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CALVO WAGES VS. SEARCH FRICTIONS: A HORSE RACE IN A DSGE MODEL OF A SMALL OPEN ECONOMY*

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Abstract

Most existing DSGE models used for monetary policy analysis and forecasting assume that the labor market always clears at a sticky nominal wage (`a la Calvo) through variations along the intensive margin of labor supply (i.e. hours), with no role for the extensive margin (i.e. employment). The latter contrasts with research on the macroeconomics of labor markets that has emphasized the relevance of the extensive margin and employment fluctuations using search and matching theory. Against this background, in this paper we conduct a horse race of a labor market specification with Calvo wages versus a search and matching specification with endogenous separations in an otherwise standard New Keynesian small open economy model, estimated with Chilean data. We conclude that the search and matching specification "wins" by a wide margin as it significantly improves the model's ability to explain and predict both labor market data and other macroeconomic variables.

Resumen

La mayoría de los modelos DSGE que se utilizan para el análisis de la política monetaria y proyecciones macroeconómicas asumen que el mercado laboral tiende a equilibrio con un salario nominal rígido (a la Calvo) a través de variaciones del margen intensivo de la oferta laboral (horas trabajadas), sin ningún rol para el margen extensivo (empleo). Esto último contrasta con estudios sobre la macroeconomía del mercado laboral los cuales han hecho hincapié de la relevancia de las fluctuaciones del empleo utilizando la teoría de búsqueda y emparejamiento. En este contexto, el presente trabajo hace competir dos tipos de fricciones en el mercado laboral: salarios rígidos a la Calvo frente a búsqueda y emparejamiento con separaciones endógenas, en un modelo neo-Keynesiano estándar para economías pequeñas y abiertas que se estima con datos de Chile. Se concluye que la especificación usando fricciones de búsqueda se desempeña significativamente mejor en términos de la capacidad del modelo para explicar y predecir tanto los datos del mercado laboral y otras variables macroeconómicas.

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1 Introduction

Calvo-type wage stickiness remains the dominant labor market friction in New Keynesian dynamic stochastic general equilibrium (DSGE) models used for policy analysis and forecasting at central banks and other policy institutions.[1] Under monopolistic wage setting à la Calvo, the labor market always clears at the sticky nominal wage through variations of labor input along the intensive margin (i.e. hours per worker), but there is no role for adjustments along the extensive margin (i.e. employment). The latter stands in stark contrast to academic research that has emphasized the role of labor market flows based on search and matching theory. According to that literature, search frictions and matching can successfully explain several relevant labor market facts such as the existence of involuntary unemployment and the dynamics of job creation and job destruction (see Pissarides, 2011).[2]

Some of that disconnect between labor market research and labor market specifications in practical policy models may be due to the fact that the usefulness of search frictions in medium-scale quantitative DSGE models for monetary policy analysis and forecasting is not yet sufficiently well understood. Hence, in this paper we let search frictions compete with Calvo wages in a DSGE framework. In particular, we assess whether and how the inclusion of a search and matching specification à la Diamond (1982), Mortensen (1982) and Pissarides (1985) with both margins of labor supply and endogenous separations following Mortensen and Pissarides (1994), Cooley and Quadrini (1999) and den Haan, Ramey, and Watson (2000) improves the empirical fit and forecasting performance of an otherwise standard New Keynesian small open economy (NK-SOE) model. The analysis is conducted using Bayesian techniques and Chilean data. While our paper forms part of several recent studies that have investigated the usefulness of labor market search and matching in macroeconomic models, as we discuss below, we are among the first to analyze the benefits of search frictions in a small open economy context. In addition, only few related studies have examined the relevance of endogenous separations with both margins of labor supply in estimated DSGE models. As we show, the latter has several relevant implications for the dynamics of our model.

The shortcomings of labor market specifications in standard DSGE models, both for closed and open economies, become clear from a brief review. In particular, exogenous labor market

[1] Examples of DSGE models used at central banks and other policy institutions that incorporate Calvo-type wage stickiness or some other form of wage stickiness that gives rise to a wage Phillips curve, e.g. due to wage adjustment costs à la Rotemberg, are discussed in Brubakk and Sveen (2009), Burgess et al. (2013), Chung, Kiley, and Laforte (2010), de Castro, Gouvea, Minella, dos Santos, and Souza-Sobrinho (2011), Del Negro et al. (2013), Dorich, Johnston, Mendes, Murchison, and Zhang (2013), Erceg, Guerrieri, and Gust (2006), González, Mahadeva, Prada, and Rodríguez (2011), Lees (2009), Medina and Soto (2007), Ratto, Roeger, and in 't Veld (2009), Schorfheide, Sill, and Kryshko (2010), and Smets, Christoffel, Coenen, Motto, and Rostagno (2010).

[2] See also Krause and Lubik (2014).

shocks are typically found to be important drivers of aggregate dynamics in those models: in the Smets and Wouters (2003) euro area model, labor supply preference shocks are the most important drivers of output while wage markup shocks are responsible for the bulk of variations in real wages; whereas in the Smets and Wouters (2007) U.S. model where there is no separate labor supply shock, wage markup shocks account for most of medium- to long-term fluctuations in output and inflation. In Adolfson, Laséen, Lindé, and Villani's (2007) NK-SOE model, labor supply shocks are also among the most important shocks to explain output, wage and inflation dynamics in Sweden. The fact that exogenous labor market shocks are so important in standard DSGE models seems unsatisfactory, not only because their underlying deeper determinants are hard to identify, but also because one might expect that labor market outcomes are to a large extent consequences of more structural shocks such as monetary or fiscal policy shocks or, in open economies, foreign shocks (i.e. shocks to foreign interest rates, foreign demand, commodity prices, etc.). In addition, all of the above models rely on relatively large real wage elasticities of individual hours worked to match fluctuations in total hours, which is known to be at odds with micro evidence (see Chetty, Guren, Manoli, and Weber, 2011).

Due to the above shortcomings, recent model developments using search and matching theory have attempted to improve labor market specifications and generate stronger endogenous propagation properties of DSGE models. For instance, Christiano, Trabandt, and Walentin (2011) describe the labor market in an NK-SOE model using a search and matching framework with variations on both margins of labor supply.[3] Their estimation results for Swedish data show that the labor supply shock becomes unimportant in explaining output, the estimated elasticity of individual hours is relatively low, and no wage markup shock is needed. However, the labor supply shock is still the most important shock for both total hours and real wages, and basic foreign shocks are relatively unimportant for aggregate dynamics.[4] An earlier study by Krause, Lopez-Salido, and Lubik (2008) based on a closed economy model with search and matching estimated with U.S. data also found a relatively low elasticity of individual hours and a small role for labor supply shocks. However, in this model price markup and (ad hoc) match efficiency shocks are the dominant force in labor market fluctuations.[5] Part of the failure of this model to explain the fluctuations of both labor market variables and other macroeconomic variables such as output and inflation through more structural shocks may be due to the absence of endogenous separations, in line with the results of Sedláçek (2014). Indeed, many studies

[3] See also Adolfson, Laséen, Christiano, Trabandt, and Walentin (2013).

[4] This is related to the problem that NK-SOE models tend to have difficulties in accounting for the substantial influence of foreign shocks identified in many time series studies (see Justiniano and Preston, 2010).

[5] Similar results were obtained by Albertini, Kamber, and Kirker (2012) in a New Keynesian small open economy model estimated with data for New Zealand.

have found that endogenous separations are important for understanding labor market flows and their interaction with output and inflation (e.g. Trigari, 2009).[6]

Hence, the success of search frictions in quantitative DSGE models has so far been mixed. Our results shed some additional light on this issue. In particular, we find that the data strongly favors the model with search frictions over the model with Calvo wages, as reflected by a significantly higher marginal data density (especially when labor market data and other macroeconomic variables are to be explained jointly), as well as a significantly better ability of the model with search frictions to match the majority of the second moments of the observed data. The forecasting performance of the model for labor market variables as well as other key variables such as output and inflation is also significantly improved by the search frictions. Our paper therefore provides further evidence that search frictions are useful to explain aggregate dynamics in quantitative DSGE models for small open economies.

The rest of the paper is organized as follows. Section 2 presents our NK-SOE model with search frictions and matching, while the variant of the model with Calvo wages is described in Section 3.[7] Section 4 describes the calibration and estimation strategy, while Section 5 compares the fit of the model under the two labor market frictions, discusses the role of search frictions in amplifying and propagating various types of shocks, and provides an analysis of the forecasting performance of the different models. Finally, section 6 concludes.

2 An NK-SOE Model with Search and Matching

This section presents our NK-SOE model with nominal and real rigidities, and search and matching à la Diamond (1982), Mortensen (1982) and Pissarides (1985) with endogenous separations in the labor market, following Cooley and Quadrini (1999) and den Haan et al. (2000). The core model shares the structure of the baseline NK-SOE model presented in García-Cicco, Kirchner, and Justel (2015).[8] Domestic goods are produced with capital and labor, there is habit formation in consumption, there are adjustment costs in investment, firms face a Calvo-pricing problem with partial indexation, and there is imperfect exchange rate pass-through into import prices in the short run due to local currency price stickiness. The economy also exports an exogenous endowment of a commodity good, which captures the importance of commodity exports in many small open economies including Chile. The economy is subject to shocks to preferences, match

[6]A few recent studies have investigated the implications of search frictions in an emerging market context, including Boz, Durdu, and Li (2015) and Medina and Naudon (2012). However, these studies are based on calibrated models that abstract from nominal rigidities as well as the intensive margin and endogenous separations, unlike in our paper.

[7]The equilibrium conditions and the strategy for the steady state for both models are provided in the appendix.

[8]The model is a shrinked-down version of the Medina and Soto (2007) model used for policy analysis and forecasting at the Central Bank of Chile.

efficiency, technology (neutral and investment-specific), commodity production, government expenditures, monetary policy, foreign demand, foreign inflation, foreign interest rates and the international price of the commodity good.

2.1 Households

There is a continuum of infinitely lived households normalized to one with identical asset endowments and identical preferences. Household members can be either employed or unemployed. All members pool their assets so as to ensure equal consumption, that is, there is perfect insurance of unemployment risk. Each member has the following separable utility function with habit formation:[9]

$$u(C_t, \check{C}_{t-1}) - g(h_t) = \frac{1}{1-\sigma}\left[\left(C_t - \varsigma \check{C}_{t-1}\right)^{1-\sigma} - 1\right] - A_{t-1}^{1-\sigma}\kappa_t \frac{h_t^{1+\phi}}{1+\phi},$$

where C_t is individual consumption of a final good, $\check{C}_t$ is aggregate consumption, h_t is hours per worker, κ_t is an exogenous shock to the disutility of labor supply, and A_t is an economy-wide stochastic trend (see below).[10,11] The parameters σ, ϕ and ς are the inverse elasticity of intertemporal substitution, the inverse Frisch elasticity of hours worked, and the degree of habit formation, respectively. The welfare function of a representative household over time is then given by[12]

$$E_t \sum_{s=0}^{\infty} \beta^s \varrho_{t+s}\left[u\left(C_{t+s}, \check{C}_{t+s-1}\right) - n_{t+s} g\left(h_{t+s}\right)\right], \tag{1}$$

where $\beta \in (0,1)$ is the intertemporal discount factor, ϱ_t is an exogenous preference shock and n_t is the number of employed household members. Note that, in equilibrium, $C_t = \check{C}_t$ for all t.

Households save and borrow by purchasing domestic currency denominated government bonds (B_t) and by trading foreign currency bonds (B_t^*) with foreign agents, both being non-state contingent assets. They also purchase an investment good (I_t) which determines next period's physical capital stock (K_t). Let r_t, r_t^* and r_t^K denote the gross real returns on B_{t-1}, B_{t-1}^* and K_t, respectively. The employed members earn a real wage of W_t per hour, while unemployed

[9] Throughout, uppercase letters denote variables containing a unit root in equilibrium (either due to technology or to long-run inflation) while lowercase letters indicate variables with no unit root. Real variables are constructed using the domestic consumption good as the numeraire. In the appendix we describe how each variable is transformed to achieve stationarity in equilibrium. Variables without time subscript denote non-stochastic steady state values in the stationary model.

[10] We assume external habit formation instead of internal habit formation as in García-Cicco, Kirchner, and Justel (2015) to simplify the analysis.

[11] The disutility of work is multiplied by $A_{t-1}^{1-\sigma}$ to maintain a balanced steady-state growth path.

[12] Under separable preferences and external habit formation, (1) results from the general specification $E_t \sum_{s=0}^{\infty} \beta^s \varrho_{t+s}\left[n_{t+s} u\left(C_{t+s}^n, \check{C}_{t+s-1}\right) - n_{t+s} g\left(h_{t+s}\right) + (1-n_{t+s}) u\left(C_{t+s}^u, \check{C}_{t+s-1}\right)\right]$ since, in equilibrium, $C_t^n = C_t^u$ for all t.

members earn an amount b_t^u of unemployment benefits, which is paid out by the government.[13] Let rer_t be the real exchange rate (i.e. the price of foreign consumption goods in terms of domestic consumption goods), let T_t denote real lump-sum tax payments to the government and let Σ_t collect real dividend income from the ownership of firms. The period-by-period budget constraint of the household is then given by

$$C_t + I_t + B_t + rer_t B_t^* + T_t = W_t h_t n_t + (1 - n_t) b_t^u + r_t B_{t-1} + rer_t r_t^* B_{t-1}^* + r_t^K K_{t-1} + \Sigma_t. \quad (2)$$

The physical capital stock evolves according to the law of motion:

$$K_t = (1-\delta) K_{t-1} + [1 - \Gamma(I_t / I_{t-1})] \varpi_t I_t, \qquad \delta \in (0,1], \quad (3)$$

where I_t denotes investment expenditures and

$$\Gamma\left(\frac{I_t}{I_{t-1}}\right) = \frac{\gamma}{2}\left(\frac{I_t}{I_{t-1}} - \bar{a}\right)^2, \qquad \gamma \geq 0, \qquad \bar{a} \geq 1,$$

are convex investment adjustment costs. The variable ϖ_t is an investment shock that captures changes in the efficiency of the investment process.[14] The household chooses C_t, I_t, K_t, B_t, and B_t^* to maximize (1) subject to (2)-(3), taking W_t, h_t, n_t, r_t, r_t^*, r_t^K, rer_t, T_t, Σ_t, B_{t-1}, B_{t-1}^* and K_{t-1} as given. The household's labor supply choice (h_t and n_t) is determined as the outcome of a bargaining process over hours and wages (see below).

The nominal interest rates are implicitly defined as

$$r_t = R_{t-1} \pi_t^{-1}, \qquad r_t^* = R_{t-1}^* \xi_{t-1} \left(\pi_t^*\right)^{-1},$$

where $\pi_t = P_t / P_{t-1}$ and $\pi_t^* = P_t^* / P_{t-1}^*$ denote the gross inflation rates of the domestic and foreign consumption-based price indices P_t and P_t^*, respectively. The variable ξ_{t-1} denotes a country premium given by (see Schmitt-Grohé and Uribe, 2003):

$$\xi_t = \bar{\xi} \exp\left[-\psi \frac{rer_t B_t^* / A_{t-1} - rer \times b^*}{rer \times b^*} + \frac{\zeta_t^o - \zeta^o}{\zeta^o} + \frac{\zeta_t^u - \zeta^u}{\zeta^u}\right], \qquad \psi > 0, \qquad \bar{\xi} \geq 1,$$

where ζ_t^o and ζ_t^u are exogenous shocks to the country premium, where we assume that ζ_t^o is observable while ζ_t^u is unobservable. The foreign nominal interest rate R_t^* evolves exogenously, whereas the domestic central bank sets R_t.

