

Röhe, Oke; Stähler, Nikolai

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Backing the right horse: Entry versus fixed costs subsidies

Oke Röhe^a, Nikolai Stähler^a

^a*Deutsche Bundesbank, Frankfurt am Main, Germany.*

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Abstract

This paper provides a tractable dynamic stochastic general equilibrium framework with endogenous firm creation and destruction and variable technology utilization to analyze the macroeconomic impact of entry costs and fixed cost subsidies. Based on this setup, we revisit empirical and theoretical evidence on the macroeconomic effects of competition-enhancing industrial policies to shed light on the causes of the in part ambiguous results found in the literature. Our simulations confirm the findings of a potentially beneficial impact of both entry costs and fixed cost subsidies on output and employment. The welfare effects, however, turn out to be less clear cut and critically depend on the relative importance of several channels. In particular, our findings highlight the key role of business dynamism and its implications for productivity in determining the welfare effects of the respective policy measures. Our results therefore illustrate the importance of considering sector-specific characteristics in the context of competitive-friendly industrial policies.

Keywords: Industrial policies, Endogenous firm dynamics , Technology utilization, DSGE models

JEL Classification H25, L52, E20, E62, L10, O30

1 Introduction

Over the recent decade many advanced countries have witnessed a noticeable slowdown in productivity growth. While part of the development has been associated with cyclical effects primarily related to the impact of the Great Recession, the sustained slowdown preceding the global financial and economic crisis contradicts causal stories from the recession itself pointing to longer-standing structural impediments (see, e.g., Byrne et al., 2013; Fernald, 2014). Against this background, the implementation of government measures aiming at fostering productivity growth have become a central issue in the policy debates with interventions to increase firm dynamics and competition in product markets as a key policy option (see, e.g., International Monetary Fund, 2016; OECD, 2018; World Bank, 2018). Besides structural reforms in the form of product market deregulation this encompasses also industrial policies targeted to promote business churn and market efficiency. Prominent examples in this respect include subsidies that reduce the entry costs faced by potential entrants as well as government aid to lower the operating costs of incumbent firms. Although such policies represent established standard instruments of industrial policy, their macroeconomic implications are still controversial.

While some studies generally emphasize the beneficial effects competition-enhancing industrial policies, including both the promotion of market entry and the support of incumbent firms (see, e.g., Dunne et al., 2013; Aghion et al., 2015), other analysis conclude that reductions in fixed operational costs can have negative macroeconomic consequences (see, e.g. Felbermayr and Prat, 2011; Hamano and Zanetti, 2017) or even fundamentally question the usefulness of subsidy policies at all (see, e.g. Acemoglu et al., 2018). Besides neglected general equilibrium effects, a main reason for this contradictory results can be attributed to the host of possible direct and indirect transmission channels of competition-enhancing policies, which, when considered in isolation, may lead to significant different conclusions about their economic implications.

The contribution of this paper is to provide a tractable dynamic stochastic general equilibrium (DSGE) framework which allows to study the macroeconomic effects of entry and fixed costs subsidies taking into account the role of prominent potential transmission mechanisms highlighted in the recent literature. These include the attenuation of product market distortions stemming from increased price competition as well as beneficial effects on productivity stemming from increased business churning (i.e. firm entry and exit). The core of our analytical framework is a flexible price

model of the business cycle with labor market frictions. To that core we add endogenous firm creation and destruction as well as variable technology utilization. Based on this setup we revisit empirical and theoretical evidence on the macroeconomic effects of competition-friendly industrial policies shedding light on the causes of the in part ambiguous results found in the literature.

Our simulations confirm the findings of a potentially beneficial impact of both entry costs and fixed cost subsidies on output and employment. The welfare implications, however, turn out to be less clear cut. While our model is able to capture both, the frequently addressed effects of business dynamism on productivity (Syverson, 2011; Decker et al., 2017, 2018) as well as the effects of increased competition on product market frictions and profitability (Jaimovich and Floetotto, 2008; Cacciatore and Fiori, 2016) it is the relative importance of these channels determining the welfare effects of the respective policy measures. Moreover, our results show that market dynamics of business destruction (firm exit) play a critical role for the welfare assessment. Therefore, our findings illustrate the importance of considering sector-specific characteristics in the context of competitive-friendly industrial policies.

Our paper is linked to a number of different literatures. First, it is related to a range of studies investigating the economic effects of entry and/or fixed costs subsidies (see, e.g., Dunne et al., 2013; Pflüger and Suedekum, 2013; Aghion et al., 2015; Hamano and Zanetti, 2017; Acemoglu et al., 2018). Taking into account general equilibrium effects, we thereby explicitly focus on the welfare effects of competition-enhancing subsidy policies illustrating the role of various transmission mechanisms discussed in the literature.

Second, our analysis adds to a vast literature dealing with the productivity-enhancing effects of business dynamism. This encompasses work primarily focussing on the (Schumpeterian) aspect of allocative efficiency (see, e.g., Baily et al., 1992; Foster et al., 2001, 2006), studies dealing with the interrelation of competition and innovation (see, e.g. Arrow, 1962; Schmidt, 1997; Porter, 1990, 2001; Syverson, 2004; Goolsbee and Syverson, 2008; Aghion et al., 2009; Bloom and Van Reenen, 2010; Griffith et al., 2010; Aghion et al., 2015) highlighting that the process of technology utilization is positively related to the degree of competition, and analyses emphasizing the productivity gains directly stemming from the increase in new firms operating closer to the technology frontier than incumbents (see, e.g., Caballero and Hammour, 1994; Jensen et al., 2001; Huergo and Jaumandreu, 2004; Balasubramanian and Lee, 2008; Coad et al., 2016; Acemoglu et al., 2018). Rather than limiting our view on a specific impact channel, we

provide a simple and tractable specification linking the degree of business dynamism to aggregate productivity.

Moreover, our analysis is related to the literature on technology adoption and utilization (see, e.g. Cohen and Levinthal, 1990; Parente and Prescott, 1994; Parente, 1995; Comin and Gertler, 2006; Bianchi et al., 2018) which points out the relevance of firms' absorptive capacity for assessing the impact of technology change on output and employment. We thereby focus on the effects of business churn on the process of technology adoption.

Finally, we contribute to a recent strand of literature emphasizing the role of endogenous entry (see, e.g., Jaimovich, 2007; Jaimovich and Floetotto, 2008; Bilbiie et al., 2012; Lewis and Poilly, 2012) and endogenous exit (see, e.g., Cavallari, 2015; Hamano and Zanetti, 2017; Casares et al., 2018) as an important propagation mechanism in DSGE models.

The rest of the paper is organized as follows. Section 2 presents the theoretical setup. Section 3 describes the calibration of the model. Section 4 discusses the results obtained under the respective subsidy policies thereby highlighting the relative importance of the various transmission channels. Section 6 performs sensitivity analysis. Section 7 concludes with the summary of the most relevant findings of the paper. Technical details concerning the theoretical setup are shown in the appendices.

2 The Model

2.1 Overview

The theoretical framework consists of a closed-economy flexible-price model of the business cycle featuring endogenous entry and exit of firms as well as a frictional labor market. Following Jaimovich (2007) and Jaimovich and Floetotto (2008), the model economy contains a large number of industries, each comprising a limited number of monopolistically competitive firms. Within a given industry, the price-elasticity of demand perceived by a firm depends on the number of competitors leading to endogenous markup variations. Facing fixed costs in production, each firm produces a unique intermediate good using aggregate technology, capital, and labor services. While capital is rented from households and labor services are provided by perfectly competitive labor firms, technology is common to all firms and composed of both a stationary and a permanent component. However, in line with analyses focussing on technology adop-

tion and utilization (see, e.g. Cohen and Levinthal, 1990; Parente and Prescott, 1994; Parente, 1995; Comin and Gertler, 2006; Bianchi et al., 2018), the impact of technology change on output depends on the absorptive capacity of the firms. Specifically, we draw on the literature on the interrelationship between business dynamism and productivity and assume that technology utilization is positively related to the intensity of the churning process.

Labor relations between households and labor firms are determined according to a standard Mortensen and Pissarides (1999) framework. Households supply capital and labor and use their funds for the consumption of a composite of industry goods and investment purposes. Specifically, there are two types of investment: investment in physical capital and investment in new firms with the latter incurring sunk entry cost (as in Ghironi and Melitz (2005) and Bilbiie et al. (2012), amongst other). Endogenous firm exit is determined by a stochastic exit value (see, e.g., Moscoso Boedo and Mukoyama, 2012; Cavallari, 2015; Lee and Mukoyama, 2018). Government spending (whether for unemployment benefits or entry and fixed cost subsidies) is financed by lump-sum taxes.

2.2 Households

The model economy features a representative household with continuum of infinitely living members along a unit interval. In equilibrium, some household members are employed, while some others are unemployed and seek for jobs. By adopting the family construct of Merz (1995) and Andolfatto (1996), we assume full consumption insurance between employed and unemployed individuals, so that there is no ex-post heterogeneity across the household members.

The representative household maximizes the stream of expected utility,

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

by choosing a sequence of consumption and investment, where $0 < \beta < 1$ is the subjective discount factor. Specifically, the household's instantaneous utility function is given by

$$U(C_t, H_t) = \ln(C_t) - \zeta \frac{H_t^{1+\chi}}{1+\chi}, \quad (2)$$

where $\zeta > 0$ measures the disutility of labor and $\chi \geq 0$ represents the inverse of the

Frisch labor supply elasticity.

