24), (B.26), and (B.27) together and solving for

$$q \quad = \quad cu \quad = \quad \left[\frac{\frac{\gamma}{1+\nu_D}\frac{\epsilon-1}{\epsilon}\psi^{\frac{1+\nu_D}{\gamma}}}{\mu_D H^{\nu_D(1-\alpha)}}\right]^{\frac{1}{\nu_D+(1+\nu_D)\frac{1-\gamma}{\gamma}}}. \tag{B.28}$$

Setting (B.3) = (B.6) and substituting for (B.2) and (B.26) results in the labor market equilibrium

$$H \quad = \quad \left[\frac{(1-\gamma)(1-\gamma)}{1-\gamma+\nu_D}\frac{1-\alpha}{\mu_H}\frac{1-g'_D}{1-\frac{g'_D}{1+\nu_H}}mc\right]^{\frac{1}{1+\nu_H}}. \tag{B.29}$$

The system of (B.24)-(B.29) fully describes the steady-state of the model.

Appendix C. Simplified Symmetric Model: FOCs and Constraints

Using the definitions of $g_{D,t} = \frac{\mu_D}{1+\nu_D} D_t^{1+\nu_D}$, $g'_{D,t} = \frac{\mu_D D_t^{\nu_D}}{f_t}$, and (B.15) and plugging them into (B.2) leads to

$$muc_t \quad = \quad \frac{1-g'_{D,t}}{\left[\left(1-\frac{g'_{D,t}}{1+\nu_D}\right)C_t\right]^{\sigma}}. \tag{C.1}$$

Plugging (C.1) in (B.1) leads to

$$\left(\frac{C_{t+1}}{C_t}\right)^{\sigma} \quad = \quad \beta \mathbb{E}_t \frac{1+r_t}{1+\pi_{t+1}} \frac{1-g'_{D,t+1}}{1-g'_{D,t}} \left(\frac{1-\frac{g'_{D,t}}{1+\nu_D}}{1-\frac{g'_{D,t+1}}{1+\nu_D}}\right)^{\sigma}. \tag{C.2}$$

Real marginal household search costs are given by substituting for D_t with (B.15) in the definition of $g'_{D,t} = \frac{\mu_D D_t^{\nu_D}}{f_t}$:

$$g'_{D,t} \quad = \quad \mu_D C_t^{\nu_D} \left(\frac{q_t^{1-\gamma}}{\psi_t}\right)^{\frac{1+\nu_D}{\gamma}}. \tag{C.3}$$

Real marginal costs (B.4) are given by

$$mc_t = \frac{1}{1+\frac{1}{\epsilon}\frac{\gamma}{1-\gamma+\nu_D}\frac{1}{g'_{D,t}}}. \tag{C.4}$$

Substituting with (B.18) in (B.16) gives the resource constraint of the economy

$$C_t = \frac{q_t}{1+c_{P,t}} A_t H_{G,t}^{1-\alpha_G} \bar{K}_G^{\alpha_G}. \tag{C.5}$$

Assuming $\kappa_W = 0$, $\eta \to \infty$ (no sticky wages, default calibration), and setting (B.3)=(B.6) while using (C.5) to substitute for C_t gives the labor market equilibrium

$$H_t = \left[\frac{1-g'_{D,t}}{\left(1-\frac{g'_{D,t}}{1+\nu_D}\right)^{\sigma}} \frac{(1+\nu_D)(1-\gamma)}{1-\gamma+\nu_D} \frac{1-\alpha}{\mu_H} mc_t \left(\frac{q_t}{1+c_{P,t}} A_t \bar{K}_G^{\alpha_G}\right)^{1-\sigma} \right]^{\frac{1}{1+\nu_H+\alpha(1-\sigma)}}. \tag{C.6}$$

Substituting with (B.4) in (B.10) gives the New-Keynesian Phillips curve

$$\frac{c'_{P,t}}{1+c_{P,t}} = \frac{1}{1-\gamma}\left(1-\frac{\gamma}{1+\nu_D}\frac{\epsilon-1}{\epsilon}\frac{1}{g'_{D,t}}\right) + \mathbb{E}_t \frac{1+\pi_{t+1}}{1+r_t}\frac{C_{t+1}mc_{t+1}}{C_t mc_t}\frac{c'_{P,t+1}}{1+c_{P,t+1}}. \tag{C.7}$$

Linearizing (C.2)-(C.7) around their non-stochastic steady-state using first-order Taylor approximation leads to the dynamic system of the model presented in section 3.