[13] We allow unemployment benefits to grow proportionately with A_{t-1} in order to maintain a balanced steady-state growth path. Then, $b_t^u = \bar{b} A_{t-1}$ with $\bar{b} \geq 0$.

[14] See Greenwood, Hercowitz, and Krusell (1997) and Justiniano, Primiceri, and Tambalotti (2011).

2.2 Labor Market

2.2.1 Labor Market Flows

The labor market is subject to Diamond-Mortensen-Pissarides-type search frictions and matching. In order to form new employment relationships (matches), workers must search and firms must post vacancies. We assume that all unemployed workers look for jobs. The number of matches in period t is given by the matching function $\mathcal{M}_t = m_t v_t^{1-\mu}(u_t^s)^{\mu}$, where u_t^s is the number of searching workers, v_t is the number of vacancies posted, m_t is an exogenous match efficiency parameter and $\mu \in (0,1)$ is the match elasticity. The timing of the model is as follows.[15] At the beginning of each period, before new matches are formed, a fraction ρ^x of existing matches terminate for exogenous reasons. Then, matching takes place. The jobs that do not separate exogenously and new matches may separate endogenously, before production starts, if the firm's operating cost $\widetilde{c}_t$ is greater than an endogenously determined threshold $\underline{c}_t$.[16] This operating cost is assumed to be i.i.d. across firms and time with c.d.f. $F(\cdot)$. The endogenous separation rate is therefore $\rho_t^n = \Pr(\widetilde{c}_t > \underline{c}_t) = 1 - F(\underline{c}_t)$, implying the job destruction or total separation rate $\rho_t = \rho^x + (1-\rho^x)\rho_t^n$. The evolution of aggregate employment is then given by $n_t = (1-\rho_t)n_{t-1} + (1-\rho_t^n)\mathcal{M}_t$, and the number of unemployed workers at the end of period t is $u_t = 1 - n_t$. This is different from the number of searching workers which is given by $u_t^s = u_{t-1} + \rho_t n_{t-1}$. The probability that a searching worker is matched to a new job is then $s_t = (1-\rho_t^n)\mathcal{M}_t/u_t^s$, while the probability that a firm fills a vacancy is $e_t = (1-\rho_t^n)\mathcal{M}_t/v_t$.

2.2.2 Bargaining over Wages and Hours

Real wages and hours per worker are determined through Nash bargaining. On the firm side, the value of an open vacancy $\mathcal{V}_t^V$ is given by an exogenous vacancy posting cost ω_t, plus the value of filling the vacancy with probability e_t conditional on having the job not severed endogenously or, otherwise, the discounted continuation value of an open vacancy in the next period:

$$\mathcal{V}_t^V = -\omega_t + e_t \int_0^{\underline{c}_t} \mathcal{V}_t^J(\widetilde{c}_t)\frac{dF(\widetilde{c}_t)}{F(\underline{c}_t)} + (1-e_t)E_t\Xi_{t,t+1}\mathcal{V}_{t+1}^V, \tag{4}$$

where $\Xi_{t,t+1}$ is the firm's stochastic discount factor for real payoffs.[17] The value of a filled job $\mathcal{V}_t^J$ given a draw $\widetilde{c}_t$ is equal to the firm's current-period profit generated by the worker (i.e. revenue

[15] Our timing assumptions are such that employment may adjust instantaneously along all relevant margins, as in Christoffel et al. (2009).

[16] We assume additive idiosyncratic operating costs as in Cooley and Quadrini (1999) to avoid excessive cross-sectional heterogeneity in hours per worker, which would result from a specification as in den Haan et al. (2000) with a multiplicative idiosyncratic productivity shock in the production function.

[17] As the firms are owned by the households, the stochastic discount factor satisfies $\Xi_{t,t+s} \equiv \beta^s(\varrho_{t+s}/\varrho_t)(\Lambda_{t+s}/\Lambda_t)$, for $s \geq 0$.

minus production costs), plus the discounted continuation values of having the job is severed next period (with probability ρ_{t+1}) or having it is not severed (with probability $1-\rho_{t+1}$):

$$\mathcal{V}_t^J(\widetilde{c}_t) = p_t^m mpn_t - W_t^n(\widetilde{c}_t)h_t - A_{t-1}\widetilde{c}_t + E_t\Xi_{t,t+1}\left[\begin{array}{c}(1-\rho_{t+1})\int_0^{\underline{c}_{t+1}}\mathcal{V}_{t+1}^J(\widetilde{c}_{t+1})\frac{dF(\widetilde{c}_{t+1})}{F(\underline{c}_{t+1})}\\ +\rho_{t+1}\mathcal{V}_{t+1}^V\end{array}\right], \quad (5)$$

where p_t^m is the relative price of wholesale goods in terms of the final good, mpn_t is the marginal product of the worker and W_t^n is the negotiated wage. On the worker side, the value of being employed in a job $\mathcal{V}_t^E$ with idiosyncratic operating cost $\widetilde{c}_t$ is equal to the worker's current-period benefit from the job (i.e. the wage payment plus the marginal rate of substitution between n_t and C_t), plus the discounted continuation values of remaining on the job or being separated and finding a new job in the next period (with probability $1-\rho_{t+1}(1-s_{t+1})$) or being separated and remaining unemployed next period (with probability $\rho_{t+1}(1-s_{t+1})$):

$$\mathcal{V}_t^E(\widetilde{c}_t) = W_t^n(\widetilde{c}_t)h_t - \frac{g(h_t)}{\Lambda_t} + E_t\Xi_{t,t+1}\left[\begin{array}{c}(1-\rho_{t+1}(1-s_{t+1}))\int_0^{\underline{c}_{t+1}}\mathcal{V}_{t+1}^E(\widetilde{c}_{t+1})\frac{dF(\widetilde{c}_{t+1})}{F(\underline{c}_{t+1})}\\ +\rho_{t+1}(1-s_{t+1})\mathcal{V}_{t+1}^U\end{array}\right], \quad (6)$$

where Λ_t is the household's marginal utility of consumption. The value of being unemployed $\mathcal{V}_t^U$ is equal to the current unemployed benefit, plus the discounted continuation values of finding a job conditional on having the match not severed next period with probability s_{t+1} or, otherwise, remaining unemployed:

$$\mathcal{V}_t^U = b_t^u + E_t\Xi_{t,t+1}\left[s_{t+1}\int_0^{\underline{c}_{t+1}}\mathcal{V}_{t+1}^E(\widetilde{c}_{t+1})\frac{dF(\widetilde{c}_{t+1})}{F(\underline{c}_{t+1})} + (1-s_{t+1})\mathcal{V}_{t+1}^U\right]. \quad (7)$$

A free entry condition applies for firms, which implies $\mathcal{V}_t^V = 0$ for all t. Thus, we obtain from (4) and (5) respectively that

$$\int_0^{\underline{c}_t}\mathcal{V}_t^J(\widetilde{c}_t)\frac{dF(\widetilde{c}_t)}{F(\underline{c}_t)} = \frac{\omega_t}{e_t}, \quad (8)$$

and

$$\mathcal{V}_t^J(\widetilde{c}_t) = p_t^m mpn_t - W_t(\widetilde{c}_t)h_t - A_{t-1}\widetilde{c}_t + E_t\Xi_{t,t+1}(1-\rho_{t+1})\frac{\omega_{t+1}}{e_{t+1}}. \quad (9)$$

Firms and workers choose the real wage $W_t^n(\widetilde{c}_t)$ and hours h_t to maximize the Nash product:

$$\max_{W_t^n, h_t}(\mathcal{V}_t^E(\widetilde{c}_t) - \mathcal{V}_t^U)^{\varphi}(\mathcal{V}_t^J(\widetilde{c}_t))^{1-\varphi},$$

where the first term is the worker's surplus and the second is the firm's surplus, while $\varphi \in (0,1)$ is the worker's relative bargaining power. The first-order conditions for $W_t^n(\widetilde{c}_t)$ and h_t imply that

$$p_t^m \frac{\partial mpn_t}{\partial h_t} = \frac{g'(h_t)}{\Lambda_t}.$$

This equation implicitly defines the amount of hours per worker. It shows that in equilibrium the marginal productivity of an extra worker-hour is equal to the marginal rate of substitution between h_t and C_t. Now, the first-order condition for $W_t^n(\widetilde{c}_t)$ implies that

$$(1-\varphi)\left(\mathcal{V}_t^E(\widetilde{c}_t) - \mathcal{V}_t^U\right) = \varphi \mathcal{V}_t^J(\widetilde{c}_t). \tag{10}$$

Using (6)-(9) in (10), taking expectations conditional on having $\widetilde{c}_t \leq \underline{c}_t$ and using $s_t/e_t = v_t/u_t^s$ yields the wage equation of an individual worker:

$$W_t^n(\widetilde{c}_t)h_t = \varphi\left[p_t^m mpn_t - A_{t-1}\widetilde{c}_t + E_t\Xi_{t,t+1}(1-\rho_{t+1})\omega_{t+1}\frac{v_{t+1}}{u_{t+1}^s}\right] + (1-\varphi)\left(b_t^u + \frac{g(h_t)}{\Lambda_t}\right). \tag{11}$$

It expresses the wage payment to the worker as a weighted average, according to the relative bargaining power of the worker and the firm, between the marginal product of the worker minus operating costs plus the cost of replacing the worker if that worker survives the exogenous job destruction shock (weighted by the relative probability of finding a job and replacing the worker, i.e. labor market tightness), and the outside option of the worker.

The aggregate real Nash wage is the average of (11) over the distribution of idiosyncratic costs:

$$W_t^n h_t = \varphi\left[p_t^m mpn_t - H(\underline{c}_t) + E_t\Xi_{t,t+1}(1-\rho_{t+1})\omega_{t+1}\frac{v_{t+1}}{u_{t+1}^s}\right] + (1-\varphi)\left(b_t^u + \frac{g(h_t)}{\Lambda_t}\right)$$

where $H(\underline{c}_t)$ is the average operating cost. In order to allow for some degree of nominal wage stickiness through indexation, following Hall (2005), we assume that the effective nominal wage paid to the worker is a weighted average of the inflation-indexed past nominal wage and the Nash wage, with weights $\varkappa_W \in [0,1)$ and $1-\varkappa_W$ respectively:[18]

$$P_t W_t = \varkappa_W \Gamma_{t-1}^W P_{t-1} W_{t-1} + (1-\varkappa_W) P_t W_t^n,$$

where Γ_t^W is a wage indexation variable that satisfies $\Gamma_t^W = (A_t/A_{t-1})^{\alpha_W}\, \pi_t^{\vartheta_W} \bar{\pi}^{1-\vartheta_W}$, where $\bar{\pi}$ is target inflation.[19] The critical threshold at which jobs are destroyed endogenously is implicitly

[18] Hall (2005) considers real wage inertia while we consider nominal wage inertia with indexation to account for the importance of inflation indexation of nominal wages in many emerging market economies including Chile. In order to keep the model simple, we do not adopt a more sophisticated specification of wage stickiness as Gertler and Trigari (2009) and Gertler, Sala, and Trigari (2008) or Christiano, Eichenbaum, and Trabandt (2015).

[19] The parameter α_W controls whether wages are indexed to the stochastic trend ($\alpha_W = 1$), as is typically the

defined by $\mathcal{V}_t^J(\underline{c}_t) = 0$.[20] Using this condition with (9) and (11), we obtain

$$A_{t-1}\underline{c}_t = p_t^m mpn_t - b_t^u - \frac{g(h_t)}{\Lambda_t} + E_t\Xi_{t,t+1}(1-\rho_{t+1})\frac{1-\varphi s_{t+1}}{1-\varphi}\frac{\omega_{t+1}}{e_{t+1}}.$$

Note that a higher marginal product of the worker increases $\underline{c}_t$ (i.e. ρ_t^n decreases) while an increase in the worker's outside option decreases $\underline{c}_t$ (i.e. ρ_t^n increases).

2.3 Firms

There are different types of firms that are all owned by the households. There is a set of perfectly competitive wholesale firms that produce different varieties of a home good with labor and capital as inputs, a set of monopolistically competitive retail firms that buy and re-sell those varieties, a set of monopolistically competitive importing firms, and three groups of perfectly competitive aggregators: one packing different varieties of the home good into a composite home good, one packing imported varieties into a composite foreign good, and another one that bundles the composite home and foreign goods to create a final good. This final good is purchased by households (C_t, I_t) and the government (G_t).[21] In addition, there is a set of competitive firms producing a homogeneous commodity good that is exported abroad. A proportion of those commodity-exporting firms is owned by the government and the remaining proportion is owned by foreign agents. The total mass of firms in each sector is normalized to one. Throughout, we denote productions/supply with the letter Y and inputs/demand with X.

2.3.1 Final Goods

A representative final goods firm demands composite home and foreign goods in the amounts X_t^H and X_t^F, respectively, and combines them according to the technology

$$Y_t^C = \left[(1-o)^{\frac{1}{\eta}}\left(X_t^H\right)^{\frac{\eta-1}{\eta}} + o^{\frac{1}{\eta}}\left(X_t^F\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \qquad o \in (0,1), \qquad \eta > 0. \tag{12}$$

Let p_t^H and p_t^F denote the relative prices of X_t^H and X_t^F in terms of the final good. Subject to (12), the firm maximizes its profits $\Pi_t^C = Y_t^C - p_t^H X_t^H - p_t^F X_t^F$ over the input demands X_t^H and X_t^F taking p_t^H and p_t^F as given.

case in models with Calvo wages, or not ($\alpha_W = 0$).

[20] The joint surplus of a match is given by $\mathcal{V}_t^S(\widetilde{c}_t) = \mathcal{V}_t^J(\widetilde{c}_t) + \mathcal{V}_t^E(\widetilde{c}_t) - \mathcal{V}_t^U$. A match is endogenously separated whenever $\mathcal{V}_t^S(\widetilde{c}_t) \leq 0$ which is equivalent to $\mathcal{V}_t^J(\widetilde{c}_t) \leq 0$.

[21] The final good is also used to pay vacancy posting and operating costs.

2.3.2 Home Composite Goods

A representative home composite goods firm demands home goods of all varieties $j \in [0,1]$ in amounts $X_t^H(j)$ and combines them according to the technology

$$Y_t^H = \left[\int_0^1 X_t^H(j)^{\frac{\epsilon_H - 1}{\epsilon_H}} dj\right]^{\frac{\epsilon_H}{\epsilon_H - 1}}, \qquad \epsilon_H > 0. \tag{13}$$

Let $p_t^H(j)$ denote the price of the good of variety j in terms of the home composite good. Subject to (13), the firm maximizes its profits $\Pi_t^H = p_t^H Y_t^H - \int_0^1 p_t^H p_t^H(j) X_t^H(j) dj$ over the input demands $X_t^H(j)$ taking the relative prices p_t^H and $p_t^H(j)$ as given, which yields the input demand functions

$$X_t^H(j) = p_t^H(j)^{-\epsilon_H} Y_t^H, \quad \text{for all } j. \tag{14}$$

2.3.3 Wholesale Goods of Variety j and the Job Creation Condition

Wholesale goods of variety j are produced according to the technology

$$Y_t^H(j) = z_t K_{t-1}(j)^{\alpha}[A_t n_t(j) h_t(j)]^{1-\alpha}, \qquad \alpha \in [0,1), \tag{15}$$

where z_t is an exogenous stationary neutral technology shock, while A_t (with $a_t \equiv A_t/A_{t-1}$) is a non-stationary labor-augmenting technology trend, both common to all varieties. The wholesale firms chooses how much capital to rent and how much labor to hire, subject to a identical vacancy posting cost of ω_t per vacancy and firm-specific operating cost per worker $\widetilde{c}_t(j)$ (these costs are assumed to be paid in terms of final goods). Letting $p_t^m(j)$ denote the relative price of wholesale good j in terms of the final good, firm j's profit is given by

$$\Pi_t^m(j) = p_t^m(j) Y_t^H(j) - r_t^K K_{t-1}(j) - W_t h_t(j) n_t(j) - \mathcal{C}_t(j) - \mathcal{L}_t(j),$$

where

$$\mathcal{C}_t(j) = n_t(j) A_{t-1} \kappa_{\widetilde{c}} \int_0^{\underline{c}_t(j)} \widetilde{c}_t(j) \frac{dF(\widetilde{c}_t(j))}{F(\underline{c}_t(j))} = n_t(j) H(\underline{c}_t(j)),$$

is the total operating cost of firm j conditional on working with $\kappa_{\widetilde{c}} \geq 0$, while $\mathcal{L}_t(j) = \omega_t v_t(j)$ is the vacancy posting cost with $\omega_t = \omega A_{t-1}$, $\omega \geq 0$.[22] The firm's workforce evolves over time as the number of workers whose jobs do not get terminated plus new hires:

$$n_t(j) = (1-\rho_t) n_{t-1}(j) + e_t v_t(j). \tag{16}$$

[22]We allow operating costs and vacancy posting costs to grow proportionately with the technology trend to maintain a balanced steady-state growth path.