Normalizing the labor force to one, H_t denotes both the number of employed individuals and the employment rate, while $U_t = 1 - H_t$ represents the number of unemployed job-seekers or the unemployment rate. When employed, household members are paid a nominal wage W_t by the representative labor firm. Unemployed household member, in contrast, receive unemployment benefits $\kappa_t^B P_t$, where P_t denotes the aggregate price index and κ_t^B represents real premium benefits which are indexed by time to ensure stationarity. Specifically, we have $\kappa_t^B = \kappa^B A_t$, with $\kappa^B > 0$ being a constant and A_t denoting the level of non-stationary technology. Wages, employment, and unemployment are determined on the labor market, while unemployment benefits are assumed to be an exogenous payment by the government.

During period t the household further receives $R_t K_{t-1}$ nominal factor payments from supplying K_{t-1} units of capital to the intermediate goods producing firms, where R_t denotes nominal rental rate for capital, and nominal profits from the ownership of firms. The profits Π_t can be splittend into

$$\Pi_t = \Pi_t^L + N_t \Pi_t^G, \quad (3)$$

where Π_t^L arises from the representative labor firm, while Π_t^G is distributed by each of the N_t intermediate goods producing firms.

The household uses its funds net of lump-sum taxes, T_t , to purchase a composite industry good Y_t from the final goods sector at price P_t , which can be used for consumption C_t or investment purposes. Specifically, the household faces two types of investment decisions: investment in its physical capital stock I_t and investment in new firms N_t^e . While the capital accumulation process is given by

$$K_t = (1 - \delta_K) K_{t-1} + I_t, \quad (4)$$

with $0 < \delta_K < 1$ denoting the rate of depreciation, the firm dynamics are characterized by the following law of motion:

$$N_t = (1 - \delta_{n,t}) N_{t-1} + N_t^e, \quad (5)$$

where $0 < \delta_{n,t} < 1$ represents an endogenous rate of firm exit. Hence, the real budget

constraint of the representative household is given by

$$C_t + I_t + v_t N_t^e \leq \frac{W_t}{P_t} H_t + \kappa_t^B U_t + \frac{R_t}{P_t} K_{t-1} + \frac{\Pi_t}{P_t} - T_t, \quad (6)$$

where v_t denotes the real firm value.

2.3 Firms

2.3.1 Sector Level

In line with Jaimovich (2007) and Jaimovich and Floetotto (2008), the final good Y_t is produced by a perfectly competitive representative firm, which aggregates a measure one continuum of industry goods $Q_t(j)$ according to the constant elasticity of substitution (CES) technology

$$Y_t = \left[\int_0^1 Q_t(j)^\omega dj \right]^{\frac{1}{\omega}}, \quad (7)$$

where $0 < \omega < 1$ determines the elasticity of substitution between industry goods $Q_t(j)$. Letting $P_t(j)$ denoting the price index of industry j in period t , the following demand function for industry goods is obtained from the profit maximization problem of a representative final goods producing firm:

$$Q_t(j) = \left[\frac{P_t(j)}{P_t} \right]^{\frac{1}{\omega-1}} Y_t, \quad (8)$$

where the price of the final output is given by

$$P_t = \left[\int_0^1 P_t(j)^{\frac{\omega}{\omega-1}} dj \right]^{\frac{\omega-1}{\omega}}. \quad (9)$$

2.3.2 Industry Level

Within each industry j , there is a mass $N_t(j)$ of firms, each producing one differentiated intermediate good. The intermediate goods are bundled into an industry good $Q_t(j)$ according to the CES aggregating function:

$$Q_t(j) = N_t(j)^{1-\frac{1}{\tau}} \left[\sum_{i=1}^{N_t(j)} x_t(j, i)^\tau \right]^{\frac{1}{\tau}}, \quad (10)$$

where $x_t(j, i)$ denotes the output of intermediate goods producing firm i in industry j in period t and $0 < \tau < 1$ determines the elasticity of substitution between the intermediate goods.

Given the demand function for industry goods (8), static profit maximization yields the following demand for intermediate good $x_t(j, i)$:

$$x_t(j, i) = \left[\frac{p_t(j, i)}{P_t(j)} \right]^{\frac{1}{\tau-1}} \frac{Q_t(j)}{N_t(j)}, \quad (11)$$

where $p_t(j, i)$ denotes the period t output price of firm i in industry j .

2.3.3 Firm Level

Using labor services $lab_t(j, i)$ and capital $k_{t-1}(j, i)$, each intermediate good is produced by a single monopolistically competitive firm having access to the increasing-returns-to-scale technology

$$x_t(j, i) \leq k_{t-1}(j, i)^\alpha [\Gamma_t(j, i) lab_t(j, i)]^{1-\alpha} - \phi(1 - sub_f) A_t, \quad (12)$$

where $\phi > 0$ denotes operating fixed costs of production, sub_f is a fixed costs subsidy, $1 > \alpha > 0$ represents the elasticity of output with respect to capital, and $\Gamma_t(j, i)$ captures the level of utilized technology. As regards the absorptive capacity of the firm, we draw on the literature on business dynamism, allowing for productivity gains stemming from the increased business churn which is usually defined as the sum of entry and exit rates (Add lit.). Specifically, we allow for productivity gains directly stemming from the increase in firm entry and exit rates and assume that the utilization process is governed by the functional relationship

$$\Gamma_t(j, i) = z_t A_t u_t^a(j, i) \quad (13)$$

with $u_t^a(j, i) = \kappa^u(j, i) \left(\frac{N_t^e}{N_t} + \delta_{n,t} \right)^{\rho_N}$, where $\kappa^u(j, i) > 0$ is a firm specific scale parameter and $\rho_N = \hat{\rho}_N / (1 - \alpha)$ with $0 \leq \hat{\rho}_N < 1$.

The stationary component of technology z_t evolves according to the autoregressive process

$$\ln(z_t) = \rho_z \ln(z_{t-1}) + \varepsilon_{zt} \quad (14)$$

with $1 > \rho_z > 0$ and $\varepsilon_{zt} \sim N(0, \sigma_z^2)$. Following Parente and Prescott (1994), Fang

(2017), and Casares et al. (2018), the non-stationary technology component is treated as an exogenous process, representing the evolution of the worldwide technology frontier. Specifically, we define the productivity shock A_t as a random walk with drift of the form

$$\ln(A_t) = \ln(A_{t-1}) + \ln(g_t^a), \quad (15)$$

where $g_t^a = \frac{A_t}{A_{t-1}}$ evolves according to the stationary process

$$\ln(g_t^a) = (1 - \rho_a) \ln(g^a) + \rho_a \ln(g_{t-1}^a) + \varepsilon_{at} \quad (16)$$

with $0 < \rho_a < 1$, $g^a > 0$, and $\varepsilon_{at} \sim N(0, \sigma_a^2)$.

In every period an intermediate goods producer chooses $lab_t(j, i)$, $k_{t-1}(j, i)$, and $p_t(j, i)$ to maximize its profits

$$\Pi_t^G(j, i) = p_t(j, i)x_t(j, i) - P_{L,t}lab_t(j, i) - R_tk_{t-1}(j, i) \quad (17)$$

subject to the production technology (12) and the demand for industry (8) and intermediate goods (11).

While each firm exerts some market power, it acts as a price taker in the factor markets with factor prices for labor services and capital given by $P_{L,t}$ and R_t . Cost minimization leads to the standard first order conditions for labor services and capital:

$$P_{L,t} = \varphi_t(j, i) \left\{ (1 - \alpha)k_{t-1}(j, i)^\alpha [\Gamma_t(j, i)lab_t(j, i)]^{-\alpha} \Gamma_t(j, i) \right\}, \quad (18)$$

$$R_t = \varphi_t(j, i) \left\{ \alpha k_{t-1}(j, i)^{\alpha-1} [\Gamma_t(j, i)lab_t(j, i)]^{1-\alpha} \right\}, \quad (19)$$

letting $\varphi_t(j, i)$ denote the firm's nominal marginal costs.

Taking into account that its pricing decision affects the industry price level $P_t(j)$, but not the aggregate price level P_t , the optimal price $p_t(j, i)$ each firm sets is a markup μ_t over marginal costs:

$$p_t(j, i) = \mu_t \varphi_t(j, i). \quad (20)$$

Restricting attention to a symmetric equilibrium the markup can be expressed as

$$\mu_t = \left[\frac{(1 - \omega)N_t - (\tau - \omega)}{\tau(1 - \omega)N_t - (\tau - \omega)} \right], \quad (21)$$

implying an inverse relationship between the market power and the number of incum-

bent firms, i.e. the degree of market competition. Thereby, we follow Jaimovich (2007) and Jaimovich and Floetotto (2008) and assume that $\omega < \tau$, from which it follows that the elasticity of substitution between any two goods within an industry is higher than the elasticity of substitution across industries.

Hence, using (21), total profits distributed to the household are given by

$$N_t \Pi_t^G = \left(\frac{\mu_t - 1}{\mu_t} \right) Y_t - \frac{N_t \phi(1 - sub_f) A_t}{\mu_t}, \quad (22)$$

while total output can be rewritten as

$$Y_t = \frac{K_{t-1}^\alpha (\Gamma_t Lab_t)^{1-\alpha}}{\mu_t} + N_t \Pi_t^G, \quad (23)$$

where $Y_t = N_t x_t$, $Lab_t = N_t lab_t$, and $K_{t-1} = N_t k_{t-1}$.