Appendix C.1. Capacity Utilization Phillips Curve

The linearized system of the non-linear system (C.2)-(C.7) is given by

$$\hat{H}_{G,t} = \frac{1}{1+\nu_H+\alpha_G(1-\sigma)}\left(\hat{mc}_t - \Phi \hat{g}'_{D,t} + (1-\sigma)\left[\hat{q}_t + \hat{A}_t\right]\right), \tag{C.8}$$

$$\hat{mc}_t = \frac{1}{1+(\epsilon-1)\left(1-\frac{\gamma}{1+\nu_D}\right)}\hat{g}'_{D,t}, \tag{C.9}$$

$$\hat{C}_t = \hat{q}_t + \hat{A}_t + (1-\alpha_G)\hat{H}_{G,t}, \tag{C.10}$$

$$\hat{g}'_{D,t} = \nu_D \hat{C}_t + (1+\nu_D)\frac{1-\gamma}{\gamma}\hat{q}_t - \frac{1+\nu_D}{\gamma}\hat{\psi}_t, \tag{C.11}$$

$$\sigma\left(\mathbb{E}_t \hat{C}_{t+1} - \hat{C}_t\right) = \hat{r}_t - \mathbb{E}_t \hat{\pi}_{t+1} - \Phi\left(\mathbb{E}_t \hat{g}'_{D,t+1} - \hat{g}'_{D,t}\right), \tag{C.12}$$

$$\hat{\pi}_t = \frac{1}{\kappa(1-\gamma)}\hat{g}'_{D,t} + \hat{\xi}_t + \beta \mathbb{E}_t \hat{\pi}_{t+1}. \tag{C.13}$$

Solving (C.8)-(C.11) for $\hat{g}'_{D,t}$:

$$\hat{g}'_{D,t} = \frac{\left(\nu_D + (1+\nu_D)\frac{1-\gamma}{\gamma}\right)\hat{C}_t - (1+\nu_D)\frac{1-\gamma}{\gamma}\hat{A}_t - \frac{1+\nu_D}{\gamma}\hat{\psi}_t}{1+(1+\nu_D)\frac{1-\gamma}{\gamma}\varphi}, \tag{C.14}$$

where $\varphi = \frac{1-\alpha}{1+\nu_H}\left(\frac{1}{1+(\epsilon-1)\left(1-\frac{\gamma}{1+\nu_D}\right)} - \Phi\right)$. Plug (C.14) in (C.13) and using $\hat{C}_t = \hat{A}_t + \hat{cu}_t$ results in

$$\begin{aligned}\hat{\pi}_t &= \frac{1}{\kappa(1-\gamma)}\left(\frac{\nu_D + (1+\nu_D)\frac{1-\gamma}{\gamma}}{1+(1+\nu_D)\frac{1-\gamma}{\gamma}\varphi}\hat{cu}_t + \frac{\nu_D\hat{A}_t - \frac{1+\nu_D}{\gamma}\hat{\psi}_t}{1+(1+\nu_D)\frac{1-\gamma}{\gamma}\varphi}\right) + \hat{\xi}_t + \beta\mathbb{E}_t\hat{\pi}_{t+1}, \\ &= \frac{1}{\kappa(1-\gamma)}\frac{1}{\Omega+\varphi}\hat{cu}_t + \hat{\Theta}_t + \beta\mathbb{E}_t\hat{\pi}_{t+1},\end{aligned} \tag{C.15}$$

where $\Omega = \frac{1-\nu_D\varphi}{\nu_D+(1+\nu_D)\frac{1-\gamma}{\gamma}}$ and $\hat{\Theta}_t = \frac{1}{\kappa(1-\gamma)}\frac{\nu_D\hat{A}_t - \frac{1+\nu_D}{\gamma}\hat{\psi}_t}{1+(1+\nu_D)\frac{1-\gamma}{\gamma}\varphi} + \hat{\xi}_t$. (C.15) is called the "New-Keynesian Capacity Utilization Phillips Curve".

Appendix C.2. Output Gap Model

To derive the output gap model, we first have to derive the flexible price model, where I assume that $\kappa = 0$ and $\hat{\xi}_t = 0\forall t$. The model equations (C.12)-(C.14) are given for the flexible price model

$$\mathbb{E}_t\hat{C}^N_{t+1} - \hat{C}^N_t = \hat{r}^N_t - \Phi\left(\mathbb{E}_t\hat{g}'^N_{D,t+1} - \hat{g}'^N_{D,t}\right) \tag{C.16}$$

$$0 = \hat{g}'^N_{D,t} \tag{C.17}$$

$$\hat{C}^N_t = \frac{(1+\nu_D)\frac{1-\gamma}{\gamma}\hat{A}_t + \frac{1+\nu_D}{\gamma}\hat{\psi}_t}{\nu_D + (1+\nu_D)\frac{1-\gamma}{\gamma}} \tag{C.18}$$

It follows that for $\hat{cu}^N_t = \hat{C}^N_t - \hat{A}_t$ that

$$\hat{cu}^N_t = \left(\frac{(1+\nu_D)\frac{1-\gamma}{\gamma}}{\nu_D+(1+\nu_D)\frac{1-\gamma}{\gamma}} - 1\right)\hat{A}_t + \frac{\frac{1+\nu_D}{\gamma}}{\nu_D+(1+\nu_D)\frac{1-\gamma}{\gamma}}\hat{\psi}_t. \tag{C.19}$$