Since today's choice of $v_t(j)$ affects tomorrow's workforce, the firm faces an intertemporal decision problem to maximize expected discounted profits. Hence, the firm chooses $K_{t-1}(j)$, $n_t(j)$ and $v_t(j)$ to maximize $E_t \sum_{s=0}^{\infty} \Xi_{t,t+s} \Pi_{t+s}^m(j)$ subject to (15) and (16). The first-order conditions for this problem yield the job creation condition:[23]

$$\frac{\omega_t}{e_t} = p_t^m mpn_t - H(\underline{c}_t) - W_t h_t + E_t \Xi_{t,t+1}(1-\rho_{t+1})\frac{\omega_{t+1}}{e_{t+1}}.$$

That is, firms post vacancies to expand employment until the effective cost of posting an additional vacancy (ω_t times the expected duration of the vacancy $1/e_t$) equals the marginal product of an extra worker plus the production costs plus its expected return from the reduction of vacancy posting costs if the job survives job destruction in period $t+1$.

2.3.4 Retail Goods of Variety j

Retail firms buy and distribute wholesale goods. There is one retailer associated with each variety of the wholesale good. The retailer distributing variety j satisfies the demand given by (14) but it has monopoly power for its variety. Given nominal marginal costs $P_t^H mc_t^H(j) = P_t p_t^m(j) = P_t p_t^m$, the firm chooses its price $P_t^H(j)$ to maximize profits.[24] In setting prices, the firm faces a Calvo-type problem, whereby each period it can change its price optimally with probability $1-\theta_H$, and if it cannot optimally change its price, it indexes its previous price according to a weighted product of past and steady state inflation with weights $\vartheta_H \in [0,1]$ and $1-\vartheta_H$.

2.3.5 Foreign Composite Goods

A representative foreign composite goods firm demands foreign goods of all varieties $j \in [0,1]$ in amounts $X_t^F(j)$ and combines them according to the technology

$$Y_t^F = \left[\int_0^1 X_t^F(j)^{\frac{\epsilon_F - 1}{\epsilon_F}} dj\right]^{\frac{\epsilon_F}{\epsilon_F - 1}}, \qquad \epsilon_F > 0. \tag{17}$$

Let $p_t^F(j)$ denote the price of the good of variety j in terms of the foreign composite good. Subject to (17), the firm maximizes its profits $\Pi_t^F = p_t^F Y_t^F - \int_0^1 p_t^F p_t^F(j) X_t^F(j) dj$ over the input demands $X_t^F(j)$ taking the relative prices p_t^F and $p_t^F(j)$ as given. The first-order conditions yields the input demand functions:

$$X_t^F(j) = p_t^F(j)^{-\epsilon_F} Y_t^F, \quad \text{for all } j. \tag{18}$$

[23]We drop subscripts j due to symmetry.

[24]Note that $mc_t^H(j)$ is real marginal cost expressed in terms of home composite goods prices.

2.3.6 Foreign Goods of Variety j

Importing firms buy an amount M_t of a homogenous foreign good at the price P_t^{F*} in the world market and convert this good into varieties $Y_t^F(j)$ that are sold domestically, where $M_t = \int_0^1 Y_t^F(j)dj$. The firm producing variety j satisfies the demand given by (18) but it has monopoly power for its variety. As it takes one unit of the foreign good to produce one unit of variety j, nominal marginal costs in terms of composite goods prices are

$$P_t^F mc_t^F(j) = P_t^F mc_t^F = S_t P_t^{F*}, \tag{19}$$

where S_t is the nominal exchange rate (defined as the price of one unit of foreign currency in terms of domestic currency). Given marginal costs, the firm producing variety j chooses its price $P_t^F(j)$ to maximize profits. In setting prices, the firm faces a Calvo-type problem, whereby each period it can change its price optimally with probability $1-\theta_F$, and if it cannot optimally change its price, it indexes its previous price according to a weighted product of past and steady state inflation with weights $\vartheta_F \in [0,1]$ and $1-\vartheta_F$. In this way, the model features delayed pass-trough from international to domestic prices.

2.3.7 Commodities

A representative commodity producing firm produces a quantity of a commodity good Y_t^{Co} in each period. Commodity production evolves exogenously according to the process

$$\log(Y_t^{Co}/A_{t-1}) = (1-\rho_{y^{Co}})\log(\bar{y}^{Co}) + \rho_{y^{Co}}\log(Y_{t-1}^{Co}/A_{t-2}) + \varepsilon_t^{y^{Co}}, \qquad \rho_{y^{Co}} \in [0,1), \qquad \bar{y}^{Co} > 0.$$

The entire production is sold abroad at a given international price P_t^{Co*}. The real foreign and domestic prices are denoted as p_t^{Co*} and p_t^{Co}, respectively, where p_t^{Co*} is assumed to evolve exogenously. The real domestic currency income generated in the commodity sector is therefore equal to $p_t^{Co}Y_t^{Co}$. The government receives a share $\chi \in [0,1]$ of this income and the remaining share goes to foreign agents.

2.4 Fiscal and Monetary Policy

The government consumes an exogenous stream of final goods (G_t), pays unemployment benefits, levies lump-sum taxes, issues one-period bonds and receives a share of the income generated in the commodity sector. We assume for simplicity that the public asset position is completely denominated in domestic currency. Hence, the government satisfies the following period-by-period constraint

$$G_t + b_t^u u_t + r_t B_{t-1} = T_t + B_t + \chi p_t^{Co} Y_t^{Co}.$$

Monetary policy is carried out according to a Taylor rule of the form

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\bar{\pi}}\right)^{\alpha_\pi} \left(\frac{Y_t/Y_{t-1}}{a_{t-1}}\right)^{\alpha_y}\right]^{1-\rho_R} \exp(\varepsilon_t^R),$$

where R is the monetary policy rate in the long-run, $\bar{\pi}$ is target inflation and ε_t^R is an n.i.d. shock that captures deviations from the rule.

2.5 Rest of the World

Foreign agents demand home composite goods and buy the domestic commodity production. There are no transaction costs or other barriers to trade. The structure of the foreign economy is identical to the domestic economy, but the domestic economy is assumed to be small relative to the foreign economy. The latter implies that the foreign producer price level P_t^{F*} is identical to the foreign consumption-based price index P_t^*. Further, let P_t^{H*} denote the price of home composite goods expressed in foreign currency. Given full tradability and competitive export pricing, the law of one price holds separately for home composite goods and the commodity good, i.e. $P_t^H = S_t P_t^{H*}$ and $P_t^{Co} = S_t P_t^{Co*}$. That is, domestic and foreign prices of both goods are identical when expressed in the same currency. Due to local currency pricing, a weak form of the law of one price holds for foreign composite goods, i.e. $P_t^F mc_t^F = S_t P_t^{F*}$ from (19). The real exchange rate rer_t therefore satisfies

$$rer_t = \frac{S_t P_t^*}{P_t} = \frac{S_t P_t^{F*}}{P_t} = \frac{P_t^F mc_t^F}{P_t} = p_t^F mc_t^F,$$

and the commodity price in terms of domestic consumption goods is given by

$$p_t^{Co} = \frac{P_t^{Co}}{P_t} = \frac{S_t P_t^{Co*}}{P_t} = \frac{S_t P_t^*}{P_t} p_t^{Co*} = p_t^F p_t^{Co*}.$$

We also have the relation $rer_t/rer_{t-1} = \pi_t^S \pi_t^* / \pi_t$,where $\pi_t^S = S_t/S_{t-1}$. Further, foreign demand for the home composite good X_t^{H*} is given by the schedule

$$X_t^{H*} = o^* \left(\frac{P_t^{H*}}{P_t^*}\right)^{-\eta^*} Y_t^*, \qquad o^* \in (0,1), \qquad \eta^* > 0,$$

where Y_t^* denotes foreign aggregate demand or GDP. Both Y_t^* and π_t^* evolve exogenously.

2.6 Aggregation and Market Clearing

Taking into account the market clearing conditions for the different markets, we can define the trade balance in units of final goods as

$$TB_t = p_t^H X_t^{H*} + rer_t p_t^{Co*} Y_t^{Co} - rer_t IMP_t,$$

Further, we define real GDP as follows:

$$Y_t \equiv C_t + I_t + G_t + X_t^{H*} + Y_t^{Co} - IMP_t.$$

Then, the GDP deflator (p_t^Y, expressed as a relative price in terms of the final consumption good) is implicitly defined as

$$p_t^Y Y_t = C_t + I_t + G_t + TB_t.$$

Finally, we can show that the net foreign asset position evolves according to

$$rer_t B_t^* = rer_t r_t^* B_{t-1}^* + TB_t - (1-\chi) rer_t p_t^{Co*} Y_t^{Co}.$$

2.7 Driving Forces

For each exogenous variable in the model, we assume a process of the form

$$\log(x_t/\bar{x}) = F_x \log(x_{t-1}/\bar{x}) + \varepsilon_t^x, \qquad F_x \in [0,1), \qquad \bar{x} > 0,$$

for $x = \{\varrho, \kappa, m, \varpi, z, a, \zeta^o, \zeta^u, R^*, \pi^*, p^{Co*}, y^{Co}, y^*, g\}$, where the ε_t^x are n.i.d. shocks. We further assume that the idiosyncratic shock $\widetilde{c}_t$ is log-normally distributed with mean 0 and standard deviation $\sigma_{\widetilde{c}}$.[25]

3 The Model with Calvo Wages

This section briefly describes the model with monopolistic wage setting à la Calvo, following Schmitt-Grohé and Uribe (2006, 2007). Most of the model is identical to the model with search frictions. The differences are discussed below.

[25] Several alternative distributions of the idiosyncratic shock have been used in the literature. Mortensen and Pissarides (1994) use a uniform distribution on the interval $[-1, 1]$ for the idiosyncratic shock. Den Haan et al. (2000) and Walsh (2005) use a log-normal distribution with mean 0. Guerrieri (2008) considers shocks distributed according to uniform, Pareto and log-normal distributions and finds no significant difference. Similarly, Tortorice (2013) finds that there is very little difference when using the uniform distribution in comparison to the log-normal distribution. Hence, we simply follow most of the literature and use a log-normal distribution.

3.1 Households

Expected discounted utility of a representative household is given by

$$E_t \sum_{s=0}^{\infty} \beta_{t+s}^{s} \varrho_{t+s} \left[\frac{1}{1-\sigma} \left(C_{t+s} - \varsigma C_{t+s-1} \right)^{1-\sigma} - \kappa A_{t+s-1}^{1-\sigma} \frac{h_{t+s}^{1+\phi}}{1+\phi} \right]. \tag{20}$$

The period-by-period budget constraint of the household is given by

$$C_t + I_t + B_t + rer_t B_t^* + T_t = W_t h_t + r_t B_{t-1} + rer_t r_t^* B_{t-1}^* + r_t^K K_{t-1} + \Sigma_t. \tag{21}$$

The household chooses C_t, I_t, K_t, B_t, and B_t^* to maximize (20) subject to (21) and the capital stock level, taking r_t, r_t^*, r_t^K, rer_t, T_t, Σ_t, B_{t-1}, B_{t-1}^* and K_{t-1} as given.

3.2 Labor Union

Following Schmitt-Grohé and Uribe (2006, 2007), labor decisions are made by a central authority, a union, which supplies labor monopolistically to a continuum of labor markets indexed by $i \in [0,1]$. Households are indifferent between working in any of these markets. In each market, the union faces a demand for labor given by $h_t(i) = [W_t^n(i)/W_t^n]^{-\epsilon_W} h_t^d$, where $W_t^n(i)$ denotes the nominal wage charged by the union in market i, W_t^n is an aggregate hourly wage index that satisfies $(W_t^n)^{1-\epsilon_W} = \int_0^1 W_t^n(i)^{1-\epsilon_W} di$, and h_t^d denotes aggregate labor demand by firms. The union takes W_t^n and h_t^d as given and, once wages are set, it satisfies all labor demand. In addition, the total number of hours allocated to the different labor markets must satisfy the resource constraint $h_t = \int_0^1 h_t(i)di$. Wage setting is subject to a Calvo-type problem, whereby each period the household (or union) can set its nominal wage optimally in a fraction $1-\theta_W$ of randomly chosen labor markets, and in the remaining markets, the past wage rate is indexed to a weighted product of past and steady state inflation with weights $\vartheta_W \in [0,1]$ and $1-\vartheta_W$.

3.3 Wholesale Goods of Variety j

Wholesale goods of variety j are produced according to the technology

$$Y_t^H(j) = z_t K_{t-1}(j)^{\alpha} [A_t h_t^d(j)]^{1-\alpha}, \qquad \alpha \in [0,1). \tag{22}$$

Firm j's profit is given by $\Pi_t^m(j) = p_t^m(j) Y_t^H(j) - r_t^K K_{t-1}(j) - W_t h_t^d(j)$. The firm chooses $K_{t-1}(j)$ and $h_t^d(j)$ to maximize $\Pi_t^m(j)$ subject to (22). From the labor market clearing conditions we then obtain that $h_t = h_t^d \Delta_t^W$ in equilibrium, where Δ_t^W is a wage dispersion term.

3.4 Driving Forces

The Calvo wages model abstracts from matching shock (m_t).

4 Parametrization Strategy

Our empirical strategy combines both calibrated and estimated parameters. The calibrated parameters and targeted steady state values are presented in Table 1. For most of the parameters not related with the search frictions we draw from related studies for Chile, as indicated in the table, while others are endogenously determined in steady state to target some first moments ($\bar{\pi}^*$, $\bar{\kappa}$, o^*, $\bar{g}$ and $\bar{y}^{Co}$). The parameters that deserve additional explanation are those related to the search frictions: ω (the vacancy posting cost), $\bar{b}$ (the unemployment benefit), $\mu_{\tilde{c}}$ and $\kappa_{\tilde{c}}$ (the parameters of the stochastic operating cost), ρ^x (the exogenous separation rate), and φ (the workers' bargaining weight). The values of those parameters are either chosen to match observed statistics and available evidence for Chile, or following related studies for other countries.

[Table 1 here.]