2.4 Labor Market

We assume that intermediate good producers purchase labor services from labor firms which allows to separate the production of goods from wage bargaining. Specifically, homogenous labor services, Lab_t , are produced by a representative labor firm, which posts vacancies, hires workers from the household sector at a nominal wage rate W_t , and sells the labor services at the perfectly competitive price $P_{L,t}$. The production function of the labor firm is given by

$$Lab_t = H_t \quad (24)$$

implying a linear relationship between labor services and the number of workers.

To find a worker, the firm has to start searching, which is costly due to frictions on the labor market and takes time. As it is common in the literature, the probability of finding a worker depends on a constant return to scale matching technology which converts unemployed workers U_t and vacancies Vac_t into matches M_t (see Mortensen and Pissarides, 1999; Pissarides, 2000). Specifically, the number of employer contracts per unit of time is given by

$$M_t(U_t, Vac_t) = \kappa^e U_t^\varepsilon Vac_t^{1-\varepsilon} \quad (25)$$

where $\kappa^e > 0$ measures the efficiency of the matching function and $0 < \varepsilon < 1$ represents

the elasticity of the number of job matches with respect to the stock of unemployed workers. Letting $\theta_t = Vac_t/U_t$ denote the labor market tightness, firms meet with an unemployed worker at rate $q_t = M_t(U_t, Vac_t)/Vac_t = \kappa^e \theta_t^{-\varepsilon}$, whereas unemployed workers find a vacant job at rate $\rho_t = \theta_t q_t = M_t(U_t, Vac_t)/U_t = \kappa^e \theta_t^{1-\varepsilon}$. While new matches in period t , M_t , become productive for the first time in period $t + 1$, existing matches might be destroyed at an exogenous separation rate s , implying that fraction of workers are dismissed at the beginning of each period for unspecified reasons (see Pissarides, 2000). Workers losing their jobs at time t are not allowed to search until the next period. Hence, the law of motion for employed workers is given by

$$H_t = (1 - s)H_{t-1} + M_{t-1} \quad (26)$$

$$= (1 - s)H_{t-1} + q_{t-1}Vac_{t-1} \quad (27)$$

$$= (1 - s)H_{t-1} + \rho_{t-1}U_{t-1}, \quad (28)$$

while unemployment evolves according to

$$U_t = (1 - \rho_{t-1})U_{t-1} + sH_{t-1}. \quad (29)$$

Taking into account (24) and (27), the representative labor firm solves the following dynamic optimization problem

$$\max_{H_t, Vac_t} E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \frac{\Pi_t^L}{P_t}, \quad (30)$$

where λ_t measures the representative household's marginal utility of an additional unit of real profits received during period t and where

$$\frac{\Pi_t^L}{P_t} = \frac{P_{L,t}}{P_t} Lab_t - \frac{W_t}{P_t} H_t - \kappa_t^v Vac_t \quad (31)$$

with κ_t^v denoting the cost of posting a vacancy. Specifically, to ensure stationarity, it is assumed that hiring costs evolve according to $\kappa_t^v = \kappa^v A_t$ with $\kappa^v > 0$.

Defining ψ_t as the Lagrangian multiplier on the employment law of motion (27), the first-order conditions for H_t and Vac_t are

$$\Psi_t = \frac{P_{L,t}}{P_t} - \frac{W_t}{P_t} + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \Psi_{t+1} (1 - s) \right], \quad (32)$$

$$\frac{\kappa_t^v}{q_t} = \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \Psi_{t+1} \right), \quad (33)$$

where $\Psi_t = \psi_t / \lambda_t$.

When a vacancy and a job-seeking worker meet, a rent is created. The division of the rent is determined in a Nash bargaining game between the labor firm and a union. Specifically, it is assumed that both parties choose the nominal wage W_t to maximize the joint surplus generated from the employment relationship. To describe the bargaining process the marginal value of a match for both the firm and the union need to be derived.

The surplus for the firm is given by the difference between the value of a filled job and the value of posting a vacancy. As Ψ_t is the real marginal value of an extra worker for the firm, the value of a filled job is already given by equation (32). Hence, it depends on the current price for labor services minus wage payments plus the discounted continuation value. Further, note that equation (33) is an arbitrage condition stating that the expected value of a newly created job has to equal expected search costs. Since we assume free market entry the value of posting a vacancy must be zero in equilibrium.

The surplus of the match for the union, which represents the interest of both employed and unemployed household members, is the difference between a worker's real marginal value of having a job, V_t^H and the worker's real marginal value of being unemployed V_t^U . Hence, using equations (1), (6), (28), and (29), the marginal value of having a household member employed, Ω_t , can be expressed as¹

$$\Omega_t = V_t^H - V_t^U, \quad (34)$$

$$= \frac{W_t}{P_t} - \kappa_t^B - \zeta \frac{H_t^x}{\lambda_t} + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} (1 - s - \rho_t) (V_{t+1}^H - V_{t+1}^U) \right], \quad (35)$$

$$= \frac{W_t}{P_t} - \kappa_t^B - \zeta \frac{H_t^x}{\lambda_t} + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} (1 - s - \rho_t) \Omega_{t+1} \right]. \quad (36)$$

Letting $0 < \xi < 1$ denote the union's bargaining power in the wage negotiation, the Nash bargaining problem is given by

$$\max_{W_t} (\Omega_t)^\xi (\Psi_t)^{1-\xi}, \quad (37)$$

which implies that the worker and the labor firm split the surplus of a match according

¹A detailed derivation is provided in the Appendix.

to the following sharing rule

$$\Omega_t = \frac{\xi}{1 - \xi} \Psi_t. \quad (38)$$

Solving equation (38) for W_t/P_t by using equations (34), (32), and (33) yields the wage equation

$$\frac{W_t}{P_t} = \xi \left(\frac{P_{L,t}}{P_t} + \theta_t \kappa_t^v \right) + (1 - \xi) \left(\zeta \frac{H_t^x}{\lambda_t} + \kappa_t^B \right). \quad (39)$$

2.5 Market Entry and Exit

Every period, there exist N_t intermediate goods producing firms and an unbounded set of potential entrants. Entry decisions are made by a large group of potential entrepreneurs. To found a new firm, an entrepreneur faces an entry cost η , denominated in effective labor units (see, e.g., Ghironi and Melitz, 2005; Bilbiie et al., 2012), while we assume that the government can subsidize these sunk entry costs. The entrepreneurs subsequently sell the firms to the household for the present discounted value of future profits v_t . Entry occurs until firm value and (subsidized) entry costs are equalized. Hence, the free entry condition can be expressed as

$$v_t = \eta \frac{W_t/P_t}{z_t} (1 - sub_e), \quad (40)$$

where sub_e denotes the entry subsidy. There is no time to build assumption for entering firms, which implies that new firms, N_t^e , become productive in the same period in which they are entering the market. After production has occurred, fraction $\delta_{n,t}$ of firms exit from the market. Thus, the law of motion for the number of firms in the economy at period t is given by (5), i.e. $N_t = (1 - \delta_{n,t})N_{t-1} + N_t^e$, where $0 < \delta_{n,t} < 1$ represents the probability of exiting the market.

Drawing on the industrial organization literature, firms' exit decision is based on a stochastic exit value (see, e.g., Doraszelski and Pakes, 2007; Pakes et al., 2007; Weintraub et al., 2008; Moscoso Boedo and Mukoyama, 2012; Dunne et al., 2013; Lee and Mukoyama, 2018). Specifically, it is assumed that an intermediate goods producing firm observes its random exit value S_j at the beginning of each period, i.e., before production takes place. If the observed scrap value is higher than previous period's (stationary) real profits $\tilde{\pi}_{t-1}^G = \pi_{t-1}^G/A_{t-1}$ the firm will leave the market.² In this respect, the choice of

²As outlined in Cavallari (2015), using heterogenous scrap values has the advantage of implying exit rates between zero and one for firms of any size thereby allowing to capture the empirical evidence of positive exit rates across the firm size distribution.

lagged profits is motivated by recent empirical evidence for the United States presented in Tian (2018), indicating that firm death positively lags the business cycles.

Following Cavallari (2015), we assume that the scrap value is Pareto distributed across firms. Hence, the exit rate in period t is given by

$$\delta_{n,t} \equiv Pr(S_j > \tilde{\pi}_{t-1}^G) = 1 - F(\tilde{\pi}_{t-1}^G), \quad (41)$$

where

$$F(S_j) = \begin{cases} 1 - \left(\frac{S_j}{S_{min}}\right)^{-\kappa} & S_j \geq S_{min} \\ 0 & S_j \leq S_{min} \end{cases} \quad (42)$$

is the cumulative distribution function of S_j and where κ and S_{min} represent the respective shape and scale parameters of the distribution.

2.6 Government

The model is closed by specifying the behavior of the government. We assume that unemployment benefits and subsidies are covered by lump-sum taxes T_t according to the following balanced budget constraint

$$T_t = U_t \kappa_t^B + \eta \frac{W_t/P_t}{z_t} sub_e N_t^e + \phi sub_f N_t A_t, \quad (43)$$

where we abstract from further government spending for simplicity.

3 Calibration

To be done.