The gap variables are defined as e.g. $\tilde{C}_t = \hat{C}_t - \hat{C}_t^N$. The system of equations for the output gap model are given by

$$\mathbb{E}_t \tilde{C}_{t+1} - \tilde{C}_t = \tilde{r}_t - \mathbb{E}_t \hat{\pi}_{t+1} - \Phi \left(\tilde{g}'_{t+1} - \tilde{g}'_{D,t} \right) \tag{C.20}$$

$$\tilde{g}'_{D,t} = \frac{\nu_D + (1+\nu_D) \frac{1-\gamma}{\gamma}}{1 + (1+\nu_D) \frac{1-\gamma}{\gamma} \varphi} \tilde{C}_t \tag{C.21}$$

$$\hat{\pi}_t = \frac{1}{\kappa (1-\gamma)} \tilde{g}'_{D,t} + \hat{\xi}_t + \beta \mathbb{E}_t \hat{\pi}_{t+1}, \tag{C.22}$$

where $\tilde{cu}_t = \tilde{C}_t$ and $\hat{r}_t^N = \frac{(1+\nu_D)\frac{1-\gamma}{\gamma}(\rho_A - 1)\hat{A}_t + \frac{1+\nu_D}{\gamma}\left(\rho_\psi - 1\right)\hat{\psi}_t}{\nu_D + (1+\nu_D)\frac{1-\gamma}{\gamma}}$.

Appendix D. Data Description and Calibration

Appendix D.1. Data and Calibration Sources

I calibrate the model economy to replicate U.S. data from 1985 to 2019. Time is in quarters. I use the one-sided HP filter from Stock and Watson (1999) to detrend the data. In order to be consistent, I detrend the simulation output as well using the one-sided HP filter.

Appendix D.2. Data Construction

Phillips Curve Slope.. The convex price adjustment costs parameter κ is set endogenously to replicate a output gap Phillips curve slope of 0.1. This value of the Phillips curve slope follows from the Calvo (1983) approach to the New-Keynesian Phillips curve where firms adjust their prices roughly once every three quarters - the average of the interval of price adjustment frequency as calculated by Bils and Klenow (2004). I set all other parameters of the slope of the Phillips curve and calculate κ as the residual.

Capacity Utilization Rate.. To be able to calculate economy-wide capacity utilization rates, I follow a two-step approach. **First**, there is survey data for US industry capacity utilization as defined in section Appendix D.1. I adjust the data following Morin and Stevens (2004) from 1995q1 going forward by adding $4\% - point$ to account for a methodological break in the data.

Table D.5: Calibration of the Model and its Sources

Parameter	Description	Value	Source
μ_H	Labor Supply Disutility Level	1	Normalization
ν_H	Inverse Labor Supply Elasticity	1	Christiano et al. (2005)
α	Production Elasticity Capital	0	Constant-returns-to-scale
η	Labor input substitutability	21	Christiano et al. (2005)
κ_W	Wage-adjustment costs	120	Follows κ_P without goods market SAM.
τ_W	Household wage subsidies	*Endo*	Set to offset wage markups in steady-state.
γ	Demand elasticity w.r.t. matching	0.11	Bai et al. (2017)
ψ	Goods market matching efficiency	*Endo*	Set to target st.st. capacity utilization $\bar{cu} = 0.86$.
μ_D	Search effort disutility	*Endo*	Set to target $f = q$, as no data is available.
ν_D	Inverse search effort elasticity	0.1	Bai et al. (2017)
ϵ	Goods substitution elasticity	6	Christiano et al. (2005)
κ_P	Price adjustment costs	*Endo*	See data construction.
τ_P	Firm price Subsidies	*Endo*	Set to offset price markups in steady-state.
β	Period discount rate	0.9925	Christiano et al. (2005)
i_R	Intrest rate inertia	0.8	Smets and Wouters (2007)
i_π	Taylor coefficient w.r.t. inflation	1.5	Smets and Wouters (2007)
σ_A	Technology shock standard deviation	0.0045	Smets and Wouters (2007)
σ_P	Cost-push shock standard deviation	0.01	Set to match the std.dev. of GDP.
σ_M	Monetary Policy shock standard deviation	0.0024	Smets and Wouters (2007)
σ_E	SAM shock standard deviation	0.01	Set to match the std.dev. of GDP.
ρ_A	Technology shock autocorrelation	0.9	Smets and Wouters (2007)
ρ_P	Cost-push shock autocorrelation	0.8	Common value in the literature.
ρ_E	SAM shock autocorrelation	0.8	Common value in the literature.