We derive the vacancy posting cost (ω) from the steady state calculations to match an average unemployment rate (u) of around 8 percent between 1987 and 2014.[26] The implied vacancy cost to GDP ratio is approximately 4 percent, which is close to the value in Trigari (2009). The unemployment benefit ($\bar{b}$) is set to 0 based on OECD data.[27] Following Cooley and Quadrini (1999), den Haan et al. (2000) and other related studies, we set the probability of filling a vacancy in steady state (e) to 0.7 and derive the average match efficiency parameter $\bar{m}$ from the steady state calculations. The resulting value of $\bar{m}$ is approximately 0.5. We further fix the total separation rate in steady state (ρ) based on evidence reported by Jones and Naudon (2009), who calculate quarterly labor status transition probabilities from micro survey data for Chile and find a probability of changing status from employed to unemployed, $p^{E,U}$, of about 0.04 as well as a probability of changing status from unemployed to employed, $p^{U,E}$, of about 0.47. These probabilities imply a value for ρ of approximately 7.5 percent, which is at the lower end of the range of quarterly U.S. worker separation rates of 8 to 10 percent reported by Hall (1995) and the values typically used in the literature.[28] Following den Haan et al. (2000), the exogenous separation rate (ρ^x) is then set to two thirds times the total separation rate. We further normalize the log-normal mean of the firm's operating cost to 0 and derive the scaling

[26] The average unemployment rate over the sample period from 2001Q3 to 2015Q2 was also about 8 percent.

[27] See `https://data.oecd.org/socialexp/public-unemployment-spending.htm`.

[28] The value of ρ is calculated from (6) which implies that $p^{E,U} = \rho(1 - p^{U,E})$ in steady state, such that $\rho = p^{E,U}/(1 - p^{U,E}) \approx 0.0755$.

parameter $\kappa_{\tilde{c}}$ from the steady state calculations in order to match the targeted value of ρ. The workers' bargaining weight (φ) is set to 0.5, following the related literature.

We also calibrate the parameters characterizing those exogenous processes for which we have a data counterpart. In particular, for g we use linearly detrended real government consumption, for y^{Co} we use linearly detrended real mining production in the copper sector, for R^* we use the 3-month U.S. dollar London Interbank Offered Rate, for y^* we use linearly detrended real GDP of commercial partners while for π^* we use CPI inflation (in dollars) of commercial partners (both trade-weighted), and for p^{Co*} we use the price of refined copper at the London Metals Exchange (in dollars) deflated by the same price index used to construct π^*.[29]

The other parameters of the model were estimated using Bayesian techniques, solving the model with a log-linear approximation around the non-stochastic steady state. The list of these parameters and the priors are described in columns one to five of Table 4.[30] Because we estimate two different versions of the model, we used different data sets for each model. In both cases, the following variables were used (all for the inflation targeting sample from 2001Q3 to 2015Q2): the growth rates of real GDP, private consumption and investment, the CPI inflation rate, the monetary policy rate, the multilateral real exchange rate, the growth rate of real wages, total hours worked (hours per worker times employment divided by the labor force) and the EMBI Chile (which we match by the endogenous component of the country premium ξ_t plus the observed shock to the country premium ζ_t^o). We also include as observables the variables used to estimate the exogenous processes previously described.[31] In addition, for the model including search frictions, we also use as observable the unemployment rate.

Overall, we use 16 observed variables in the estimation. Our estimation strategy also includes i.i.d. measurement errors for all observables. The variance of the latter was set to 10% of the variance of the corresponding observables.

5 Results

In this section, we first assess the goodness of fit of the model under the different labor market specifications, in order to understand if and how the presence of search and matching helps to improve the ability of the model to account for the dynamics observed in the data. We then discuss the differences in the inferred parameters and compare the variance decomposition to find out which shocks are the most important drivers of the dynamics under Calvo wages

[29] The data source is the Central Bank of Chile's statistical database; see `http://si3.bcentral.cl/Siete`.

[30] The prior means were set to represent (when available) the estimates of related papers for the Chilean economy (e.g. Medina and Soto, 2007).

[31] While the parameters of these exogenous processes were calibrated, including these variables in the data set is informative for the inference of the innovations associated with these exogenous processes.

and under search frictions. In addition, we analyze the impulse responses to selected shocks to understand the propagation properties of the different labor market frictions. Finally, we compare the forecasting performance of the two model variants against each other and against reduced-form Bayesian vector autoregressive (BVAR) benchmark forecasting models.

5.1 Goodness of Fit

To have an overall measure of goodness of fit, we compute the marginal data density implied by the posterior distribution of the parameters for each model. Since the models where estimated with different data sets, the marginal data densities for the estimation samples are not comparable. We therefore compute, based on the posterior distribution for the model with search frictions, the marginal data densities of a different set of variables, excluding from the full data set (X^T) the unemployment rate (u^T). The values for the marginal data densities for the data set excluding the unemployment rate are indeed comparable. In addition, we are interested in the fit of each model for the data without the remaining two labor market variables, i.e. total hours worked ($h^T \times n^T$) and real wage growth ($\Delta \log W^T$). Thus, we have also computed the marginal data densities for those data sets. Finally, since the model with search frictions has an additional shock, the match efficiency shock (m_t), which may give this model additional degrees of freedom to match the data compared to the model with Calvo wages, we have also computed the marginal data density for the model with search frictions shutting down this shock.[32]

[Table 2 here.]

The results in Table 2 show that the overall fit of the model with search frictions is significantly better than the fit of the model with Calvo wages. This result holds for the data sets including the different labor market variables (see the second and third rows of the table), as well as the data set without the labor market variables (see the fourth row), and independently of whether the match efficiency shock is active or not. The difference between the marginal data densities is largest, more than 50 log points, for the data set that includes hours worked. The difference is still more than 30 log points for the data set that includes real wage growth as the only labor market variable. For the data set without the labor market data, the difference is smaller, about 2 log points. According to the usual scales of interpretation, this constitutes strong to very strong evidence in favor of the model with search frictions.[33] Importantly, the model with search frictions not only explains the labor market variables significantly better than the model with Calvo wages, but also the remaining macroeconomic data.

[32]The marginal data densities were computed through the Laplace approximation at the mean of the posterior distribution of the parameters.

[33]See Jeffreys (1961) and Kass and Raftery (1995).

[Table 3 here.]

To obtain a more detailed view of which variables are better matched by each model, Table 3 reports the standard deviations and first-order autocorrelation coefficients of selected variables implied by the posterior mean of the parameters, and compares these statistics with the corresponding empirical moments. In terms of the standard deviations shown in the third to fifth columns of the table, the model with search frictions matches most variables better (with a few exceptions including real GDP, private consumption and the nominal trade balance). The model with Calvo wages grossly overstates the standard deviation of hours worked, real and nominal wages and the real exchange rate. Likely related to the latter, it also overstates the standard deviation of inflation and the monetary policy rate. The autocorrelation coefficients in the sixth to eighth columns of the table show that the model with search frictions matches the empirical moments of all variables better than the model with Calvo wages. Note that the model with Calvo wages overstates the persistence of all variables.

Overall, this goodness-of-fit analysis yields as a main conclusion that the model with search frictions performs significantly better than the model with Calvo wages in terms of fitting both labor market data and other macroeconomic data. We examine next which properties of the model with search frictions can explain this difference.

5.2 Estimated Parameters and Dynamics

Columns six to nine in Table 4 display the posterior mean and the 90% highest posterior density intervals of the estimated parameters of the two model variants. We will comment on those parameters whose inference is different between the models to see how the presence of the different labor market specifications affects the results.

[Table 4 here.]

One parameter whose estimated value is different between the two models is the inverse Frisch elasticity of hours worked (ϕ), whose posterior mean is almost 30% higher in the model with search frictions. Hence, the intensive margin seems to be less important in that model compared to the model with Calvo wages. This result is in line with the findings of Christiano et al. (2011) and other calibrations of search and matching models with both margins of labor supply (e.g. Trigari, 2009). It may seem surprising that the model with Calvo wages also has a low elasticity of hours worked, since that model can only explain the observed variations in total hours through variations in individual hours (i.e. the intensive margin). The low elasticity may be due to the need to avoid large countercyclical reactions of hours worked to foreign shocks that generate strong wealth effects on labor supply.[34]

In terms of the parameters related to the nominal rigidities, both models rely on relatively large degrees of wage stickiness, as reflected by a high Calvo parameter for wages (θ_W) or a high wage inertia parameter ($\varkappa_W$). However, the degree of indexation of nominal wages to past inflation (ϑ_W) is much larger in the model with Calvo wages. Also, that model has a significantly higher Calvo parameter for home prices (θ_H) as well as a relatively low estimated reaction of monetary policy to inflation (α_π). Taken together, those results imply that both wages and inflation tend to be highly persistent in that model (see Table 3).

Other parameters that differ significantly between the two models are the ones that determine the real rigidities. In particular, the model with Calvo wages has a significantly higher degree of higher habit formation (ς) and a higher elasticity of investment adjustment costs (γ). The latter may explain the relatively large size (i.e. the estimated innovation standard deviation and autocorrelation coefficient) of the consumption preference shock (ϱ) and the investment-specific technology shock (ϖ) in that model. In addition, the model with Calvo wages seems to require a relatively large labor supply preference shock (κ).

[Table 5 here.]

However, instead of comparing the parameters of the exogenous shocks directly, it is more instructive to see how the different shocks explain aggregate fluctuations. To that end, Table 5 displays the unconditional variance decomposition obtained for each version of the model for selected variables, computed at the respective posterior mean. In the model with Calvo wages, technology shocks (and in particular investment-specific technology shocks) are the dominant driving force for most variables, followed by foreign shocks. On the other hand, in the model with search frictions foreign shocks are the most important driving force for several variables, including consumption, investment, real wages and the unemployment rate. While labor supply preference shocks are important to explain hours worked in that model, those shocks are relatively unimportant for the remaining variables.[35] In addition, match efficiency shocks explain merely up to 24% of the variance of the unemployment rate.[36] In addition, the model with search frictions attributes a larger shock to transitory TFP shocks (for most variables) and monetary policy shocks (especially for inflation).

[34]Open-economy studies sometimes address this issue by assuming preferences with a low or zero wealth effect of labor supply, such as preferences of the Greenwood, Hercowitz, and Huffman (1988) type.

[35]Since labor supply shocks are not very important to explain unemployment in the model with search frictions, we may conclude that labor supply shocks tend to explain variations in individual but not total hours worked in that model.

[36]This finding is in line with the results of Sedláçek (2014) who shows that variations in match efficiency can be explained by endogenous separations such as in our model.

Thus, the variance decomposition shows that foreign shocks become more important to explain the dynamics in the model with search frictions. Furthermore, several other shocks seem to be amplified. To better understand the properties of the model that can explain those findings, we examine next the estimated impulse responses to selected shocks. In particular, we analyze the impulse responses to a one-standard deviation stationary TFP shock (a supply shock), a domestic monetary policy shock (a demand shock) and a foreign interest rate shock (a foreign shock), which are shown in Figures 1, 2 and 3, respectively. In each figure, we compare the estimated impulse responses from the model with search frictions (blue solid lines) to the responses if we shut down the endogenous separations, i.e. $\rho_t^n = 0$ for all t (red dashed lines) and the model with Calvo wages (green dash-dotted lines).[37]

[Figures 1 and 2 here.]

Figure 1 for the stationary TFP shock shows that the search frictions amplify the responses of real GDP, private consumption and the trade balance. The responses of most of the remaining variables are similar as in the model with Calvo wages, with the exception of hours per worker whose response is subdued in the model with search frictions. Instead, the extensive margin of labor supply, i.e. employment, is the relevant margin of adjustment in that model. In addition, the results show that the presence of endogenous separations is key to generate a significant response of employment in the model with search frictions. The latter is also true for the monetary policy shock shown in Figure 2, but in the case of this shock the responses of output and several other variables are smaller in the model with search frictions compared to the model with Calvo wages. The reason is that total hours worked, i.e. employment times hours per worker, does not fall as much in the model with search frictions as in the model with Calvo wages. However, the strong response of hours per worker in the model with Calvo wages seems to be rejected by the data, as we have seen in the previous section.

Unlike for the monetary policy shock, the responses of output and several other variables to the foreign interest rate shock are indeed amplified by the search frictions (see Figure 3). As in the previous cases, the presence of endogenous separations is critical for the propagation of the shock, since without the latter employment would fall by much less. Note that under this shock labor supply moves into opposite directions along the intensive margin and the extensive margin. However, with endogenous separations, the response of employment is stronger than the response of hours per worker, such that total hours worked falls.

[37] To have the impulse responses comparable, we use the parameters from the model with search frictions for each case. We calibrate the extra parameter in the model with Calvo wages, θ_W, to its posterior mean value from that model, i.e. 0.915.

[Figure 3 here.]

Note that for all of the above shocks, the model with search and matching successfully replicates the so called Beveridge curve, i.e. the empirically observed negative relation between vacancies and unemployment. Some other studies with different timing assumptions of the matching process than in our model have instead obtained a counterfactual positive relation in the presence of endogenous separations (e.g. Krause and Lubik, 2007).[38]

The above analysis leads us to two additional conclusions. First, search frictions and matching generate quantitatively relevant additional endogenous propagation properties of the model through variations of labor supply along the extensive margin, while the intensive margin becomes relatively less important. Second, the presence of endogenous separations is critical for the transmission of shocks by the labor market.[39]

5.3 Forecasting Performance

As a final step of the analysis, we conduct an out-of-sample forecasting experiment in order to judge how well the two models we analyze predict labor market data and other key variables such as output and inflation. For this experiment we estimated the model recursively and, for each estimation, forecasted the evolution of the observed variables several quarters ahead, starting in 2007Q1. Thus, the first estimation sample is 2001Q3-2006Q4 while the last sample is 2001Q3-2015Q1. The experiment is similar as in Adolfson, Lindé, and Villani (2007) who evaluate the forecasting performance of a small open economy DSGE model for Swedish output, inflation and the monetary policy rate, and Christiano et al. (2011) who extend that analysis to a model with search and matching and financial frictions. In addition to output, inflation and the monetary policy rate, we also analyze the forecasting performance of the two models for the real exchange rate, total hours worked and real wage growth.

Figure 4 shows the recursive forecasts for those variables from the model with search frictions (left-hand side) and the model with Calvo wages (right-hand side). The results show that the model with search frictions does a better job than the model with Calvo wages in forecasting the evolution of all variables. In particular, real wages as well as total hours worked are predicted significantly better by the model with search frictions, but also inflation, the monetary policy rate and–with less but still noticeable differences–output and the real exchange rate. Note that the model with Calvo wages strongly overstates the persistence of inflation, in line with Section 5.1, which seems to be partly due to bad forecasts of real wage growth (given adequate predictions of the exchange rate).

[38]A similar finding was obtained by Christoffel et al. (2009).

[39]These findings are well established in the literature (e.g. Den Haan et al., 2000; Trigari, 2009).

[Figure 4 here.]

To analyze the forecasting performance at different horizons, we also compute the root mean squared errors (RMSE) of the recursive forecasts at different horizons for the two models. As a benchmark, we compare the RMSE with those implied by three reduced-form BVARs that differ in the type of information that they incorporate. In particular, we estimate a basic model that includes real GDP growth, inflation, the monetary policy rate, the real exchange rate, total hours worked and real wage growth (BVAR1), as well as two bigger models that include all of the previous variables plus the growth rates of real private consumption and investment and real government consumption (BVAR2), or alternatively commercial partners' real GDP, the foreign interest rate, the copper price and commercial partners' inflation (BVAR3). All BVARs are estimated with a standard Minnesota-type prior following Doan, Litterman, and Sims (1983) and include four lags.

[Figure 5 here.]

The RMSE for the different DSGE models and BVARs are shown in Figure 5. The results show that, while the DSGE model with Calvo wages predicts most variables roughly as well or better than the different BVARs, it is outperformed by the model with search frictions for almost all variables and horizons considered (1-10 quarters). The only exception is real wage growth, where the model with Calvo wages predicts as well as the model with search frictions. Especially at short horizons, the RMSE for inflation, the monetary policy rate, the real exchange rate and hours worked from the model with search frictions are small (relative to the observed standard deviations). Hence, while the basic DSGE model with Calvo wages does perform relatively well compared to reduced-form empirical alternatives, which is a well-established finding in the literature (e.g. Smets and Wouters, 2003, 2007; Adolfson et al., 2007), the forecasting performance of the model is strongly improved by the inclusion of search frictions. The improved forecasting performance seems to be mainly due to the fact that the search frictions can successfully explain the joint evolution of labor market data and other variables.