4 Results

In this section, we present the simulation results of the two industrial policies under consideration. To investigate the consequences of entry and fixed costs subsidies we study the dynamic adjustment assuming that the economy is at the non-stochastic steady state. We consider a permanent increase of the respective subsidy in a perfect foresight environment. Specifically, the policy shock comes as an initial surprise to agents, who then have perfect foresight from that moment on. Transition dynamics from the initial equilibrium to the final equilibrium are found by solving the model as a nonlinear, forward-looking, deterministic system. In addition to analyzing the dynamic adjustment, we conduct a welfare analysis of the subsidy policies. Finally, we perform a sensitivity exercises to check the robustness of our results. In order to ensure comparability across policy measures, subsidy volumes of equal magnitude are considered over the simulation horizon. To disentangle the interrelationship of the various transmission channels, we compare of the dynamic adjustment of selected key variables for model specifications with and without technology utilization.

4.1 Dynamic Adjustment

Figures 1 show the effects of a permanent increase in entry subsidies for the model version without variable technology utilization assuming that all firms approach the world technology frontier. Lower entry costs induce an immediate entry of new firms, implying a decrease of market concentration as measured by the number of incumbent firms. Moreover, a noticeable increase of the firm exit rate is observable. The increase in the number producers raises labor and capital demand generating an increase in wages and the rental rate for capital. As a consequence, output, employment, and investment into physical capital increase in the aftermath of the policy intervention. However, consumption declines not only in the short term, but also converges to a lower steady state level. This development is partly explained by the profitable investment opportunities in new firms which induces households to save more, offsetting the positive impact of higher expected future income on current consumption. In addition, stronger competition on the product market leads to a decrease in markups and profits generating a negative wealth effect weighing on consumption expenditure.

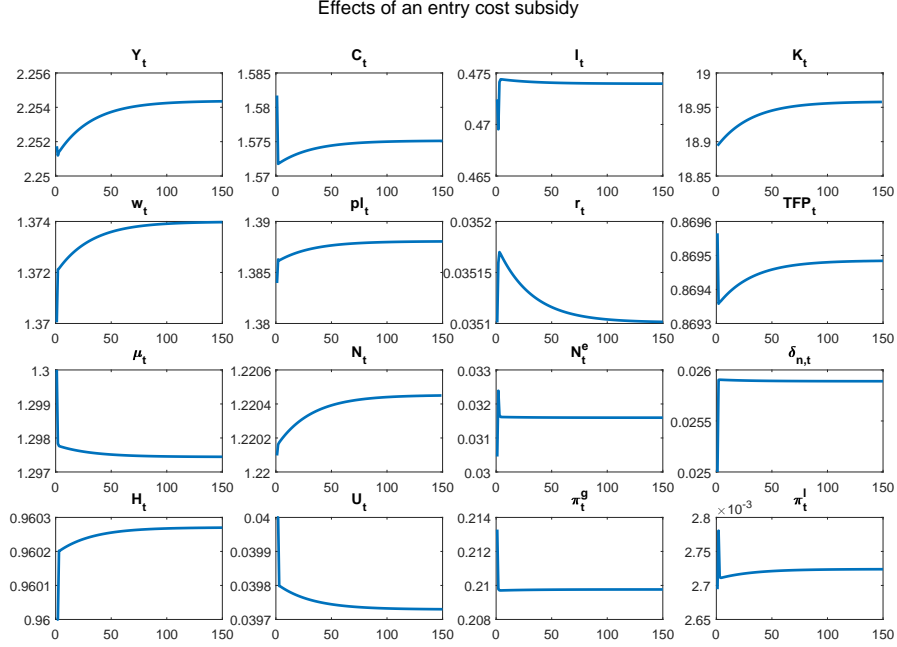


Figure 1: Effects of an entry cost subsidy on key macroeconomic variables without technology utilization.

Figure 2 shows the respective effects of a permanent fixed costs subsidy. While from a qualitative perspective, the reduction in fixed costs turns out to have a similar effect on output, employment, and capital investment, the dynamic adjustment of consumption noticeably differs compared to the previous scenario. Although consumption declines on impact as a consequence of higher investment into new firms and capital, it adjusts gradually to a higher long run level. The latter can be attributed to a wealth effect stemming from a permanent increase in firm profits distributed to the households. Although the policy induced reduction in fixed costs leads to an increase in the number of firms and therefore lower markups, it initially boosts incumbents' profits which, although being depressed by increased competition, remain above their initial steady state level. In addition, noticeable differences with respect to patterns of firm entry and exit become prevalent. Although reduced operational costs induce a rise in firm entry, the number of entrants drops directly afterwards remaining only slightly above the initial steady state level. As regards business destruction, we even find the firm

exit rate to decrease in the aftermath of the policy intervention implying an overall reduction in business dynamism as measured by the sum of firm entry and exit rates.

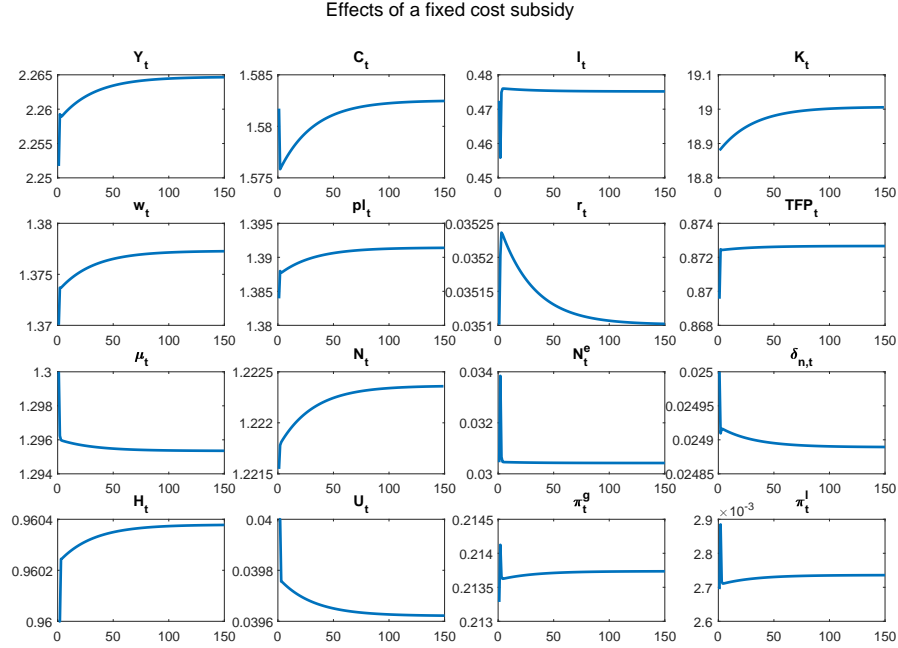


Figure 2: Effects of a fixed cost subsidy on key macroeconomic variables without technology utilization.

When considering variable technology utilization, we assume the existence of a gap between the national and the global technology frontier. Thereby, the size of the technology gap critically depends on the the degree of business dynamism as captured by the entry and exit rates of firms. Similar to the scenario without technology absorption we find both policy interventions to have a positive effect on output and employment. Moreover, we find the increase in the number of producers to have a dampening effect on markups. As regards consumption, however, the simulation results show noticeable differences compared to the scenario without technology adoption. Specifically, consumption shows an immediate rise in response to the entry costs subsidy, gradually adjusting to a higher long run level. In contrast, household consumption drops in case of fixed costs subsidy reflecting the adverse effects on productivity stemming from the decrease in business churn.

To be completed!

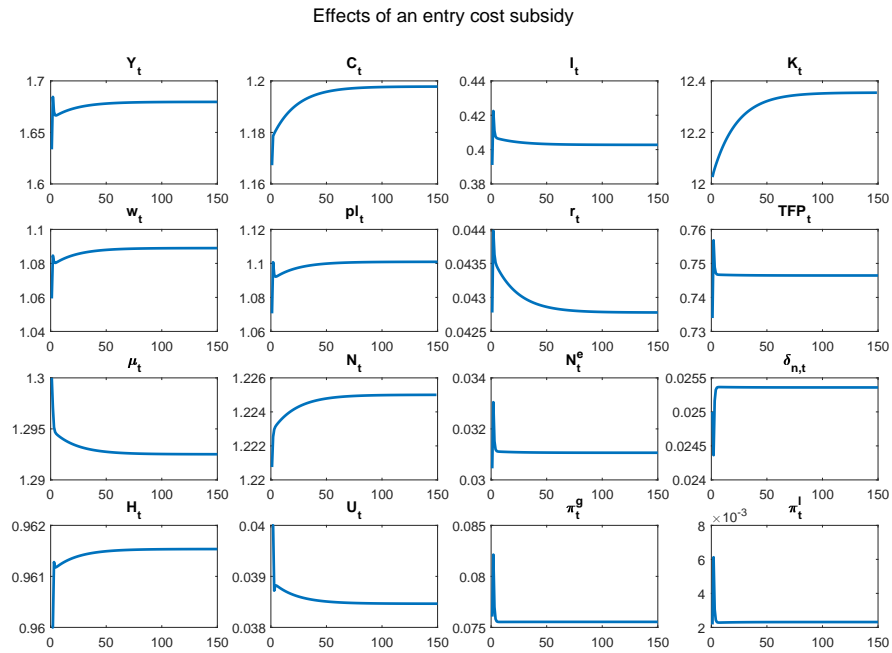


Figure 3: Effects of an entry cost subsidy on key macroeconomic variables allowing for technology utilization.