Second, I construct an economy-wide capacity utilization rate for the US by using EU data to proxy for the capacity utilization rate of the service sector. Neglecting the argriculture, forestry, fishing, and hunting sector[11], economy-wide capacity utilization is given by

$$cu_t = \frac{GDP_t}{Y_t} = \frac{GDP_{ind,t} + GDP_{ser,t}}{Y_{ind,t} + Y_{ser,t}},$$

where variables with subscript "ind" represent industry sector variables and with subscript "ser" represent service sector variables. As we are interested in the cyclical deviations of

[11] There is no data on the capacity utilization of agriculture, forestry, fishing, and hunting sector. Also not for other economies similar to the US. As this sector comprises about 1% of the U.S. economy we neglect it in the analysis of economy-wide capacity utilization.

Table D.6: US Data Sources

Variable	FRED Code	Source
cu_{ind}	$[TCU]$	FRED database FED St Louis / U.S. Board of Governors of the FRS
$GDP_{real,ind}$	$[INDPRO]$	FRED database FED St Louis / U.S. Board of Governors of the FRS
$GDP_{real,ser}$	$GDPbyIndustry$	U.S. Bureau of Economic Analysis
GDP_{nom}	$[GDP]$	FRED database FED St Louis / U.S. Bureau of Economic Analysis
GDP_{real}	$[GDPC1]$	FRED database FED St Louis / U.S. Bureau of Economic Analysis
$CivilianPopulation$	$[CNP16OV]$	FRED database FED St Louis / U.S. Bureau of Labor Statistics
$TotalHours$	$[HOANBS]$	FRED database FED St Louis / U.S. Bureau of Labor Statistics
$Employees$	$[PAYEMS]$	FRED database FED St Louis / U.S. Bureau of Labor Statistics
$GDP_{real,potential}$	$[GDPPOT]$	FRED database FED St Louis / U.S. Congressional Budget Office
$Unemployment$	$[UNRATE]$	FRED database FED St Louis / U.S. Bureau of Labor Statistics
$Unemployment_{potential}$	$[NROU]$	FRED database FED St Louis / U.S. Congressional Budget Office

capacity utilization, I take a first-oder Taylor approximation around the non-stochastic steady of the economy-wide capacity utilization rate given by

$$\hat{cu}_t \quad = \quad \frac{GDP_{ind}}{Y}G\hat{D}P_{ind,t} + \frac{GDP_{ser}}{Y}G\hat{D}P_{ser,t} - \frac{GDP}{Y^2}\left(Y_{ind}\hat{Y}_{ind,t} + Y_{ser}\hat{Y}_{ser,t}\right),$$

where variables without a time subscript represent the non-stochastic steady-state. Sector-specific production capacity $\hat{Y}_{ind,t}$ and $\hat{Y}_{ser,t}$ can be approximated by sector capacity utilization rates and sector real GDP given by

$$\begin{aligned}
\hat{cu}_{ind,t} &= cu_{ind}\left(G\hat{D}P_{ind,t} - \hat{Y}_{ind,t}\right) \quad \Leftrightarrow \quad \hat{Y}_{ind,t} = G\hat{D}P_{ind,t} - \frac{\hat{cu}_{ind,t}}{cu_{ind}}, \\
\hat{cu}_{ser,t} &= cu_{ser}\left(G\hat{D}P_{ser,t} - \hat{Y}_{ser,t}\right) \quad \Leftrightarrow \quad \hat{Y}_{ser,t} = G\hat{D}P_{ser,t} - \frac{\hat{cu}_{ser,t}}{cu_{ser}},
\end{aligned}$$

where capacity utilization is given as percentage point deviation from its non-stochastic steady-state. Using those definitions to substitute for sector-specific production capacity, the economy-wide capacity utilization is given by

$$\begin{aligned}
\hat{cu}_t \quad = \quad & cu\frac{GDP_{ind}}{GDP}\left(1 - \frac{cu}{cu_{ind}}\right)G\hat{D}P_{ind,t} + cu\frac{GDP_{ser}}{GDP}\left(1 - \frac{cu}{cu_{ser}}\right)G\hat{D}P_{ser,t} \\
& + \frac{GDP_{ind}}{GDP}\left(\frac{cu}{cu_{ind}}\right)^2 \hat{cu}_{ind,t} + \frac{GDP_{ser}}{GDP}\left(\frac{cu}{cu_{ser}}\right)^2 \hat{cu}_{ser,t},
\end{aligned}$$

where we have reduced the number of unknowns to the non-stochastic steady-states of GDP_{ser}, cu, and cu_{ser} and to the cyclical fluctuations of $GDP_{ser,t}$, and $\hat{cu}_{ser,t}$. Service-sector

Table D.7: EU Data Sources

Variable	Code	Source
cu_{ind}		Business and consumer surveys. European commission
cu_{ser}		Business and consumer surveys. European commission
$GDP_{real,ind}$	$NAMQ\_10\_A10$	Eurostat
$GDP_{real,ser}$	$NAMQ\_10\_A10$	Eurostat
GDP_{nom}	$NAMA\_10\_GDP$	Eurostat
GDP_{real}	$NAMA\_10\_GDP$	Eurostat
$TotalHours_{ind}$	$NAMQ\_10\_A10\_E$	Eurostat
$TotalHours_{ser}$	$NAMQ\_10\_A10\_E$	Eurostat
$Employees_{ind}$	$NAMQ\_10\_A10\_E$	Eurostat
$Employees_{ser}$	$NAMQ\_10\_A10\_E$	Eurostat