6 Conclusions

In this paper we have conducted a horse race of a labor market specification with Calvo wages versus a search and matching specification with endogenous separations in an otherwise standard DSGE model for a small open economy. Our estimation results for Chilean data lead us to conclude that the search and matching specification "wins" by a wide margin as it significantly improves the model's ability to explain and predict both labor market data such as total hours worked and real wages and other macroeconomic variables such as output and inflation.

Our results thereby confirm several findings from previous studies and extend those findings to the context of an emerging market economy. In particular, similarly as Trigari (2009) we find that the model with search and matching explains variations in total hours mainly through the extensive margin of labor supply while the intensive margin is less important. Furthermore, similarly as Christiano et al. (2011) and Krause et al. (2008) we find that labor supply shocks are relatively unimportant in the model with search and matching to explain the joint evolution of both labor market variables and other variables such as output and inflation. As in those studies, the presence of endogenous separations is key for the endogenous propagation of other structural shocks through the labor market.

However, unlike some previous studies such as Krause et al. (2008), we do not find an important role for (ad hoc) match efficiency shocks. In addition, unlike the main related study in the context of an NK-SOE model, i.e. Christiano et al. (2011), we find that basic foreign shocks (in particular foreign interest rate shocks and shocks to commodity export prices) are a very important exogenous driving force in the model with search frictions. Compared to the model of Christiano et al. (2011), we see the benefits of our approach mainly in its simplicity, being a relatively straightforward extension of an otherwise standard NK-SOE model to include search and matching with endogenous separations, and the ability of the model to generate instantaneous comovements of employment along all relevant margins (i.e. hirings and firings).[40] We have found that the latter, together with the presence of endogenous separations, is important for the ability of the model to match the observed fluctuations in employment.

Overall, our results may have general implications that may be interesting to economic modellers at central banks and other policy institutions who seek to improve labor market specifications in DSGE models used for policy analysis and forecasting.

References

Adolfson, M., S. Laséen, L. Christiano, M. Trabandt, and K. Walentin (2013): "Ramses II – Model Description," Sveriges Riksbank Occasional Paper Series 12, Sveriges Riksbank.

Adolfson, M., S. Laséen, J. Lindé, and M. Villani (2007): "Bayesian estimation of an open economy DSGE model with incomplete pass-through," *Journal of International Economics*, 72(2), 481–511.

[40]Christiano et al. (2011) do not allow hirings to occur within the same quarter.

Adolfson, M., J. Lindé, and M. Villani (2007): "Forecasting Performance of an Open Economy DSGE Model," *Econometric Reviews*, 26(2-4), 289–328.

Albagli, E., G. Contreras, C. de la Huerta, E. Luttini, A. Naudon, and F. Pinto (2015): "Medium-Term Tendential Growth in Chile," Note published with Monetary Policy Report September 2015, Central Bank of Chile.

Albertini, J., G. Kamber, and M. Kirker (2012): "Estimated Small Open Economy Model With Frictional Unemployment," *Pacific Economic Review*, 17(2), 326–353.

Boz, E., C. B. Durdu, and N. Li (2015): "Emerging Market Business Cycles: The Role of Labor Market Frictions," *Journal of Money, Credit and Banking*, 47(1), 31–72.

Brubakk, L., and T. Sveen (2009): "NEMO – a new macro model for forecasting and monetary policy analysis," *Norges Bank Economic Bulletin*, 80(1), 39–47.

Burgess, S., E. Fernandez-Corugedo, C. Groth, R. Harrison, F. Monti, K. Theodoridis, and M. Waldron (2013): "The Bank of England's forecasting platform: COMPASS, MAPS, EASE and the suite of models," Bank of England working papers 471, Bank of England.

Chetty, R., A. Guren, D. Manoli, and A. Weber (2011): "Are Micro and Macro Labor Supply Elasticities Consistent? A Review of Evidence on the Intensive and Extensive Margins," *American Economic Review*, 101(3), 471–75.

Christiano, L. J., M. S. Eichenbaum, and M. Trabandt (2015): "Unemployment and Business Cycles," *Econometrica*, forthcoming.

Christiano, L. J., M. Trabandt, and K. Walentin (2011): "Introducing financial frictions and unemployment into a small open economy model," *Journal of Economic Dynamics and Control*, 35(12), 1999–2041.

Christoffel, K., J. Costain, G. de Walque, K. Kuester, T. Linzert, S. Millard, and O. Pierrard (2009): "Wage, inflation and employment dynamics with labour market matching," Banco de España Working Papers 0918, Banco de España.

Chung, H., M. T. Kiley, and J.-P. Laforte (2010): "Documentation of the Estimated, Dynamic, Optimization-based (EDO) model of the U.S. economy: 2010 version," Finance and Economics Discussion Series 2010-29, Board of Governors of the Federal Reserve System.

Cooley, T. F., and V. Quadrini (1999): "A neoclassical model of the Phillips curve relation," *Journal of Monetary Economics*, 44(2), 165–193.

de Castro, M. R., S. N. Gouvea, A. Minella, R. C. dos Santos, and N. F. Souza-Sobrinho (2011): "SAMBA: Stochastic Analytical Model with a Bayesian Approach," Working Papers Series 239, Central Bank of Brazil, Research Department.

Del Negro, M., S. Eusepi, M. Giannoni, A. M. Sbordone, A. Tambalotti, M. Cocci, R. B. Hasegawa, and M. H. Linder (2013): "The FRBNY DSGE model," Staff Reports 647, Federal Reserve Bank of New York.

den Haan, W. J., G. Ramey, and J. Watson (2000): "Job Destruction and Propagation of Shocks," *American Economic Review*, 90(3), 482–498.

Diamond, P. A. (1982): "Wage Determination and Efficiency in Search Equilibrium," *Review of Economic Studies*, 49(2), 217–27.

Doan, T., R. B. Litterman, and C. A. Sims (1983): "Forecasting and Conditional Projection Using Realistic Prior Distributions," NBER Working Papers 1202, National Bureau of Economic Research, Inc.

Dorich, J., M. K. Johnston, R. R. Mendes, S. Murchison, and Y. Zhang (2013): "ToTEM II: An Updated Version of the Bank of Canada's Quarterly Projection Model," Technical Reports 100, Bank of Canada.

Erceg, C. J., L. Guerrieri, and C. Gust (2006): "SIGMA: A New Open Economy Model for Policy Analysis," *International Journal of Central Banking*, 2(1), 1–50.

Fuentes S., R., and F. Gredig U. (2008): "The Neutral Interest Rate: Estimates for Chile," *Journal Economía Chilena (The Chilean Economy)*, 11(2), 47–58.

García-Cicco, J., M. Kirchner, and S. Justel (2015): "Domestic Financial Frictions and the Transmission of Foreign Shocks in Chile," in *Global Liquidity, Spillovers to Emerging Markets and Policy Responses*, ed. by C. Raddatz, D. Saravia, and J. Ventura, vol. 20 of *Central Banking, Analysis, and Economic Policies Book Series*, chap. 6, pp. 159–222. Central Bank of Chile.

Gertler, M., L. Sala, and A. Trigari (2008): "An Estimated Monetary DSGE Model with Unemployment and Staggered Nominal Wage Bargaining," *Journal of Money, Credit and Banking*, 40(8), 1713–1764.

Gertler, M., and A. Trigari (2009): "Unemployment Fluctuations with Staggered Nash Wage Bargaining," *Journal of Political Economy*, 117(1), 38–86.

González, A., L. Mahadeva, J. D. Prada, and D. Rodríguez (2011): "Policy Analysis Tool Applied to Colombian Needs: Patacon Model Description," *Ensayos sobre Política Económica*, 29(66), 222–245.

Greenwood, J., Z. Hercowitz, and G. W. Huffman (1988): "Investment, Capacity Utilization, and the Real Business Cycle," *American Economic Review*, 78(3), 402–17.

Greenwood, J., Z. Hercowitz, and P. Krusell (1997): "Long-Run Implications of Investment-Specific Technological Change," *American Economic Review*, 87(3), 342–62.

GUERRIERI, V. (2008): "Heterogeneity, Job Creation and Unemployment Volatility," *Scandinavian Journal of Economics*, 109(4), 667–693.

HALL, R. E. (1995): "Lost Jobs," *Brookings Papers on Economic Activity*, 26(1), 221–274.

——— (2005): "Employment Fluctuations with Equilibrium Wage Stickiness," *American Economic Review*, 95(1), 50–65.

JEFFREYS, H. (1961): *The Theory of Probability*. Oxford University Press, 3 edn.

JONES, I., AND A. NAUDON (2009): "Labor Market Dynamics and Evolution of Unemployment in Chile," *Notas de Investigación Journal Economía Chilena (The Chilean Economy)*, 12(3), 79–87.

JUSTINIANO, A., AND B. PRESTON (2010): "Can structural small open-economy models account for the influence of foreign disturbances?," *Journal of International Economics*, 81(1), 61–74.

JUSTINIANO, A., G. PRIMICERI, AND A. TAMBALOTTI (2011): "Investment Shocks and the Relative Price of Investment," *Review of Economic Dynamics*, 14(1), 101–121.

KASS, R. E., AND A. E. RAFTERY (1995): "Bayes Factors," *Journal of the American Statistical Association*, 90(430), 773–795.

KRAUSE, M. U., D. LOPEZ-SALIDO, AND T. A. LUBIK (2008): "Inflation dynamics with search frictions: A structural econometric analysis," *Journal of Monetary Economics*, 55(5), 892–916.

KRAUSE, M. U., AND T. A. LUBIK (2007): "The (ir)relevance of real wage rigidity in the New Keynesian model with search frictions," *Journal of Monetary Economics*, 54(3), 706–727.

——— (2014): "Modeling Labor Markets in Macroeconomics: Search and Matching," Working Paper 14-19, Federal Reserve Bank of Richmond.

LEES, K. (2009): "Introducing KITT: The Reserve Bank of New Zealand new DSGE model for forecasting and policy design," *Reserve Bank of New Zealand Bulletin*, 72, 5–20.

MEDINA, J. P., AND A. NAUDON (2012): "Labor Market Dynamics in Chile: The Role of the Terms of Trade," *Journal Economa Chilena (The Chilean Economy)*, 15(1), 32–75.

MEDINA, J. P., AND C. SOTO (2007): "The Chilean Business Cycles Through the Lens of a Stochastic General Equilibrium Model," Working Papers Central Bank of Chile 457, Central Bank of Chile.

MORTENSEN, D. T. (1982): "Property Rights and Efficiency in Mating, Racing, and Related Games," *American Economic Review*, 72(5), 968–79.

MORTENSEN, D. T., AND C. A. PISSARIDES (1994): "Job Creation and Job Destruction in the Theory of Unemployment," *Review of Economic Studies*, 61(3), 397–415.

PISSARIDES, C. A. (1985): "Short-run Equilibrium Dynamics of Unemployment Vacancies, and Real Wages," *American Economic Review*, 75(4), 676–90.

Pissarides, C. A. (2011): "Equilibrium in the Labor Market with Search Frictions," *American Economic Review*, 101(4), 1092–1105.

Ratto, M., W. Roeger, and J. in 't Veld (2009): "QUEST III: An estimated open-economy DSGE model of the euro area with fiscal and monetary policy," *Economic Modelling*, 26(1), 222–233.

Schmitt-Grohé, S., and M. Uribe (2003): "Closing small open economy models," *Journal of International Economics*, 61(1), 163–185.

Schmitt-Grohé, S., and M. Uribe (2006): "Optimal fiscal and monetary policy in a medium-scale macroeconomic model," Working Paper Series 0612, European Central Bank.

Schmitt-Grohé, S., and M. Uribe (2007): "Optimal Inflation Stabilization in a Medium-Scale Macroeconomic Model," in *Monetary Policy under Inflation Targeting*, ed. by F. S. Miskin, K. Schmidt-Hebbel, and N. Loayza, vol. 11 of *Central Banking, Analysis, and Economic Policies Book Series*, chap. 5, pp. 125–186. Central Bank of Chile.

Schorfheide, F., K. Sill, and M. Kryshko (2010): "DSGE model-based forecasting of non-modelled variables," *International Journal of Forecasting*, 26(2), 348–373.

Sedláçek, P. (2014): "Match efficiency and firms' hiring standards," *Journal of Monetary Economics*, 62(C), 123–133.

Smets, F., K. Christoffel, G. Coenen, R. Motto, and M. Rostagno (2010): "DSGE models and their use at the ECB," *SERIEs*, 1(1), 51–65.

Smets, F., and R. Wouters (2003): "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economic Association*, 1(5), 1123–1175.

Smets, F., and R. Wouters (2007): "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, 97(3), 586–606.

Tortorice, D. L. (2013): "Endogenous separation, wage rigidity and the dynamics of unemployment," *Journal of Macroeconomics*, 38(PB), 179–191.

Trigari, A. (2009): "Equilibrium Unemployment, Job Flows, and Inflation Dynamics," *Journal of Money, Credit and Banking*, 41(1), 1–33.

Walsh, C. E. (2005): "Labor Market Search, Sticky Prices, and Interest Rate Policies," *Review of Economic Dynamics*, 8(4), 829–849.

A Equilibrium Conditions of the Search Model

The variables in uppercase that are not prices contain a unit root in equilibrium due to the presence of the non-stationary technology shock A_t. We transform these variables to have a stationary version of the model. To do this, with the exceptions we enumerate below, lowercase variables denote the uppercase variable divided by A_{t-1} (e.g. $c_t \equiv \frac{C_t}{A_{t-1}}$). The only exception is the Lagrange multiplier Λ_t that is multiplied by A_{t-1}^{σ} (i.e. $\lambda_t \equiv \Lambda_t A_{t-1}^{\sigma}$), for it decreases along the balanced growth path.