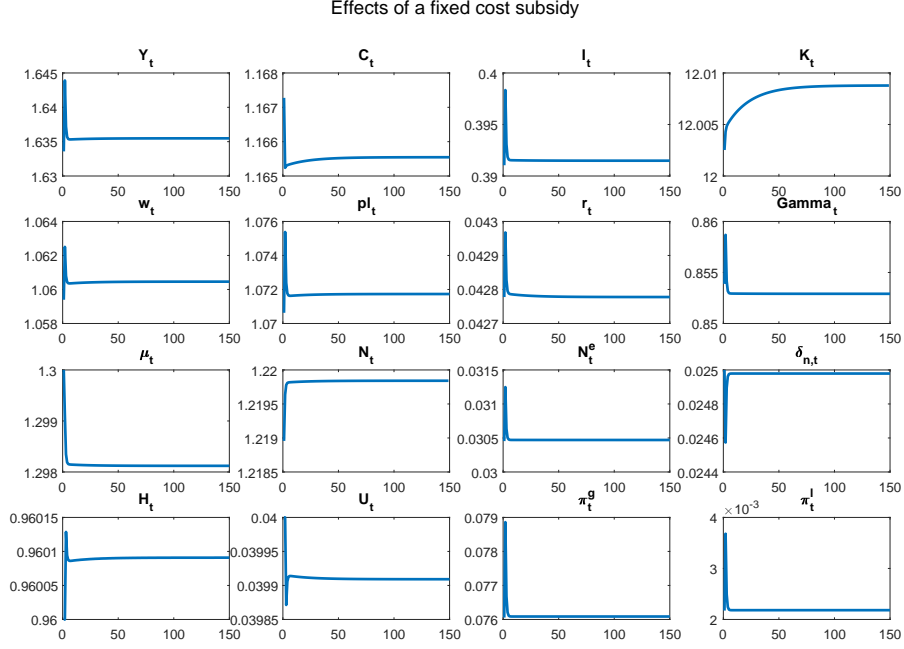


Figure 4: Effects of a fixed cost subsidy on key macroeconomic variables allowing for technology utilization.

5 Welfare analysis

In RBC models, welfare is the decisive criterion for the evaluation of different policies/policy regimes (see Lucas, 2003). As a result, this also applies to the evaluation of entry versus fix cost subsidies. The welfare gains and losses that arise are usually evaluated by means of consumption equivalents. That is, how many units of initial steady state consumption households would be willing to give up to live in an alternative regime. We will take into account the welfare difference between the initial and the final steady state as well as the transition thereto. More precisely, we calculate the consumption-equivalent welfare gain, ce , such that

$$\sum_{t=0}^{\infty} \beta^t U((1+ce)\bar{C}, \bar{H}) = \sum_{t=0}^{\infty} \beta^t U(C_t, H_t),$$

where the utility function $U(\cdot)$ is given by equations (1) and (2). The bar indicates initial steady-state values. Hence, ce represents the amount of initial steady-state consumption a household is willing to give up in order to live in the alternative regime after the policy change. Table 1 summarizes the results.

Table 1: Welfare gains from policy change

	Steady state	With transition
Entry cost subsidy, no technology utilization ($\hat{\rho}_N = 0$)	-0.421	-0.465
Fix cost subsidy, no technology utilization ($\hat{\rho}_N = 0$)	0.043	-0.057
Entry cost subsidy, with technology utilization ($\hat{\rho}_N = 0.9$)	2.58	2.25
Fix cost subsidy, with technology utilization ($\hat{\rho}_N = 0.9$)	-0.149	-0.151

6 Robustness Analysis

To be done.

7 Conclusion

This paper provides a tractable dynamic stochastic general equilibrium framework with endogenous firm creation and destruction and variable technology utilization to analyze the macroeconomic effects of entry costs and fixed cost subsidies. Based on this setup, we revisit empirical and theoretical evidence on the macroeconomic effects of competition-friendly industrial policies. Thereby, we shed light on the causes of the in part ambiguous results found in the literature. Our simulations confirm the findings of a potentially beneficial impact of both entry costs and fixed cost subsidies on output and employment. The welfare implications, however, turn out to be less clear cut and depend on the relative importance of a range of different transmission mechanisms. In particular, our findings highlight a key role of business churning, i.e., the entry and exit of firms, in determining the welfare effects of the respective policy measures. Hence, our results illustrate the importance of considering sector-specific characteristics in the context of competitive-enhancing industrial policies.

Appendices

The appendix contains further details on the theoretical model. Section A describes the derivation of the model in greater detail, section B summarizes the symmetric equilibrium, section C lays out the stationary equilibrium conditions, while section D derives the steady state of the model.

A Model

- Households:

The representative household chooses $\{C_t, I_t, K_t, N_t\}_{t=0}^{\infty}$ to maximize utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(C_t) - \zeta \frac{H_t^{1+\chi}}{1+\chi} \right],$$

subject to the budget constraint

$$C_t + I_t + v_t N_t^e \leq \frac{W_t}{P_t} H_t + \kappa_t^B U_t + \frac{R_t}{P_t} K_{t-1} + \frac{(\Pi_t^L + N_t \Pi_t^G)}{P_t} - T_t,$$

the law of motion for capital

$$K_t = (1 - \delta_K) K_{t-1} + I_t,$$

and the law of motion for firms

$$N_t = (1 - \delta_{n,t}) N_{t-1} + N_t^e.$$

Hence, the Lagrangian can be written as

$$\begin{aligned} \Lambda = E_0 \sum_{t=0}^{\infty} \Bigg\{ & \beta^t \left[\ln(C_t) - \zeta \frac{H_t^{1+\chi}}{1+\chi} \right] \\ & - \beta^t \lambda_t \left[C_t + K_t - (1 - \delta_K) K_{t-1} + v_t N_t - \frac{W_t}{P_t} H_t - \kappa_t^B U_t \right. \\ & \left. - \frac{R_t}{P_t} K_{t-1} - \frac{(\Pi_t^L + N_t \Pi_t^G)}{P_t} + T_t - v_t (1 - \delta_{n,t}) N_{t-1} \right] \Bigg\}. \end{aligned}$$

The first-order conditions corresponding to this problem are

$$\Lambda_C = \frac{1}{C_t} - \lambda_t = 0,$$

$$\Lambda_K = \lambda_t - \beta E_t \left\{ \lambda_{t+1} \left[(1 - \delta_k) + \frac{R_{t+1}}{P_{t+1}} \right] \right\} = 0,$$

$$\Lambda_N = \lambda_t \left(v_t - \frac{\Pi_t^G}{P_t} \right) - \beta E_t \{ \lambda_{t+1} [v_{t+1}(1 - \delta_{n,t+1})] \} = 0,$$

and

$$\begin{aligned} \Lambda_\lambda = & C_t + K_t - (1 - \delta_k)K_{t-1} + v_t N_t - \frac{W_t}{P_t} H_t - \kappa_t^B U_t \\ & - \frac{R_t}{P_t} K_{t-1} - \frac{(\Pi_t^L + N_t \Pi_t^G)}{P_t} + T_t - v_t (1 - \delta_{n,t}) N_{t-1} = 0. \end{aligned}$$

Finally, we impose the standard transversality conditions to guarantee that firms and capital do not grow too quickly:

$$\begin{aligned} \lim_{t \rightarrow \infty} \beta^t \lambda_t N_t &= 0, \\ \lim_{t \rightarrow \infty} \beta^t \lambda_t K_t &= 0. \end{aligned}$$

- Sector Level:

The representative final goods producing wants to maximize its profits

$$P_t Y_t - \int_0^1 P_t(j) Q_t(j) dj$$

subject to the constant returns to scale technology

$$Y_t = \left[\int_0^1 Q_t(j)^\omega dj \right]^{\frac{1}{\omega}}.$$

Hence, the firm's optimization problem can be written as

$$\max_{Q_t(j)} \Pi_t^S = P_t \left[\int_0^1 Q_t(j)^\omega dj \right]^{\frac{1}{\omega}} - \int_0^1 P_t(j) Q_t(j) dj,$$

which leads to the following first-order condition characterizing the demand for industry goods:

$$Q_t(j) = \left[\frac{P_t(j)}{P_t} \right]^{\frac{1}{\omega-1}} Y_t.$$

By substituting this expression into the constant elasticity of substitution aggregator of industry goods, we get the price for final goods

$$P_t = \left[\int_0^1 P_t(j)^{\frac{\omega}{\omega-1}} dj \right]^{\frac{\omega-1}{\omega}}.$$

- Industry Level:

Profits earned in industry j are given by

$$P_t(j) Q_t(j) - \sum_{i=1}^N x_t(j, i) p_t(j, i).$$

and intermediate goods are bundled into an industry good $Q_t(j)$ according to the CES aggregating function

$$Q_t(j) = N_t(j)^{1-\frac{1}{\tau}} \left[\sum_{i=1}^{N_t(j)} x_t(j, i)^\tau \right]^{\frac{1}{\tau}}.$$

Hence, the profit maximization problem at the industry level is given by

$$\max_{x_t(j, i)} \Pi_t^I = P_t(j) \left\{ N_t(j)^{1-\frac{1}{\tau}} \left[\sum_{i=1}^{N_t(j)} x_t(j, i)^\tau \right]^{\frac{1}{\tau}} \right\} - \sum_{i=1}^N x_t(j, i) p_t(j, i),$$

which leads to the following first-order condition characterizing the demand for

intermediate goods:

$$x_t(j, i) = \left[\frac{p_t(j, i)}{P_t(j)} \right]^{\frac{1}{\tau-1}} \frac{Q_t(j)}{N_t(j)}.$$