GDP can be calculated by substracting industry-sector GDP (Board of Governors of the Federal Reserve System (US), Industrial Production: Total Index [IPB50001SQ]) from real GDP. For service-sector capacity utilization we only have indirect approximations. For the European Union there is survey data for service-sector capacity utilization. I use the data to approximate service-sector capacity utilization using industry-sector capacity utilization as the correlations between both sector-specific real GDP and sector-specific capacity utilization is very high for the European Union. I approximate U.S. service-sector capacity utilization by U.S. industry-sector capacity utilization using the relative standard deviation of EU service-sector to industry-sector capacity utilization as the slope. Therefore, U.S. service-sector capacity utilization is approximated by

$$\hat{cu}_{serUS,t} = \frac{std(\hat{cu}_{serEU,t})}{std(\hat{cu}_{indEU,t})}\hat{cu}_{indUS,t} = \gamma_{CU,EU}\hat{cu}_{indUS,t},$$

where $\gamma_{CU,EU}$ is the slope parameter of the approximation equation. Plugging everything back into the economy-wide capacity utilization measure, we get

$$\begin{aligned}\hat{cu}_t &= cu\left[\left(1-\frac{cu}{cu_{ser}}\right)\hat{GDP}_t + \frac{GDP_{ind}}{GDP}\left(\frac{cu}{cu_{ser}}-\frac{cu}{cu_{ind}}\right)\hat{GDP}_{ind,t}\right] \\ &\quad + \left[\frac{GDP_{ind}}{GDP}\left(\frac{cu}{cu_{ind}}\right)^2 + \left(1-\frac{GDP_{ind}}{GDP}\right)\left(\frac{cu}{cu_{ser}}\right)^2\gamma_{CU,EU}\right]\hat{cu}_{ind,t}.\end{aligned}$$

Appendix E. Dynamics of the Model and the Output Gap Model

Appendix E.1. Proof Proposition 1

Proof.

$$\begin{aligned} mc &= \frac{\epsilon - 1}{\epsilon} \\ H &= \left(\frac{1-\alpha}{\mu_H} mc\right)^{\frac{1}{1+\nu_H}} \\ cu &= \psi \\ C &= H^{1-\alpha} cu \end{aligned}$$

If we set $\psi = 1$, then:

$$C = \left(\frac{1-\alpha}{\mu_H}\frac{\epsilon - 1}{\epsilon}\right)^{\frac{1-\alpha}{1+\nu_H}}$$

□

Appendix E.2. Proof Proposition 3

Proof. Setting $\gamma = 0$ makes goods market matching completely supply driven. This leaves shopping effort D_t undetermined, thus I set $D_t = 1 \forall t$. The model reduces to a one-sided search-and-matching model. If the goods matching function is constant-returns-to-scale, the goods matching function and real GDP become a linear function of available production capacity. While the goods market matching efficiency ψ determines steady state capacity utilization, it does not impact its fluctuations. Normalizing $\psi = 1$, we return to the textbook New-Keynesian model both in steady-state and business cycle fluctuations as search and matching on the goods market drops out. It is given by

$$\begin{aligned} \mathbb{E}_t \tilde{C}_{t+1} &= \left(\hat{r}_t - \hat{r}_t^N - \mathbb{E}_t \hat{\pi}_{t+1}\right) + \tilde{C}_t, \\ \hat{\pi}_t &= \frac{\epsilon}{\kappa_P}\frac{1+\nu_H}{1-\alpha}\tilde{C}_t + \hat{\xi}_t + \beta \mathbb{E}_t \hat{\pi}_{t+1}, \\ \hat{r}_t &= i_r \hat{r}_{t-1} + (1 - i_r)\left[i_\pi \hat{\pi}_t + i_{gdp} \hat{C}_t\right] + \hat{M}_t, \end{aligned}$$