Then, the rational expectations equilibrium of the stationary version of the model is the set of sequences

$$\{\lambda_t, c_t, h_t, w_t, i_t, k_t, r_t^K, q_t, y_t, y_t^C, y_t^F, y_t^H, x_t^F, x_t^H, x_t^{H*}, R_t, \xi_t, \pi_t, \pi_t^S, rer_t, p_t^H, \tilde{p}_t^H, p_t^F, \tilde{p}_t^F, p_t^Y,$$
$$p_t^m, mc_t^H, f_t^H, \Delta_t^H, mc_t^F, f_t^F, \Delta_t^F, b_t^*, imp_t, tb_t, n_t, u_t, u_t^s, v_t, s_t, e_t, w_t^n, \gamma_t^W, \rho_t, \rho_t^n, \underline{c}_t, h(\underline{c}_t)\}_{t=0}^{\infty},$$

(47 variables) such that for given initial values and exogenous sequences

$$\{\kappa_t, \varrho_t, \varpi_t, z_t, a_t, m_t, \zeta_t^o, \zeta_t^u, R_t^*, \pi_t^*, p_t^{Co*}, y_t^{Co}, y_t^*, g_t\}_{t=0}^{\infty},$$

and assuming

$$\widetilde{c}_t \sim \log N(0, \sigma_{\widetilde{c}}),$$

the following conditions are satisfied:

$$\lambda_t = \left(c_t - \varsigma \frac{c_{t-1}}{a_{t-1}}\right)^{-\sigma}, \tag{23}$$

$$\lambda_t = \frac{\beta}{a_t^{\sigma}} R_t E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\pi_{t+1}} \right\}, \tag{24}$$

$$\lambda_t = \frac{\beta}{a_t^{\sigma}} R_t^* \xi_t E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\pi_{t+1}^S \lambda_{t+1}}{\pi_{t+1}} \right\}, \tag{25}$$

$$q_t = \frac{\beta}{a_t^{\sigma}} E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left[r_{t+1}^K + q_{t+1}(1-\delta) \right] \right\}, \tag{26}$$

$$\begin{aligned} \frac{1}{q_t} \quad = \quad & \left[1 - \frac{\gamma}{2} \left(\frac{i_t}{i_{t-1}} a_{t-1} - \bar{a} \right)^2 - \gamma \left(\frac{i_t}{i_{t-1}} a_{t-1} - \bar{a} \right) \frac{i_t}{i_{t-1}} a_{t-1} \right] u_t \\ & + \frac{\beta}{a_t^{\sigma}} \gamma E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \frac{q_{t+1}}{q_t} \left(\frac{i_{t+1}}{i_t} a_t - \bar{a} \right) \left(\frac{i_{t+1}}{i_t} a_t \right)^2 u_{t+1} \right\}, \end{aligned} \tag{27}$$

$$k_t = (1-\delta) \frac{k_{t-1}}{a_{t-1}} + \left[1 - \frac{\gamma}{2} \left(\frac{i_t}{i_{t-1}} a_{t-1} - \bar{a} \right)^2 \right] \varpi_t i_t, \tag{28}$$

$$n_t = (1-\rho_t) n_{t-1} + (1-\rho_t^n) m_t v_t^{1-\mu} (u_t^s)^{\mu}, \tag{29}$$

$$\rho_t = \rho^x + (1-\rho_t^x) \rho_t^n, \tag{30}$$

$$\rho_t^n = 1 - F(\underline{c}_t) = 1 - \Phi\left(\frac{\ln \underline{c}_t}{\sigma_{\widetilde{c}}}\right), \tag{31}$$

where Φ is the standard normal c.d.f.,

$$u_t = 1 - n_t, \tag{32}$$

$$u_t^s = u_{t-1} + \rho_t n_{t-1}, \tag{33}$$

$$s_t = (1-\rho_t^n) m_t (v_t/u_t^s)^{1-\mu}, \tag{34}$$

$$e_t = (1-\rho_t^n) m_t (v_t/u_t^s)^{-\mu}, \tag{35}$$

$$p_t^m (1-\alpha)^2 z_t a_t^{1-\alpha} \left(\frac{k_{t-1}}{a_{t-1} n_t}\right)^{\alpha} = \kappa_t \frac{h_t^{\alpha+\phi}}{\lambda_t}, \tag{36}$$

$$w_t^n h_t = \varphi \left[\begin{array}{c} p_t^m (1-\alpha) z_t a_t^{1-\alpha} \left(\frac{k_{t-1}}{a_{t-1} n_t}\right)^{\alpha} h_t^{1-\alpha} - h(\underline{c}_t) \\ + E_t \frac{\beta}{a_t^{\sigma-1}} \frac{\varrho_{t+1}}{\varrho_t} \frac{\lambda_{t+1}}{\lambda_t} (1-\rho_{t+1}) \omega \frac{v_{t+1}}{u_{t+1}^s} \end{array} \right] + (1-\varphi)\left(\bar{b} + \frac{\kappa_t}{\lambda_t}\frac{h_t^{1+\phi}}{1+\phi}\right), \tag{37}$$

$$\pi_t w_t = \varkappa_W \gamma_{t-1}^W \frac{w_{t-1}}{a_{t-1}} + (1-\varkappa_W)\pi_t w_t^n, \tag{38}$$

$$\gamma_t^W = a_t^{\alpha_W} \pi_t^{\vartheta_W} \bar{\pi}^{1-\vartheta_W}, \tag{39}$$

$$\underline{c}_t = p_t^m (1-\alpha) z_t a_t^{1-\alpha} \left(\frac{k_{t-1}}{a_{t-1} n_t}\right)^{\alpha} h_t^{1-\alpha} - \bar{b} + E_t \frac{\beta}{a_t^{\sigma-1}} \frac{\varrho_{t+1}}{\varrho_t} \frac{\lambda_{t+1}}{\lambda_t} (1-\rho_{t+1}) \frac{\omega}{e_{t+1}} \frac{1-\varphi s_{t+1}}{1-\varphi} - \frac{\kappa_t}{\lambda_t}\frac{h_t^{1+\phi}}{1+\phi}, \tag{40}$$

$$h(\underline{c}_t) = \frac{\kappa_{\widetilde{c}} \exp\left(\frac{\sigma_a^2}{2}\right) \Phi\left(\frac{\ln \underline{c}_t - \sigma_{\widetilde{c}}^2}{\sigma_{\widetilde{c}}}\right)}{1-\rho_t^n}, \tag{41}$$

$$\frac{\omega}{e_t} = p_t^m (1-\alpha) z_t a_t^{1-\alpha} \left(\frac{k_{t-1}}{a_{t-1} n_t}\right)^{\alpha} h_t^{1-\alpha} - h(\underline{c}_t) - w_t h_t + E_t \frac{\beta}{a_t^{\sigma-1}} \frac{\varrho_{t+1}}{\varrho_t} \frac{\lambda_{t+1}}{\lambda_t} (1-\rho_{t+1}) \frac{\omega}{e_{t+1}}, \tag{42}$$

$$y_t^H \Delta_t^H = z_t \left(\frac{k_{t-1}}{a_{t-1}}\right)^{\alpha} (a_t h_t n_t)^{1-\alpha}, \tag{43}$$

$$r_t^K = p_t^m \alpha \frac{y_t^H}{k_{t-1}} a_{t-1}, \tag{44}$$

$$y_t^C = \left[(1-o)^{\frac{1}{\eta}} \left(x_t^H\right)^{\frac{\eta-1}{\eta}} + o^{\frac{1}{\eta}} \left(x_t^F\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{45}$$

$$x_t^H = (1-o)\left(p_t^H\right)^{-\eta} y_t^C, \tag{46}$$

$$x_t^F = o\left(p_t^F\right)^{-\eta} y_t^C, \tag{47}$$

$$p_t^H mc_t^H = p_t^m, \tag{48}$$

$$\begin{aligned} f_t^H \;=\; & \left(\tilde{p}_t^H\right)^{-\epsilon_H} mc_t^H y_t^H \\ & + \frac{\beta}{a_t^{\sigma-1}} \theta_H E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_H} \pi^{1-\vartheta_H}}{\pi_{t+1}}\right)^{-\epsilon_H} \left(\frac{\tilde{p}_t^H}{\tilde{p}_{t+1}^H}\right)^{-\epsilon_H} \left(\frac{p_t^H}{p_{t+1}^H}\right)^{-1-\epsilon_H} f_{t+1}^H \right\}, \end{aligned} \tag{49}$$

$$f_t^H = \left(\tilde{p}_t^H\right)^{1-\epsilon_H} y_t^H \left(\frac{\epsilon_H - 1}{\epsilon_H}\right) + \frac{\beta}{a_t^{\sigma-1}} \theta_H E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_H} \pi^{1-\vartheta_H}}{\pi_{t+1}}\right)^{1-\epsilon_H} \left(\frac{\tilde{p}_t^H}{\tilde{p}_{t+1}^H}\right)^{1-\epsilon_H} \left(\frac{p_t^H}{p_{t+1}^H}\right)^{-\epsilon_H} f_{t+1}^H \right\}, \tag{50}$$

$$1 = \theta_H \left(\frac{p_{t-1}^H}{p_t^H} \frac{\pi_{t-1}^{\vartheta_H} \pi^{1-\vartheta_H}}{\pi_t}\right)^{1-\epsilon_H} + (1-\theta_H) \left(\tilde{p}_t^H\right)^{1-\epsilon_H}, \tag{51}$$

$$\Delta_t^H = (1-\theta_H) \left(\tilde{p}_t^H\right)^{-\epsilon_H} + \theta_H \left(\frac{p_{t-1}^H}{p_t^H} \frac{\pi_{t-1}^{\vartheta_H} \pi^{1-\vartheta_H}}{\pi_t}\right)^{-\epsilon_H} \Delta_{t-1}^H, \tag{52}$$

$$p_t^F mc_t^F = rer_t, \tag{53}$$

$$f_t^F = \left(\tilde{p}_t^F\right)^{-\epsilon_F} y_t^F mc_t^F + \frac{\beta}{a_t^{\sigma-1}} \theta_F E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_F} \pi^{1-\vartheta_F}}{\pi_{t+1}}\right)^{-\epsilon_F} \left(\frac{\tilde{p}_t^F}{\tilde{p}_{t+1}^F}\right)^{-\epsilon_F} \left(\frac{p_t^F}{p_{t+1}^F}\right)^{-1-\epsilon_F} f_{t+1}^F \right\}, \tag{54}$$

$$f_t^F = \left(\tilde{p}_t^F\right)^{1-\epsilon_F} y_t^F \left(\frac{\epsilon_F - 1}{\epsilon_F}\right) + \frac{\beta}{a_t^{\sigma-1}} \theta_F E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_F} \pi^{1-\vartheta_F}}{\pi_{t+1}}\right)^{1-\epsilon_F} \left(\frac{\tilde{p}_t^F}{\tilde{p}_{t+1}^F}\right)^{1-\epsilon_F} \left(\frac{p_t^F}{p_{t+1}^F}\right)^{-\epsilon_F} f_{t+1}^F \right\}, \tag{55}$$

$$1 = \theta_F \left(\frac{p_{t-1}^F}{p_t^F} \frac{\pi_{t-1}^{\vartheta_F} \pi^{1-\vartheta_F}}{\pi_t}\right)^{1-\epsilon_F} + (1-\theta_F) \left(\tilde{p}_t^F\right)^{1-\epsilon_F}, \tag{56}$$

$$\Delta_t^F = (1-\theta_F) \left(\tilde{p}_t^F\right)^{-\epsilon_F} + \theta_F \left(\frac{p_{t-1}^F}{p_t^F} \frac{\pi_{t-1}^{\vartheta_F} \pi^{1-\vartheta_F}}{\pi_t}\right)^{-\epsilon_F} \Delta_{t-1}^F, \tag{57}$$

$$x_t^{H*} = o^* \left(\frac{p_t^H}{rer_t}\right)^{-\eta^*} y_t^*, \tag{58}$$

$$y_t^H = x_t^H + x_t^{H*}, \tag{59}$$

$$\frac{rer_t}{rer_{t-1}} = \frac{\pi_t^S \pi_t^*}{\pi_t}, \tag{60}$$

$$y_t^F = x_t^F, \tag{61}$$

$$imp_t = y_t^F \Delta_t^F, \tag{62}$$

$$tb_t = p_t^H x_t^{H*} + rer_t p_t^{Co*} y_t^{Co} - rer_t imp_t, \tag{63}$$

$$rer_t b_t^* = rer_t \frac{b_{t-1}^*}{a_{t-1} \pi_t^*} R_{t-1}^* \xi_{t-1} + tb_t - (1-\chi) rer_t p_t^{Co*} y_t^{Co}, \tag{64}$$

$$\xi_t = \bar{\xi} \exp\left[-\psi \frac{rer_t b_t^* - rer \times b^*}{rer \times b^*} + \frac{\zeta_t^o - \zeta^o}{\zeta^o} + \frac{\zeta_t^u - \zeta^u}{\zeta^u}\right], \tag{65}$$

$$y_t^C = c_t + i_t + g_t + n_t h(\underline{c}_t) + \omega v_t, \tag{66}$$

$$y_t = c_t + i_t + g_t + x_t^{H*} + y_t^{Co} - imp_t, \tag{67}$$

$$p_t^Y y_t = c_t + i_t + g_t + tb_t, \tag{68}$$

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\bar{\pi}}\right)^{\alpha_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\alpha_y}\right]^{1-\rho_R} \exp(\varepsilon_t^R). \tag{69}$$

B Steady State of the Search Model

We show how to compute the steady state for given values of h, u, $\rho = p^{E,U}/(1-p^{U,E})$, $s_{\rho^x} = \rho^x/\rho$, e, p^H, $s^{tb} = tb/\left(p^Y y\right)$, $s^g = g/\left(p^Y y\right)$ and $s^{Co} = rer \times p^{Co*} y^{Co}/\left(p^Y y\right)$. The parameters $\bar{\kappa}$, ω, $\kappa_{\tilde{c}}$, ρ^x, $\bar{m}$, $\bar{\pi}^*$, o^*, $\bar{g}$ and $\bar{y}^{Co}$ are determined endogenously while the values of the remaining parameters are taken as given.

From the exogenous processes for ϱ_t, ϖ_t, z_t, a_t, y_t^{Co}, ζ_t^o, ζ_t^u, R_t^*, y_t^* and p_t^{Co*},

$$\varrho = \bar{\varrho},\ \varpi = \bar{\varpi},\ z = \bar{z},\ a = \bar{a},\ y^{Co} = \bar{y}^{Co},\ \zeta^o = \bar{\zeta}^o,\ \zeta^u = \bar{\zeta}^u,\ R^* = \bar{R}^*,\ y^* = \bar{y}^*,\ p^{Co*} = \bar{p}^{Co*},$$

From (65),

$$\xi = \bar{\xi}.$$

From (69),

$$\pi = \bar{\pi}.$$

From (24),

$$R = a^\sigma \pi / \beta.$$

From (27),

$$q = \varpi^{-1}.$$

From (26),

$$r^K = q\left(\frac{a^\sigma}{\beta} - 1 + \delta\right).$$

From (25),

$$\pi^S = a^\sigma \pi / (\beta R^* \xi).$$

From (60) and the exogenous process for π_t^*,

$$\pi^* = \bar{\pi}^* = \pi / \pi^S.$$

From (51), (56),

$$\tilde{p}^H = 1,\ \tilde{p}^F = 1.$$

From (52), (57),

$$\Delta^H = (\tilde{p}^H)^{-\epsilon_H},\ \Delta^F = (\tilde{p}^H)^{-\epsilon_F}.$$

From (49)-(50), (54)-(55),

$$mc^H = \frac{\epsilon_H - 1}{\epsilon_H} \tilde{p}^H, \ mc^F = \frac{\epsilon_F - 1}{\epsilon_F} \tilde{p}^F.$$

From (48),

$$p^m = p^H mc^H.$$

From (32),

$$n = 1 - u.$$

From (33),

$$u^s = u + \rho n.$$

From $s_{\rho^x} = \rho^x / \rho$,

$$\rho^x = \rho s_{\rho^x}.$$

From (30),

$$\rho^n = \frac{\rho - \rho^x}{1 - \rho^x}.$$

From (31),

$$\widetilde{c} = \exp \left[\sigma_{\widetilde{c}} \Phi^{-1} \left(1 - \rho^n \right) \right].$$

From (29) and (35),

$$v = \frac{\rho n}{e}.$$

From (35) and the exogenous process for m_t,

$$m = \bar{m} = \frac{e(v/u^s)^\mu}{1 - \rho^n}.$$

From (34),

$$s = (1 - \rho^n) m (v/u^s)^{1-\mu}.$$

From (43) and (44),

$$k = a^2 hn \left(\frac{\alpha p^m z}{\Delta^H r^K} \right)^{\frac{1}{1-\alpha}}.$$

From (43),

$$y^H = z \left(k/a \right)^\alpha \left(ahn \right)^{1-\alpha} / \Delta^H.$$

From (49),

$$f^H = mc^H \left(\tilde{p}^H \right)^{-\epsilon_H} y^H / (1 - \beta a^{1-\sigma} \theta_H).$$

From (28),

$$i = k \left(\frac{1 - (1 - \delta)/a}{\varpi} \right).$$

From (45)-(46),

$$p^F = \left[\frac{1}{o} - \frac{1-o}{o}\left(p^H\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}.$$