- Firm Level:

Each intermediate goods producing firm maximizes its profits

$$\Pi_t^G(j, i) = p_t(j, i)x_t(j, i) - P_{L,t}lab_t(j, i) - R_tk_{t-1}(j, i)$$

by choosing $lab_t(j, i)$, $k_{t-1}(j, i)$, and $p_t(j, i)$ subject to the conditional demand functions for industry and intermediate goods as well as the increasing-returns-to-scale production technology

$$x_t(j, i) \leq k_{t-1}(j, i)^\alpha [\Gamma_t(j, i)lab_t(j, i)]^{1-\alpha} - \phi(1 - sub_f)A_t$$

with

$$\Gamma_t(j, i) = z_t A_t u_t^a(j, i)$$

and

$$u_t^a(j, i) = \kappa^u(j, i) \left(\frac{N_t^e}{N_t} + \delta_{n,t} \right)^{\rho_N}.$$

Hence, the respective Lagrangian can be written as

$$\begin{aligned} \Phi = & p_t(j, i) \left\{ \left[\frac{p_t(j, i)}{P_t(j)} \right]^{\frac{1}{\tau-1}} \left[\frac{P_t(j)}{P_t} \right]^{\frac{1}{\omega-1}} \frac{Y_t}{N_t(j)} \right\} - P_{L,t}lab_t(j, i) - R_tk_{t-1}(j, i) \\ & - \varphi(j, i) \left\{ \left[\frac{p_t(j, i)}{P_t(j)} \right]^{\frac{1}{\tau-1}} \left[\frac{P_t(j)}{P_t} \right]^{\frac{1}{\omega-1}} \frac{Y_t}{N_t(j)} \right. \\ & \left. - k_{t-1}(j, i)^\alpha [\Gamma_t(j, i)lab_t(j, i)]^{1-\alpha} - \phi(1 - sub_f)A_t \right\}, \end{aligned}$$

where the Lagrangian multiplier $\varphi_t(j, i)$ can be interpreted as the nominal cost of producing one additional unit of the intermediate good.

The first order conditions with respect to $lab_t(j, i)$ and $k_{t-1}(j, i)$ are

$$\Phi_{lab(j, i)} = P_{L,t} - \varphi_t(j, i) \{ (1 - \alpha)k_{t-1}(j, i)^\alpha [\Gamma_t(j, i)lab_t]^{-\alpha} \Gamma_t(j, i) \} = 0$$

$$= P_{L,t} - \varphi_t(j, i)(1 - \alpha) \left[\frac{x_t(j, i)}{lab_t(j, i)} + \frac{\phi(1 - sub_f)A_t}{lab_t(j, i)} \right] = 0$$

and

$$\begin{aligned} \Phi_{k(j, i)} &= R_t - \varphi_t(j, i) \left\{ \alpha z_t k_{t-1}(j, i)^{\alpha-1} [\Gamma_t(j, i) lab_t(j, i)]^{1-\alpha} \right\} = 0 \\ &= R_t - \varphi_t(j, i) \alpha \left[\frac{x_t(j, i)}{k_{t-1}(j, i)} + \frac{\phi(1 - sub_f)A_t}{k_{t-1}(j, i)} \right] = 0. \end{aligned}$$

By using these first order conditions, the price setting problem of the intermediate goods producing firm can be rewritten as

$$\begin{aligned} \max_{p_t(j, i)} \Pi_t^G(j, i) &= p_t(j, i) \left\{ \left[\frac{p_t(j, i)}{P_t(j)} \right]^{\frac{1}{\tau-1}} \left[\frac{P_t(j)}{P_t} \right]^{\frac{1}{\omega-1}} \frac{Y_t}{N_t(j)} \right\} \\ &\quad - \varphi_t(j, i) \left\{ \left[\frac{p_t(j, i)}{P_t(j)} \right]^{\frac{1}{\tau-1}} \left[\frac{P_t(j)}{P_t} \right]^{\frac{1}{\omega-1}} \frac{Y_t}{N_t(j)} \right\} \\ &\quad - \varphi_t(j, i) \phi(1 - sub_f)A_t. \end{aligned}$$

Taking into account that its pricing decision affects the industry price level $P_t(j)$, but not the aggregate price level P_t , the first order necessary condition for a solution to the the price setting problem is given by

$$\begin{aligned} \frac{\partial \Pi_t^G(j, i)}{\partial p_t(j, i)} &= \tau N_t(j)(\omega - 1) + p_t(j, i)^{\frac{\tau}{\tau-1}} (\tau - \omega) P_t(j)^{\frac{-\tau}{\tau-1}} \\ &\quad - \varphi_t(j, i) \left[\frac{1}{p_t(j, i)} N_t(j)(\omega - 1) + p_t(j, i)^{\frac{1}{\tau-1}} (\tau - \omega) P_t(j)^{\frac{-\tau}{\tau-1}} \right] = 0. \end{aligned}$$

By restricting attention to a symmetric equilibrium, $\forall (j, i) \in [0, 1] \times [1, N_t]$: $x_t(j, i) = x_t$, $k_t(j, i) = k_t$, $lab_t(j, i) = lab_t$, $p_t(j, i) = p_t = P_t(j) = P_t$, $N_t(j) = N_t$, $\Pi_t^G(j, i) = \Pi_t^G$, $\varphi_t(j, i) = \varphi_t$, $\Gamma_t(j, i) = \Gamma_t$ the first order condition can be expressed as

$$p_t = \mu_t \varphi_t,$$

with

$$\mu_t = \left[\frac{(1 - \omega)N_t - (\tau - \omega)}{\tau(1 - \omega)N_t - (\tau - \omega)} \right].$$

denoting the markup of price over marginal cost.

Therefore, we can express real profits as

$$\frac{\Pi_t^G}{P_t} = \frac{\mu_t - 1}{\mu_t} x_t - \frac{\phi(1 - sub_f)A_t}{\mu_t}.$$

Moreover, symmetry implies that

$$\begin{aligned} Y_t &= Q_t \\ &= N_t x_t \\ &= K_{t-1}^\alpha (\Gamma_t Lab_t)^{1-\alpha} - N_t \phi(1 - sub_f)A_t, \end{aligned}$$

with $Lab_t = N_t lab_t$ and $K_{t-1} = N_t k_{t-1}$.

Hence, it follows that

$$\frac{\Pi_t^G}{P_t} = \frac{\mu_t - 1}{\mu_t} \frac{Y_t}{N_t} - \frac{\phi(1 - sub_f)A_t}{\mu_t},$$

$$\frac{P_{L,t}}{P_t} = \frac{1}{\mu_t} (1 - \alpha) \left(\frac{K_{t-1}}{Lab_t} \right)^\alpha \Gamma_t^{1-\alpha},$$

and

$$\frac{R_t}{P_t} = \frac{1}{\mu_t} \alpha \left(\frac{K_{t-1}}{Lab_t} \right)^{\alpha-1} \Gamma_t^{1-\alpha}.$$

- Labor Firm:

The representative labor firm solves the following dynamic optimization problem

$$\max_{H_t, Vac_t} E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \frac{\Pi_t^L}{P_t}$$

subject to the production technology

$$Lab_t = H_t$$

and the law of motion

$$H_t = (1 - s)H_{t-1} + q_{t-1}Vac_{t-1},$$

with

$$\frac{\Pi_t^L}{P_t} = \frac{P_{L,t}}{P_t} Lab_t - \frac{W_t}{P_t} H_t - \kappa_t^v Vac_t$$

Hence, the respective Lagrangian can be written as

$$\begin{aligned} \mathcal{M} = E_0 \sum_{t=0}^{\infty} \left\{ \beta^t \lambda_t \left(\frac{P_{L,t}}{P_t} H_t - \frac{W_t}{P_t} H_t - \kappa_t^v Vac_t \right) \right. \\ \left. - \beta^t \psi_t [H_t - (1-s)H_{t-1} - q_{t-1} Vac_{t-1}] \right\}. \end{aligned}$$

The respective first order conditions for H_t and Vac_t are

$$\begin{aligned} \frac{\partial \mathcal{M}}{\partial H_t} &= \lambda_t \left(\frac{P_{L,t}}{P_t} - \frac{W_t}{P_t} \right) + \beta E_t [\psi_{t+1}(1-s)] - \psi_t = 0, \\ \frac{\partial \mathcal{M}}{\partial Vac_t} &= \lambda_t \kappa_t^v - \beta E_t (\psi_{t+1}) q_t = 0, \end{aligned}$$

which, defining $\Psi_t = \psi_t / \lambda_t$, can be rewritten as

$$\begin{aligned} \Psi_t &= \frac{P_{L,t}}{P_t} - \frac{W_t}{P_t} + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \Psi_{t+1} (1-s) \right], \\ \frac{\kappa_t^v}{q_t} &= \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \Psi_{t+1} \right). \end{aligned}$$

- Union:

The surplus of the match for the union, Ω_t , is the difference between a worker's real marginal value of having a job, V_t^N , and the worker's real marginal value of being unemployed, V_t^U , both of which can be derived from the following Lagrangian

$$\begin{aligned} \mathcal{V} = E_0 \sum_{t=0}^{\infty} \left\{ \beta^t \left[\ln(C_t) - \zeta \frac{H_t^{1+\chi}}{1+\chi} \right] \right. \\ - \beta^t \lambda_t \left[C_t + K_t - (1-\delta_k)K_{t-1} + v_t N_t - \frac{W_t}{P_t} H_t - \kappa_t^B U_t \right. \\ \left. - \frac{R_t}{P_t} K_{t-1} - \frac{(\Pi_t^L + N_t \Pi_t^G)}{P_t} + T_t - v_t (1-\delta_{n,t}) N_{t-1} \right] \\ - \beta^t v_t^N [H_t - (1-s)H_{t-1} - \rho_{t-1} U_{t-1}] \\ \left. - \beta^t v_t^U [U_t - (1-\rho_{t-1})U_{t-1} - sH_{t-1}] \right\}. \end{aligned}$$

The first order conditions with respect to H_t and U_t are

$$\begin{aligned}\frac{\partial \mathcal{V}}{\partial H_t} &= \lambda_t \frac{W_t}{P_t} - \varphi H_t^\chi - v_t^N + \beta E_t [v_{t+1}^N(1-s) + v_{t+1}^U s] = 0 \\ \frac{\partial \mathcal{V}}{\partial U_t} &= v_t^U - \lambda_t \kappa_t^B + \beta E_t [v_{t+1}^N \rho_t + v_{t+1}^U(1-\rho_t)] = 0,\end{aligned}$$

which, defining $V_t^U = v_t^U/\lambda_t$ and $V_t^N = v_t^N/\lambda_t$, can be rewritten as

$$\begin{aligned}V_t^N &= \frac{W_t}{P_t} - \frac{\varphi H_t^\chi}{\lambda_t} + \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} [V_{t+1}^N(1-s) + V_{t+1}^U s] \right\} \\ V_t^U &= \kappa_t^B + \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} [V_{t+1}^N \rho_t + V_{t+1}^U(1-\rho_t)] \right\}.\end{aligned}$$

Hence, the surplus of the match for the union can be expressed as

$$\begin{aligned}\Omega_t &= \frac{W_t}{P_t} - \frac{\varphi H_t^\chi}{\lambda_t} - \kappa_t^B + \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} (1-s-\rho_t) (V_{t+1}^N - V_{t+1}^U) \right\} \\ &= \frac{W_t}{P_t} - \frac{\varphi H_t^\chi}{\lambda_t} - \kappa_t^B + \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} (1-s-\rho_t) \Omega_{t+1} \right\}.\end{aligned}$$

- Wage Setting:

The Nash bargaining problem is given by

$$\max_{W_t} (\Omega_t)^\xi (\Psi_t)^{1-\xi},$$

which implies that the worker and the labor firm split the surplus of a match according to the following sharing rule

$$\Omega_t = \frac{\xi}{1-\xi} \Psi_t.$$

By substituting the expressions for the marginal surpluses Ω_t and Ψ_t into the sharing rule, we get

$$\frac{W_t}{P_t} = \xi \left(\frac{P_{L,t}}{P_t} + \theta_t \kappa_t^v \right) + (1-\xi) \left(\zeta \frac{H_t^\chi}{\lambda_t} + \kappa_t^B \right).$$

- Market Entry and Exit:

Entry occurs until firm value and (subsidized) entry costs are equalized. Hence, the free entry condition can be expressed as

$$v_t = \eta \frac{W_t/P_t}{z_t} (1 - sub_e).$$

The law of motion for the number of firms in the economy at period t is given by

$$N_t = (1 - \delta_{n,t})N_{t-1} + N_t^e,$$

where

$$\delta_{n,t} = \left(\frac{\tilde{\pi}_{t-1}^G/A_{t-1}}{S_{min}} \right)^{-\kappa}$$

representing the probability of exiting the market.

- Government:

The government budget constraint is given by

$$T_t = U_t \kappa_t^B + \eta \frac{W_t/P_t}{z_t} sub_e N_t^e + \phi sub_f N_t A_t.$$

B Symmetric Equilibrium

Under the assumption of symmetry, $\forall (j, i) \in [0, 1] \times [1, N_t]$: $x_t(j, i) = x_t$, $k_t(j, i) = k_t$, $lab_t(j, i) = lab_t$, $p_t(j, i) = p_t = P_t(j) = P_t$, $N_t(j) = N_t$, $\Pi_t^G(j, i) = \Pi_t^G$, $\varphi_t(j, i) = \varphi_t$, $\kappa^u(j, i) = \kappa^u$ the model can be summarized by the following system of equations, using the re-defined variables $w_t = W_t/P_t$, $r_t = R_t/P_t$, $p_{l,t} = P_{L,t}/P_t$, $\pi_t^G = \Pi_t^G/P_t$, and $\pi_t^L = \Pi_t^L/P_t$:

$$\frac{1}{C_t} = \lambda_t, \tag{1}$$

$$\lambda_t = \beta E_t \{ \lambda_{t+1} [(1 - \delta_k) + r_{t+1}] \}, \tag{2}$$

$$\lambda_t (v_t - \pi_t^G) = \beta E_t \{ \lambda_{t+1} [v_{t+1} (1 - \delta_{n,t+1})] \}, \tag{3}$$

$$\begin{aligned}
C_t + K_t - (1 - \delta_k)K_{t-1} + v_t N_t \\
= w_t H_t + \kappa_t^B U_t + r_t K_{t-1} + \pi_t^L + N_t \pi_t^G - T_t + v_t (1 - \delta_{n,t}) N_{t-1},
\end{aligned} \tag{4}$$

$$K_t = (1 - \delta_K)K_{t-1} + I_t, \tag{5}$$

$$N_t = (1 - \delta_{n,t})N_{t-1} + N_t^e, \tag{6}$$

$$\delta_{n,t} = \left(\frac{\pi_{t-1}^G / A_{t-1}}{S_{min}} \right)^{-\kappa}, \tag{7}$$

$$v_t = \eta \frac{w_t}{z_t} (1 - sub_e), \tag{8}$$

$$U_t = 1 - H_t, \tag{9}$$

$$\mu_t = \left[\frac{(1 - \omega)N_t - (\tau - \omega)}{\tau(1 - \omega)N_t - (\tau - \omega)} \right], \tag{10}$$

$$\pi_t^G = \frac{\mu_t - 1}{\mu_t} \frac{Y_t}{N_t} - \frac{\phi(1 - sub_f)A_t}{\mu_t}, \tag{11}$$

$$p_{L,t} = \frac{1}{\mu_t} (1 - \alpha) \left(\frac{K_{t-1}}{Lab_t} \right)^\alpha \Gamma_t^{1-\alpha}, \tag{12}$$

$$r_t = \frac{1}{\mu_t} \alpha \left(\frac{K_{t-1}}{Lab_t} \right)^{\alpha-1} \Gamma_t^{1-\alpha}, \tag{13}$$

$$Y_t = K_{t-1}^\alpha (\Gamma_t Lab_t)^{1-\alpha} - N_t \phi(1 - sub_f)A_t, \tag{14}$$

$$\Gamma_t = z_t A_t \kappa^u \left(\frac{N_t^e}{N_t} + \delta_{n,t} \right)^{\rho_N}, \tag{15}$$

$$\ln(A_t) = \ln(A_{t-1}) + \ln(g_t^a), \tag{16}$$

$$\ln(g_t^a) = (1 - \rho_a) \ln(g^a) + \rho_a \ln(g_{t-1}^a) + \varepsilon_{at} \quad (17)$$

$$\ln(z_t) = \rho_z \ln(z_{t-1}) + \varepsilon_{zt}, \quad (18)$$

$$Lab_t = H_t, \quad (19)$$

$$H_t = (1 - s)H_{t-1} + q_{t-1}Vac_{t-1}, \quad (20)$$

$$\Psi_t = p_{L,t} - w_t + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \Psi_{t+1} (1 - s) \right], \quad (21)$$

$$\frac{\kappa_t^v}{q_t} = \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \Psi_{t+1} \right), \quad (22)$$

$$\pi_t^L = p_{L,t} Lab_t - w_t H_t - \kappa_t^v Vac_t, \quad (23)$$

$$M_t = \kappa^e U_t^\varepsilon Vac_t^{1-\varepsilon}, \quad (24)$$

$$q_t = \frac{M_t}{Vac_t}, \quad (25)$$

$$\rho_t = \frac{M_t}{U_t}, \quad (26)$$

$$\theta_t = \frac{Vac_t}{U_t}, \quad (27)$$

$$U_t = (1 - \rho_{t-1})U_{t-1} + sH_{t-1}, \quad (28)$$

$$\Omega_t = w_t - \frac{\varphi H_t^\chi}{\lambda_t} - \kappa_t^B + \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} (1 - s - \rho_t) \Omega_{t+1} \right\}, \quad (29)$$

$$\Omega_t = \frac{\xi}{1 - \xi} \Psi_t, \quad (30)$$

and

$$T_t = U_t \kappa_t^B + \eta \frac{w_t}{z_t} \text{sub}_e N_t^e + \phi \text{sub}_f N_t A_t. \quad (31)$$