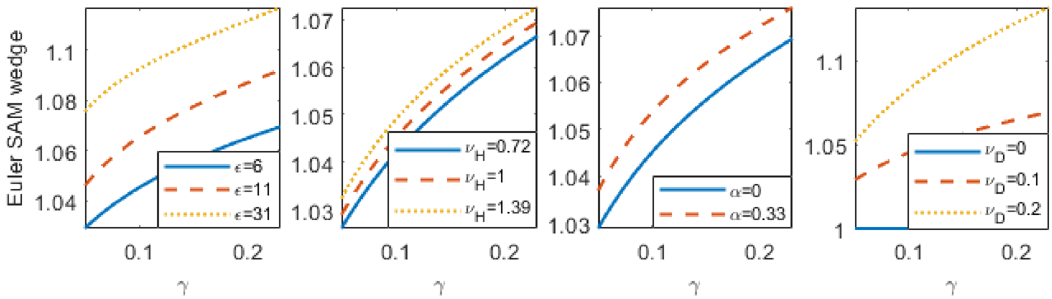
where the parameters defining the dynamic IS equation reduce to one and the slope parameter of the Phillips curve reduces to a textbook New-Keynesian version as e.g. in Ireland (2004); Gali (2015). Fluctuations in the natural interest rate are given by

$$\hat{r}_t^N \quad = \quad (-1)\Theta_A\,(1-\rho_A)\,A_t,$$

where all search and matching shocks drop out. □

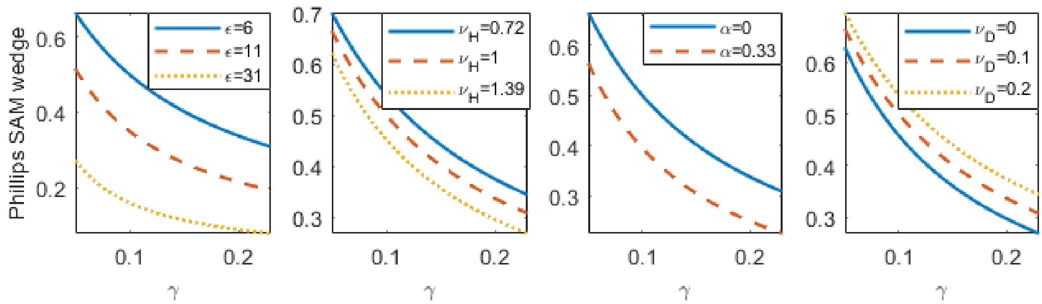
Appendix F. Robustness of the SAM wedges

Figure F.6: The Impact of Search and Matching on the Euler Equation



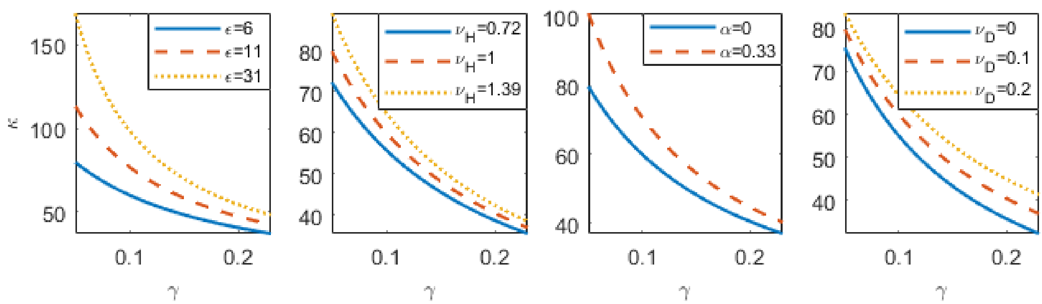
NOTE: The figure shows the Euler SAM wedge on the y-axis, which is defined as the difference in the Euler equation slope between the model presented in this paper and a textbook New-Keynesian model. The x-axis shows the demand elasticity of goods market matching γ. There are four sub-figures showing additionally different values for the main parameters of the model. The first sub-figure shows different values for the substitutability of differentiated goods ϵ. The second sub-figure shows different values of the inverse of labor supply elasticity ν_H. The third sub-figure shows different values of the production elasticity α. And the fourth sub-figure shows different values of the inverse of search effort supply elasticity ν_D.

Figure F.7: The Impact of Search and Matching on the Phillips Curve



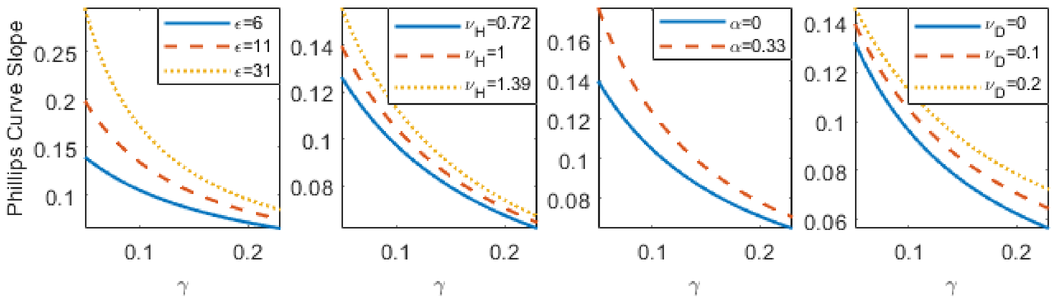
NOTE: The figure shows the Phillips SAM wedge on the y-axis, which is defined as the difference in the Phillips curve slope between the model presented in this paper and a textbook New-Keynesian model. The x-axis shows the demand elasticity of goods market matching γ. There are four sub-figures showing additionally different values for the main parameters of the model. The first sub-figure shows different values for the substitutability of differentiated goods ϵ. The second sub-figure shows different values of the inverse of labor supply elasticity ν_H. The third sub-figure shows different values of the production elasticity α. And the fourth sub-figure shows different values of the inverse of search effort supply elasticity ν_D.