From (53),

$$rer = mc^F p^F.$$

From (41),

$$h(\underline{c}) = \frac{\kappa_{\widetilde{c}}}{1-\rho^n}\exp\left(\frac{\sigma_a^2}{2}\right)\Phi\left(\frac{\ln\underline{c} - \sigma_{\widetilde{c}}^2}{\sigma_{\widetilde{c}}}\right).$$

From GDP equal to value added, equivalent to (68), (68) itself and (62),

$$p^Y y = \frac{p^H y^H + (nh(\underline{c}) + \omega v)\left[p^F\left(1 - mc^F\Delta^F\right) o\left(p^F\right)^{-\eta} - 1\right]}{1 - s^{Co} - p^F\left(1 - mc^F\Delta^F\right) o\left(p^F\right)^{-\eta}\left(1 - s^{tb}\right)}.$$

From $s^{tb} = tb/\left(p^Y y\right)$, $s^g = g/\left(p^Y y\right)$, $s^{Co} = rer \times p^{Co*}y^{Co}/\left(p^Y y\right)$ and the exogenous process for g_t,

$$tb = s^{tb}p^Y y,\ g = \bar{g} = s^g p^Y y,\ y^{Co} = \bar{y}^{Co} = s^{Co}p^Y y/\left(rer \times p^{Co*}\right).$$

From (46), (59), (66) and (68),

$$x^{H*} = y^H - (1-o)\left(p^H\right)^{-\eta}\left(p^Y y - tb + nh(\underline{c}) + \omega v\right).$$

From (63),

$$x^F = \left(p^H x^{H*} + rer \times p^{Co*}y^{Co} - tb\right)/rer.$$

From (47),

$$y^C = \left(x^F/o\right)\left(p^F\right)^{\eta}.$$

From (66),

$$c = y^C - g - i - nh(\underline{c}) - \omega v.$$

From (23),

$$\lambda = \left(c - \varsigma\frac{c}{a}\right)^{-\sigma}.$$

From (36) and the exogenous process for κ_t,

$$\kappa = \bar{\kappa} = p^m\lambda(1-\alpha)^2 za^{1-2\alpha}(k/n)^{\alpha}/h^{\alpha+\phi}.$$

From (40),

$$\underline{c} = p^m(1-\alpha)za^{1-2\alpha}\left(\frac{k}{n}\right)^{\alpha}h^{1-\alpha} + \beta a^{1-\sigma}(1-\rho)\frac{\omega}{e}\frac{1-\varphi s}{1-\varphi} - \frac{\kappa}{\lambda}\frac{h^{1+\phi}}{1+\phi} - \bar{b}.$$

From (37)-(39) and (42)-(43),

$$\omega = \frac{e\left[\left(1-\frac{1-\varkappa_W}{1-\varkappa_W a^{\alpha_W - 1}}\varphi\right)\left[p^m(1-\alpha)\left(y^H\Delta^H/n\right)-h(\underline{c})\right]-\frac{1-\varkappa_W}{1-\varkappa_W a^{\alpha_W-1}}(1-\varphi)\left(\bar{b}+\frac{\kappa}{\lambda}\frac{h^{1+\phi}}{1+\phi}\right)\right]}{1-\beta a^{1-\sigma}(1-\rho)\left(1-\frac{1-\varkappa_W}{1-\varkappa_W a^{\alpha_W-1}}\varphi s\right)}.$$

The last thirteen equations need to be solved numerically to obtain $p^Y y$, tb, g, y^{Co}, x^{H*}, x^F, y^C, c, λ, κ, $\kappa_{\tilde{c}}$ and ω. Then, from (42),

$$w = \frac{p^m(1-\alpha)za^{1-2\alpha}\left(\frac{k}{n}\right)^{\alpha}h^{1-\alpha}-\omega\left[1-\beta a^{1-\sigma}(1-\rho)\right]/e-h(\underline{c})}{h}.$$

From (39),

$$\gamma^W = a^{\alpha_W}\pi.$$

From (38),

$$w^n = \frac{1-\varkappa_W\gamma^W/(a\pi)}{1-\varkappa_W}w.$$

From (58),

$$o^* = \left(x^{H*}/y^*\right)\left(p^H/rer\right)^{\eta^*}.$$

From (64),

$$b^* = \frac{tb-(1-\chi)rer\times p^{Co*}y^{Co}}{rer\left[1-(R^*+\xi)/(\pi^* a)\right]}.$$

From (59),

$$x^H = y^H - x^{H*}.$$

From (61),

$$y^F = x^F.$$

From (54),

$$f^F = mc^F\left(\tilde{p}^F\right)^{-\epsilon_F}y^F/(1-\beta a^{1-\sigma}\theta_F).$$

From (62),

$$imp = y^F\Delta^F.$$

From (67),

$$y = c+i+g+x^{H*}+y^{Co}-imp.$$

From (68),

$$p^Y = (c+i+g+tb)/y.$$

C Equilibrium Conditions of the Calvo Wages Model

The rational expectations equilibrium of the stationary version of the model is the set of sequences

$$\{\lambda_t, c_t, h_t, h_t^d, w_t, \tilde{w}_t, mc_t^W, f_t^W, \Delta_t^W, \gamma_t^W, i_t, k_t, r_t^K, q_t, y_t, y_t^C, y_t^F, y_t^H, x_t^F, x_t^H, x_t^{H*}, R_t,$$
$$\xi_t, \pi_t, \pi_t^S, rer_t, p_t^H, \tilde{p}_t^H, p_t^F, \tilde{p}_t^F, p_t^Y, p_t^m, mc_t^H, f_t^H, \Delta_t^H, mc_t^F, f_t^F, \Delta_t^F, b_t^*, imp_t, tb_t\}_{t=0}^{\infty},$$

(41 variables) such that for given initial values and exogenous sequences

$$\{\kappa_t, \varrho_t, \varpi_t, z_t, a_t, \zeta_t^o, \zeta_t^u, R_t^*, \pi_t^*, p_t^{Co*}, y_t^{Co}, y_t^*, g_t\}_{t=0}^{\infty},$$

conditions (23)-(28), (39), (44)-(65), (67)-(69), and the following conditions are satisfied:

$$w_t mc_t^W = \kappa \frac{h_t^\phi}{\lambda_t}, \tag{70}$$

$$\begin{aligned} f_t^W &= mc_t^W \tilde{w}_t^{-\epsilon_W} h_t^d \\ &+ \frac{\beta}{a_t^{\sigma-1}} \theta_W E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\gamma_t^W}{a_t \pi_{t+1}} \right)^{-\epsilon_W} \left(\frac{\tilde{w}_t}{\tilde{w}_{t+1}} \right)^{-\epsilon_W} \left(\frac{w_t}{w_{t+1}} \right)^{-1-\epsilon_W} f_{t+1}^W \right\}, \end{aligned} \tag{71}$$

$$\begin{aligned} f_t^W &= \tilde{w}_t^{1-\epsilon_W} h_t^d \left(\frac{\epsilon_W - 1}{\epsilon_W} \right) \\ &+ \frac{\beta}{a_t^{\sigma-1}} \theta_W E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\gamma_t^W}{a_t \pi_{t+1}} \right)^{1-\epsilon_W} \left(\frac{\tilde{w}_t}{\tilde{w}_{t+1}} \right)^{1-\epsilon_W} \left(\frac{w_t}{w_{t+1}} \right)^{-\epsilon_W} f_{t+1}^W \right\}, \end{aligned} \tag{72}$$

$$1 = (1-\theta_W)\tilde{w}_t^{1-\epsilon_W} + \theta_W \left(\frac{w_{t-1}}{w_t} \frac{\gamma_t^W}{a_{t-1}\pi_t} \right)^{1-\epsilon_W}, \tag{73}$$

$$\Delta_t^W = (1-\theta_W)\tilde{w}_t^{-\epsilon_W} + \theta_W \left(\frac{w_{t-1}}{w_t} \frac{\gamma_t^W}{a_{t-1}\pi_t} \right)^{-\epsilon_W} \Delta_{t-1}^W, \tag{74}$$

$$y_t^H \Delta_t^H = z_t \left(\frac{k_{t-1}}{a_{t-1}} \right)^\alpha (a_t h_t^d)^{1-\alpha}, \tag{75}$$

$$w_t = p_t^m \alpha \frac{y_t^H}{h_t^d} a_{t-1}, \tag{76}$$

$$h_t = h_t^d \Delta_t^W, \tag{77}$$

$$y_t^C = c_t + i_t + g_t. \tag{78}$$

D Steady State of the Calvo Wages Model

We solve for the steady state for given values of h, p^H, $s^{tb} = tb/\left(p^Y y\right)$, $s^g = g/\left(p^Y y\right)$ and $s^{Co} = rer \times p^{Co*} y^{Co}/\left(p^Y y\right)$. The parameters $\bar{\pi}^*$, κ, o^*, $\bar{g}$ and $\bar{y}^{Co}$ are determined endogenously while the values of the remaining parameters are taken as given. The following equations are added to the steady state of the model with search frictions.

From (73),

$$\tilde{w} = \left(\frac{1-\theta_W \left(\gamma^W/a\pi\right)^{1-\epsilon_W}}{1-\theta_W} \right)^{\frac{1}{1-\epsilon_W}}.$$

From (74),

$$\Delta^W = \frac{1-\theta_W}{1-\theta_w \left(\gamma^W/a\pi\right)^{-\epsilon_W}} \tilde{w}^{-\epsilon_W}.$$

From (71)-(72),

$$mc^W = \left(\frac{\epsilon_W - 1}{\epsilon_W} \frac{1-\beta a^{1-\sigma} \left(\gamma^W/a\pi\right)^{-\epsilon_W} \theta_W}{1-\beta a^{1-\sigma} \left(\gamma^W/a\pi\right)^{1-\epsilon_W} \theta_W} \right) \tilde{w}.$$

From (77),

$$h^d = h/\Delta^W.$$

From (71),

$$f^W = \tilde{w}^{-\epsilon_W} h^d mc^W / \left(1-\beta a^{1-\sigma} \left(\gamma^W/a\pi\right)^{-\epsilon_W} \theta_W\right).$$

From (44), (48) and (76),

$$w = \left[\frac{\alpha^\alpha (1-\alpha)^{1-\alpha} p^H mc^H z a^{1-\alpha}}{(r^K)^\alpha} \right]^{\frac{1}{1-\alpha}}.$$

From (44) and (76),

$$k = \frac{\alpha a w h^d}{(1-\alpha) r^K}.$$

From (75),

$$y^H = z (k/a)^\alpha (a h^d)^{1-\alpha}/\Delta^H.$$

From (78),

$$c = y^C - g - i.$$

From GDP equal to value added,

$$p^Y y = p^H y^H + p^Y y s^{Co} + p^F \left(1 - mc^F \Delta^F\right) o \left(p^F\right)^{-\eta} \left(1-s^{tb}\right) p^Y y.$$

From (70),

$$\kappa = mc^W \lambda w / h^\phi.$$

The remaining equations are the same as in the model with search frictions, except for the equations corresponding to the labor market variables from the search model which are eliminated.

Table 1: Calibrated Parameters and Targeted Steady State Values.

Parameter	Description	Value	Source
Search model			
u	Unemployment rate in st. st.	0.08	Average (1987-2014)
$\bar{b}$	Unemployment benefit	0	OECD data (% of GDP)
e	Firm matching rate	0.7	Den Haan et al. (2000)
ρ	Total separation rate	0.0755	Jones and Naudon (2009)
ρ^x	Exog. separation rate	$\frac{2}{3}\rho$	Den Haan et al. (2000)
$\mu_{\tilde{c}}$	Log-normal mean of $\tilde{c}$	0	Normalization
φ	Workers' bargaining weight	0.5	Related literature
Calvo wage model			
ϵ_W	E. o. s. wages	11	Medina and Soto (2007)
Common parameters			
σ	Inverse intertemporal e. o. s.	1	Medina and Soto (2007)
α	Capital share in production	1-0.66	Medina and Soto (2007)
δ	Capital depreciation	0.06/4	Medina and Soto (2007)
ϵ_H	E. o. s. domestic aggregate	11	Medina and Soto (2007)
ϵ_F	E. o. s. imported aggregate	11	Medina and Soto (2007)
α_W	Indexation parameter	1	Medina and Soto (2007)
o	Share of F in Y^C	0.32	Average (1987-2014)
χ	Gov. share in commodity sector	0.61	Average (1987-2014)
s^{tb}	Trade balance to GDP in st. st.	0.04	Average (1987-2014)
s^g	Gov. cons. to GDP in st. st.	0.11	Average (1987-2014)
s^{Co}	Commod. prod. to GDP in st. st.	0.10	Average (1987-2014)
$\bar{\pi}$	Inflation in st. st.	3% p.a.	Inflation target in Chile
p^H	Relative price of H in st. st.	1	Normalization
h	Hours per worker in st. st.	0.3	Normalization
$\bar{a}$	Long-run growth	2% p.a.	Albagli et al. (2015)
β	Subjective discount factor	0.9995	MPR approx. 5%
R^*	Foreign rate in st. st.	4.5% p.a.	Fuentes and Gredig (2008)
ξ	Country premium in st. st.	1.5% p.a.	Average (1987-2014)

Note: All rates are annualized figures.

Table 2: Marginal Data Densities.

	Search		
	With m_t	Without m_t	Calvo W
$\log p(X^T\|\theta)$	-1268.9	-1356.2	–
$\log p(X^T \text{ without } u^T\|\theta)$	-1232.9	-1264.9	-1322.4
$\log p(X^T \text{ without } u^T \text{ and } h^T \times n^T\|\theta)$	-1122.3	-1134.5	-1168.7
$\log p(X^T \text{ without } u^T,\ h^T \times n^T \text{ and } \Delta \log W^T\|\theta)$	-1098.4	-1101.5	-1103.6

Note: X^T denotes the full data set, X^T without u^T the set excluding the unemployment rate, X^T without u^T and $h^T \times n^T$ the set excluding also total hours worked, and X^T without u^T, $h^T \times n^T$ and $\Delta \log W^T$ the set excluding also the growth rate of real wages. For the model with search frictions when excluding the unemployment rate, we also compute the marginal likelihoods shutting down the match efficiency shock (m_t). The marginal data densities are Laplace approximations at the mean of the posterior mean.

Table 3: Second Moments.

		s.d. (%)			AC order 1		
Variable	Description	Data	Search	Calvo W	Data	Search	Calvo W
$\Delta \log Y$	GDP	1.02	1.23	1.00	0.21	0.06	0.51
$\Delta \log C$	Consumption	1.08	0.88	1.26	0.64	0.59	0.76
$\Delta \log I$	Investment	4.16	4.44	5.38	0.25	0.45	0.80
TB/GDP	Nom. trade balance	5.23	4.76	5.10	0.77	0.94	0.96
π	Inflation	0.71	0.69	1.44	0.60	0.40	0.93
R	MPR	0.43	0.44	1.60	0.89	0.90	0.98
rer	Real exch. rate	5.25	9.29	15.05	0.75	0.87	0.95
ξ	EMBIG Chile	0.14	0.24	0.25	0.82	0.94	0.95
$\Delta \log W$	Real wage	0.60	0.63	0.89	0.33	0.34	0.52
π^W	Nominal wage infl.	0.43	0.55	1.79	0.60	0.72	0.89
$h \times n$	Total hours worked	1.85	2.15	6.77	0.72	0.87	0.91
u	Unemployment rate	1.41	1.52	–	0.96	0.93	–

Note: The model moments are the theoretical moments at the posterior mean.

Table 4: Estimated Parameters.