C Stationary Equilibrium

Since A_t displays a stochastic trend, the model is cast into stationary form prior to solving for equilibrium. Let $\tilde{Y}_t = Y_t/A_t$, $\tilde{K}_{t-1} = K_{t-1}/A_t$, $\tilde{C}_t = C_t/A_t$, $\tilde{\lambda}_t = \lambda_t A_t$, $\tilde{v}_t = v_t/A_t$, $\tilde{\pi}_t^G = \pi_t^G/A_t$, $\tilde{w}_t = w_t/A_t$, $\tilde{\pi}_t^L = \pi_t^L/A_t$, $\tilde{T}_t = T_t/A_t$, $\tilde{I}_t = I_t/A_t$, $\tilde{p}_{L,t} = p_{L,t}/A_t$, $\tilde{\Psi}_t = \Psi_t/A_t$, $\tilde{\Omega}_t = \Omega_t/A_t$, $\tilde{\Gamma}_t = \Gamma_t/A_t$ the equilibrium conditions can be rewritten as:

$$\frac{1}{\tilde{C}_t} = \tilde{\lambda}_t, \quad (1)$$

$$g_{t+1}^a \tilde{\lambda}_t = \beta E_t \left\{ \tilde{\lambda}_{t+1} [(1 - \delta_k) + r_{t+1}] \right\}, \quad (2)$$

$$\tilde{\lambda}_t (\tilde{v}_t - \tilde{\pi}_t^G) = \beta E_t \left\{ \tilde{\lambda}_{t+1} [\tilde{v}_{t+1} (1 - \delta_{n,t+1})] \right\}, \quad (3)$$

$$\begin{aligned} & \tilde{C}_t + g_{t+1}^a \tilde{K}_t - (1 - \delta_k) \tilde{K}_{t-1} + \tilde{v}_t N_t \\ &= \tilde{w}_t H_t + \kappa^B U_t + r_t \tilde{K}_{t-1} + \tilde{\pi}_t^L + N_t \tilde{\pi}_t^G - \tilde{T}_t + \tilde{v}_t (1 - \delta_{n,t}) N_{t-1}, \end{aligned} \quad (4)$$

$$g_{t+1}^a \tilde{K}_t = (1 - \delta_K) \tilde{K}_{t-1} + \tilde{I}_t, \quad (5)$$

$$N_t = (1 - \delta_{n,t}) N_{t-1} + N_t^e, \quad (6)$$

$$\delta_{n,t} = \left(\frac{\tilde{\pi}_{t-1}^G}{S_{min}} \right)^{-\kappa}, \quad (7)$$

$$\tilde{v}_t = \eta \frac{\tilde{w}_t}{z_t} (1 - \text{sub}_e), \quad (8)$$

$$U_t = 1 - H_t, \quad (9)$$

$$\mu_t = \left[\frac{(1 - \omega)N_t - (\tau - \omega)}{\tau(1 - \omega)N_t - (\tau - \omega)} \right], \quad (10)$$

$$\tilde{\pi}_t^G = \frac{\mu_t - 1}{\mu_t} \frac{\tilde{Y}_t}{N_t} - \frac{\phi(1 - sub_f)}{\mu_t}, \quad (11)$$

$$\tilde{p}_{L,t} = \frac{1}{\mu_t} (1 - \alpha) \left(\frac{\tilde{K}_{t-1}}{Lab_t} \right)^\alpha \tilde{\Gamma}_t^{1-\alpha}, \quad (12)$$

$$r_t = \frac{1}{\mu_t} \alpha \left(\frac{\tilde{K}_{t-1}}{Lab_t} \right)^{\alpha-1} \tilde{\Gamma}_t^{1-\alpha}, \quad (13)$$

$$\tilde{Y}_t = \tilde{K}_{t-1}^\alpha \left(\tilde{\Gamma}_t Lab_t \right)^{1-\alpha} - N_t \phi(1 - sub_f), \quad (14)$$

$$\tilde{\Gamma}_t = z_t \kappa^u \left(\frac{N_t^e}{N_t} + \delta_{n,t} \right)^{\rho_N}, \quad (15)$$

$$\ln(g_t^a) = (1 - \rho_a) \ln(g^a) + \rho_a \ln(g_{t-1}^a) + \varepsilon_{at}, \quad (16)$$

$$\ln(z_t) = \rho_z \ln(z_{t-1}) + \varepsilon_{zt}, \quad (17)$$

$$Lab_t = H_t, \quad (18)$$

$$H_t = (1 - s)H_{t-1} + q_{t-1}Vac_{t-1}, \quad (19)$$

$$\tilde{\Psi}_t = \tilde{p}_{L,t} - \tilde{w}_t + \beta E_t \left[\frac{\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t} \tilde{\Psi}_{t+1} (1 - s) \right], \quad (20)$$

$$\frac{\kappa^v}{q_t} = \beta E_t \left(\frac{\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t} \tilde{\Psi}_{t+1} \right), \quad (21)$$

$$\tilde{\pi}_t^L = \tilde{p}_{L,t} Lab_t - \tilde{w}_t H_t - \kappa^v Vac_t, \quad (22)$$

$$M_t = \kappa^e U_t^\varepsilon Vac_t^{1-\varepsilon}, \quad (23)$$

$$q_t = \frac{M_t}{Vac_t}, \quad (24)$$

$$\rho_t = \frac{M_t}{U_t}, \quad (25)$$

$$\theta_t = \frac{Vac_t}{U_t}, \quad (26)$$

$$U_t = (1 - \rho_{t-1})U_{t-1} + sH_{t-1}, \quad (27)$$

$$\tilde{\Omega}_t = \tilde{w}_t - \frac{\varphi H_t^\chi}{\tilde{\lambda}_t} - \kappa^B + \beta E_t \left\{ \frac{\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t} (1 - s - \rho_t) \tilde{\Omega}_{t+1} \right\}, \quad (28)$$

$$\tilde{\Omega}_t = \frac{\xi}{1 - \xi} \tilde{\Psi}_t, \quad (29)$$

and

$$\tilde{T}_t = U_t \kappa^B + \eta \frac{\tilde{w}_t}{z_t} sub_e N_t^e + \phi sub_f N_t. \quad (30)$$

D Steady State

In absence of shocks, i.e., $\varepsilon_{zt} = \varepsilon_{at} = 0$ for all $t = 0, 1, 2, \dots$, the economy converges to a steady state. Taking the calibrated values for δ_n , μ , q , U , z , and g^a , we can solve for the remaining variables as follows:

Use (9) to solve for

$$H = 1 - U.$$

From (18) we get

$$Lab = H.$$

Use (2) to solve for

$$r = \frac{g^a}{\beta} - (1 - \delta_k).$$

Equation (10) can be used to solve for

$$N = \frac{(\mu - 1)(\tau - \omega)}{\mu\tau(1 - \omega) - (1 - \omega)}.$$

Then we can use (6) to get

$$N^e = \delta_n N$$

and (15) to solve for

$$\tilde{\Gamma} = \kappa^u \left(\frac{N^e}{N} + \delta_n \right)^{\rho_N}.$$

Next use (13) to solve

$$\tilde{K} = \left(\frac{\alpha}{r\mu} \right)^{\frac{1}{1-\alpha}} Lab \tilde{\Gamma},$$

and (12) to get

$$\tilde{p}_L = \frac{(1-\alpha)}{\mu} \left(\frac{\tilde{K}}{Lab} \right)^\alpha \tilde{\Gamma}^{1-\alpha}.$$

From (5) we get

$$\tilde{I} = [g^a - (1 - \delta_K)] \tilde{K}.$$

Now, use(14) to solve for

$$\tilde{Y} = \tilde{K}^\alpha \left(\tilde{\Gamma} Lab \right)^{1-\alpha} - N\phi(1 - sub_f). \quad (31)$$

From (11) we get

$$\tilde{\pi}^G = \frac{\mu - 1}{\mu} \frac{\tilde{Y}}{N} - \frac{\phi(1 - sub_f)}{\mu}.$$

Next use (3) to solve for

$$\tilde{v} = \frac{1}{1 - \beta(1 - \delta_n)} \tilde{\pi}^G.$$

Use (27) to solve for

$$\rho = \frac{sH}{U}.$$

From (25) we get

$$M = \rho U$$

and from (24)

$$Vac = \frac{M}{q}.$$

Now, use (26) to solve for

$$\theta = \frac{Vac}{U}.$$

From (1), (4), (5), (6), (8), (11), (12), (13), (14), (22), and (30) we get

$$\tilde{\lambda} = \frac{1}{\tilde{Y} - \kappa^v Vac - \phi sub_f N - \tilde{I} - \frac{\tilde{v} N^e}{(1-sub_e)}}.$$

Hence, we can use 1 to solve for

$$\tilde{C} = \frac{1}{\tilde{\lambda}}.$$

Next, use (20), (21), (24), (25), (26), (28), and (28) to solve for

$$\tilde{w} = \xi (\tilde{p}_L + \theta \kappa^v) + (1 - \xi) \left(\frac{\zeta H^\chi}{\tilde{\lambda}} + \kappa^B \right).$$

Now we can solve for (22)

$$\tilde{\pi}^L = \tilde{p}_L Lab - \tilde{w} H - \kappa^v Vac.$$

From (21) we get

$$\tilde{\Psi} = \frac{\kappa^v}{\beta q},$$

while we can use (29) to solve for

$$\tilde{\Omega} = \frac{\xi}{1 - \xi} \tilde{\Psi}.$$

Finally, use (30) to solve for

$$\tilde{T} = U \kappa^B + \eta \frac{\tilde{w}}{z} sub_e N^e + \phi sub_f N.$$

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