Figure F.8: The Impact of Search and Matching on κ when the Slope is fixed



NOTE: The figure shows the price adjustment costs parameter κ for a fixed Phillips curve slope of 0.1 on the y-axis. The x-axis shows the demand elasticity of goods market matching γ. There are four sub-figures showing additionally different values for the main parameters of the model. The first sub-figure shows different values for the substitutability of differentiated goods ϵ. The second sub-figure shows different values of the inverse of labor supply elasticity ν_H. The third sub-figure shows different values of the production elasticity α. And the fourth sub-figure shows different values of the inverse of search effort supply elasticity ν_D.

Figure F.9: The Impact of Search and Matching on κ when the Slope is fixed



NOTE: The figure shows the slope of the Phillips curve on the y-axis. The x-axis shows the demand elasticity of goods market matching γ. There are four sub-figures showing additionally different values for the main parameters of the model. The first sub-figure shows different values for the substitutability of differentiated goods ϵ. The second sub-figure shows different values of the inverse of labor supply elasticity ν_H. The third sub-figure shows different values of the production elasticity α. And the fourth sub-figure shows different values of the inverse of search effort supply elasticity ν_D.

Appendix G. Capacity Utilization and the Business Cycle

Appendix G.1. Determinants of Capacity Utilization

Table G.8: Second Moments EU-27 Data

	Rel.Std.Dev.	Correlations				
		GDP	cu	H	q	π
GDP	1.00	1	0.84	0.92	0.53	0.23
cu	0.75	–	1	0.69	0.87	0.26
H	0.84	–	–	1	0.32	0.05
q	0.60	–	–	–	1	0.35
π	0.13	–	–	–	–	1

NOTE: The data is retrived from the FRED database of the FED St. Louis. Time is in quarters and covers 1996q1 to 2019q4. All time series are de-trended using a one-sided HP filter. Further details can be found in appendix Appendix D.

Figure G.10: IRFs for the model economy with default calibration and $\gamma = 0.23$

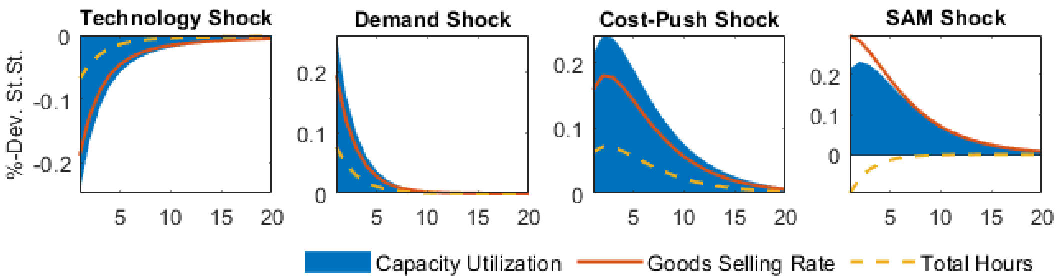
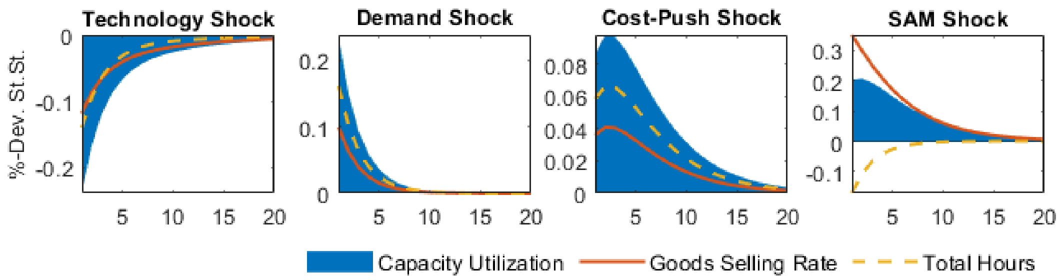


Figure G.11: IRFs for the model economy with default calibration and $\nu_D = 1.00$



NOTE: The figure shows impulse response functions to the shocks of the model economy. All shocks are expansionary. The blue areas show the impulse response of capacity utilization. It is the sum of the impulse responses of the goods selling rate shown by the solid orange curves and the impulse responses of total hours shown by the dashed yellow curves.

Table G.9: Second moments for the default calibration: Varying Parameters

	$\gamma = 0.23$							$\hat{\psi}_t = 0 \forall t$						
	RStd	Correlations						RStd	Correlations					
		GDP	cu	H	q	π	mc		GDP	cu	H	q	π	mc
GDP	1.00	1	0.84	0.70	0.82	0.34	0.70	1.00	1	0.81	0.81	0.81	0.60	0.81
cu	0.76	–	1	0.84	0.98	0.50	0.84	0.75	–	1	1	1	0.83	1
H	0.23	–	–	1	0.73	0.66	1.00	0.38	–	–	1	1	0.83	1
q	0.61	–	–	–	1	0.41	0.73	0.42	–	–	–	1	0.83	1
π	0.24	–	–	–	–	1	0.66	0.23	–	–	–	–	1	0.83
mc	0.51	–	–	–	–	–	1	0.80	–	–	–	–	–	1

NOTE: The second moments are computed by simulating the model economy for 20000 periods with 20 repetitions. I de-trend all results with a one-sided HP filter to be methodologically consistent with the data computations. *RStd* describes the standard deviation of a variable relative to GDP, hence $RStd = \frac{std(Variable)}{std(GDP)}$. *Correlations* shows the contemporaneous correlation of different model variables.

Figure G.12: IRFs for the model economy with sticky wages calibration and $\gamma = 0.23$

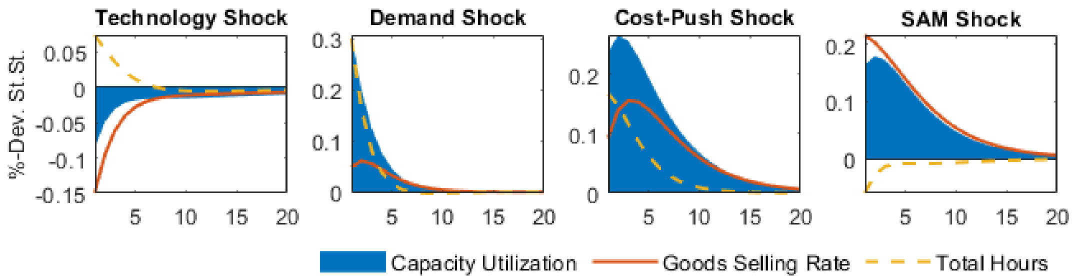
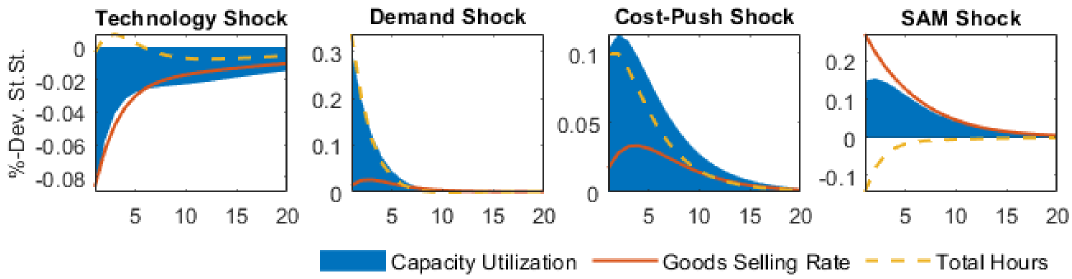


Figure G.13: IRFs for the model economy with sticky wages calibration and $\nu_D = 1.00$



NOTE: The figure shows impulse response functions to the shocks of the model economy with the sticky wages calibration ($\kappa_W = 120, \eta = 21$). All shocks are expansionary. The blue areas show the impulse response of capacity utilization. It is the sum of the impulse responses of the goods selling rate shown by the solid orange curves and the impulse responses of total hours shown by the dashed yellow curves.

Table G.10: Second moments for the sticky wages calibration: Varying Parameters

	$\gamma = 0.23$							$\hat{\psi}_t = 0 \forall t$						
	RStd	Correlations						RStd	Correlations					
		GDP	cu	H	q	π	mc		GDP	cu	H	q	π	mc
GDP	1.00	1	0.88	0.85	0.55	0.19	0.41	1.00	1	0.86	0.89	0.49	0.46	0.53
cu	0.77	–	1	0.90	0.73	0.35	0.58	0.76	–	1	0.98	0.75	0.69	0.78
H	0.66	–	–	1	0.36	0.45	0.54	0.74	–	–	1	0.61	0.65	0.64
q	0.37	–	–	–	1	0.05	0.40	0.19	–	–	–	1	0.63	1
π	0.18	–	–	–	–	1	0.46	0.16	–	–	–	–	1	0.63
mc	0.29	–	–	–	–	–	1	0.36	–	–	–	–	–	1

NOTE: The second moments are computed by simulating the model economy with sticky wages ($\kappa_W = 120, \eta = 21$) for 20000 periods with 20 repetitions. I de-trend all results with a one-sided HP filter to be methodologically consistent with the data computations. *RStd* describes the standard deviation of a variable relative to GDP, hence $RStd = \frac{std(Variable)}{std(GDP)}$. *Correlations* shows the contemporaneous correlation of different model variables.