Param.	Description	Prior			Posterior			
					Search		Calvo W	
		Dist.	Mean	s.d.	Mean	90% HPDI	Mean	90% HPDI
ϕ	Inv. elast. of h	norm	2	2	5.640	[3.609, 7.850]	4.416	[2.230, 6.567]
ς	Habit formation	beta	0.7	0.1	0.714	[0.644, 0.783]	0.842	[0.768, 0.919]
ψ	Country prem. elast.	invg	0.01	Inf	0.005	[0.003, 0.006]	0.003	[0.002, 0.005]
η	E. o. s. H and F	invg	1.5	0.25	2.513	[1.959, 3.079]	1.639	[1.299, 2.001]
η^*	RER elast. of X^{H*}	invg	0.25	0.1	0.374	[0.216, 0.531]	0.179	[0.114, 0.239]
γ	Inv. adj. cost	norm	4	1.5	0.667	[0.158, 1.191]	5.446	[3.567, 7.246]
$\sigma_{\tilde{c}}$	s.d. of $\tilde{c}$	norm	0.1	0.05	0.261	[0.207, 0.316]	–	–
μ	Match elast.	beta	0.5	0.1	0.629	[0.499, 0.756]	–	–
$\varkappa_W$	Inertia of W	beta	0.5	0.15	0.924	[0.899, 0.949]	–	–
θ_W	Calvo prob. W	beta	0.75	0.1	–	–	0.915	[0.881, 0.950]
ϑ_W	Index. past infl. W	beta	0.5	0.15	0.286	[0.160, 0.408]	0.703	[0.532, 0.888]
θ_H	Calvo prob. H	beta	0.75	0.1	0.450	[0.355, 0.549]	0.818	[0.770, 0.867]
ϑ_H	Index. past infl. H	beta	0.5	0.15	0.490	[0.235, 0.728]	0.197	[0.082, 0.309]
θ_F	Calvo prob. F	beta	0.75	0.1	0.890	[0.853, 0.929]	0.718	[0.648, 0.789]
ϑ_F	Index. past infl. F	beta	0.5	0.15	0.612	[0.450, 0.782]	0.485	[0.247, 0.720]
ρ_R	MPR rule R_{t-1}	beta	0.75	0.1	0.808	[0.769, 0.847]	0.766	[0.715, 0.819]
α_π	MPR rule π_t	norm	1.5	0.1	1.511	[1.361, 1.657]	1.263	[1.157, 1.367]
α_y	MPR rule Δy_t	norm	0.125	0.05	0.147	[0.068, 0.223]	0.108	[0.028, 0.188]
ρ_ϱ	AC cons. pref. sh.	beta	0.75	0.1	0.793	[0.688, 0.895]	0.809	[0.678, 0.946]
ρ_κ	AC labor pref. sh.	beta	0.75	0.1	0.751	[0.613, 0.897]	0.778	[0.645, 0.915]
ρ_m	AC matching sh.	beta	0.75	0.1	0.813	[0.750, 0.879]	–	–
ρ_ϖ	AC inv. sh.	beta	0.75	0.1	0.719	[0.605, 0.837]	0.951	[0.922, 0.979]
ρ_z	AC temp. TFP sh.	beta	0.75	0.1	0.872	[0.800, 0.942]	0.602	[0.495, 0.711]
ρ_a	AC perm. TFP sh.	beta	0.375	0.1	0.358	[0.210, 0.509]	0.458	[0.322, 0.602]
ρ_{ζ^o}	AC obs. risk sh.	beta	0.75	0.1	0.856	[0.786, 0.926]	0.837	[0.753, 0.924]
ρ_{ζ^u}	AC unobs. risk sh.	beta	0.75	0.1	0.845	[0.763, 0.933]	0.822	[0.762, 0.884]
σ_ϱ	s.d. cons. pref. sh.	invg	0.01	Inf	0.023	[0.018, 0.029]	0.053	[0.031, 0.077]
σ_κ	s.d. labor pref. sh.	invg	0.01	Inf	0.053	[0.035, 0.070]	0.159	[0.003, 0.276]
σ_m	s.d. matching sh.	invg	0.01	Inf	0.132	[0.090, 0.171]	–	–
σ_ϖ	s.d. inv. shock	invg	0.01	Inf	0.018	[0.009, 0.028]	0.067	[0.047, 0.087]
σ_z	s.d. temp. TFP sh.	invg	0.01	Inf	0.008	[0.006, 0.009]	0.016	[0.013, 0.019]
σ_a	s.d. perm. TFP sh.	invg	0.01	Inf	0.003	[0.002, 0.003]	0.007	[0.005, 0.008]
σ_{ζ^o}	s.d. obs. risk sh.	invg	0.003	Inf	0.001	[0.001, 0.001]	0.001	[0.001, 0.001]
σ_{ζ^u}	s.d. unobs. risk sh.	invg	0.003	Inf	0.005	[0.003, 0.008]	0.007	[0.004, 0.009]
σ_R	s.d. MPR shock	invg	0.003	Inf	0.002	[0.001, 0.002]	0.002	[0.001, 0.002]

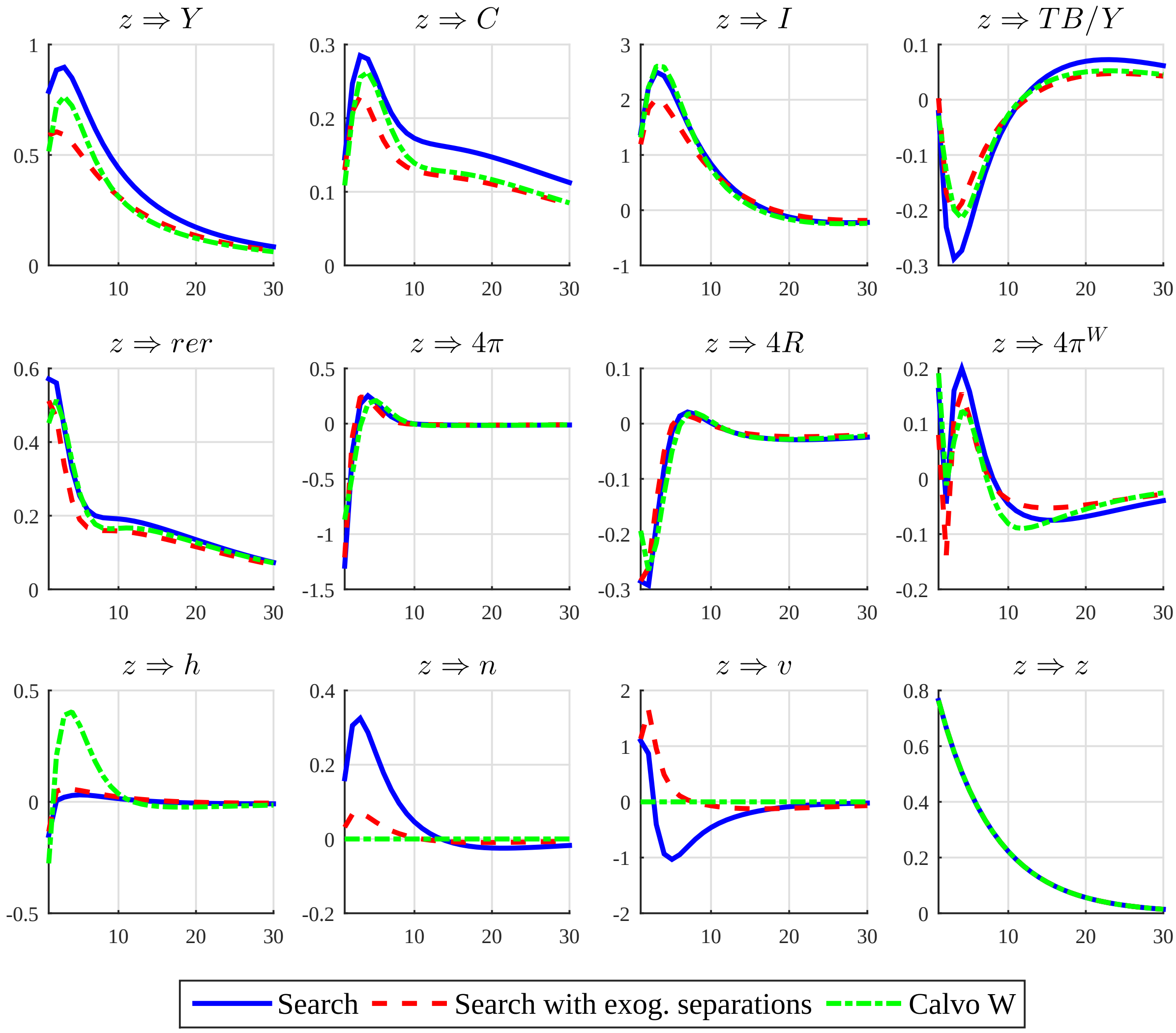
Note: The results are based on 500,000 draws from the posterior distribution using the Metropolis-Hastings (MH) algorithm, dropping the first 250,000 draws to achieve convergence. The average acceptation rate of the MH algorithm was approximately 25% for each model. HPDI are the highest posterior density intervals. The priors for the parameters ϕ and α_π were truncated at 0 and 1, respectively. The computations were conducted using Dynare 4.4.3.

Table 5: Variance Decomposition.

	Shock																		
Variable	TFP trans. z	TFP perm. a	Inv. tech. ϖ	**Total tech. sh.**	Cons. pref. ϱ	Lab. sup. κ	**Total pref. sh.**	**MP rate** e^R	**Gov. cons.** g	Risk obs. ζ^o	Risk unobs. ζ^u	**Total risk sh.**	For. rate R^*	For. infl. π^*	Co. price p^{Co*}	For. dem. y^*	**Total for. sh.**	**Co. prod.** y^{Co}	**Match eff.** m
	A. Search																		
y	35	2	5	42	3	7	9	1	0	0	12	12	17	5	12	0	34	1	1
c	2	1	1	4	8	0	8	0	0	0	13	14	13	13	48	0	74	0	0
i	13	0	11	24	5	3	8	1	0	0	25	25	26	5	10	0	42	0	0
TB/GDP	3	0	4	7	0	1	1	2	0	0	17	17	23	9	39	1	72	1	0
π	17	1	32	50	4	10	14	21	0	0	4	4	3	2	2	1	8	0	3
R	4	1	41	46	3	2	5	4	0	0	12	12	16	5	12	0	32	0	0
rer	2	0	2	4	0	0	1	1	0	1	49	50	23	12	9	0	44	0	0
ξ	1	0	1	2	0	0	0	1	0	39	4	43	16	18	19	0	54	0	0
w	7	1	1	9	1	0	1	1	0	0	18	18	23	11	34	0	69	0	3
$h \times n$	12	0	12	25	6	39	44	4	0	0	5	5	5	1	2	0	8	0	14
u	18	0	8	26	0	2	2	5	0	0	13	13	15	4	11	0	29	0	24
	B. Calvo W																		
y	0	1	92	94	1	1	2	0	0	0	1	1	2	0	1	0	3	0	–
c	0	3	35	38	19	0	19	0	0	0	5	5	8	6	24	0	38	0	–
i	0	1	87	88	2	0	2	0	0	0	2	2	5	1	2	0	8	0	–
TB/GDP	0	1	30	31	2	0	2	0	0	0	8	8	15	6	37	0	58	1	–
π	1	1	74	75	3	0	3	1	0	0	10	11	7	2	2	0	10	0	–
R	0	1	80	81	3	0	3	1	0	0	6	6	6	1	2	0	9	0	–
rer	0	2	59	61	1	0	1	0	0	0	14	14	10	5	9	0	24	0	–
ξ	0	1	29	30	1	0	1	0	0	31	3	34	6	10	19	0	35	0	–
w	0	0	51	51	2	2	4	0	0	0	5	5	11	5	23	0	40	0	–
$h \times n$	15	1	71	87	4	4	8	1	0	0	1	1	1	0	1	0	2	0	–

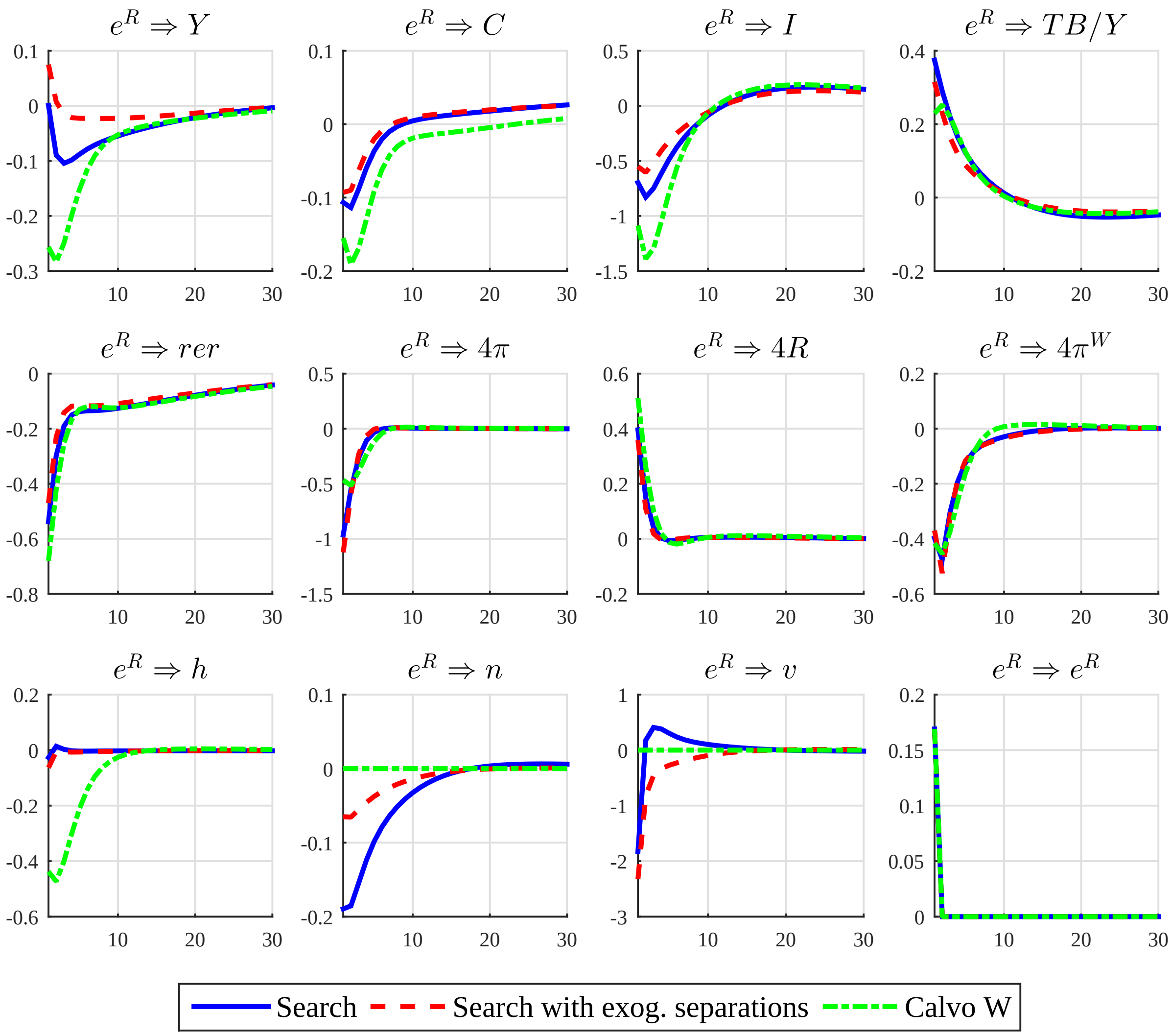
Note: The table entries are the fraction of the unconditional theoretical variances at the posterior mean (in %) explained by the shocks.

Figure 1: Impulse Responses to a Transitory TFP Shock (z).



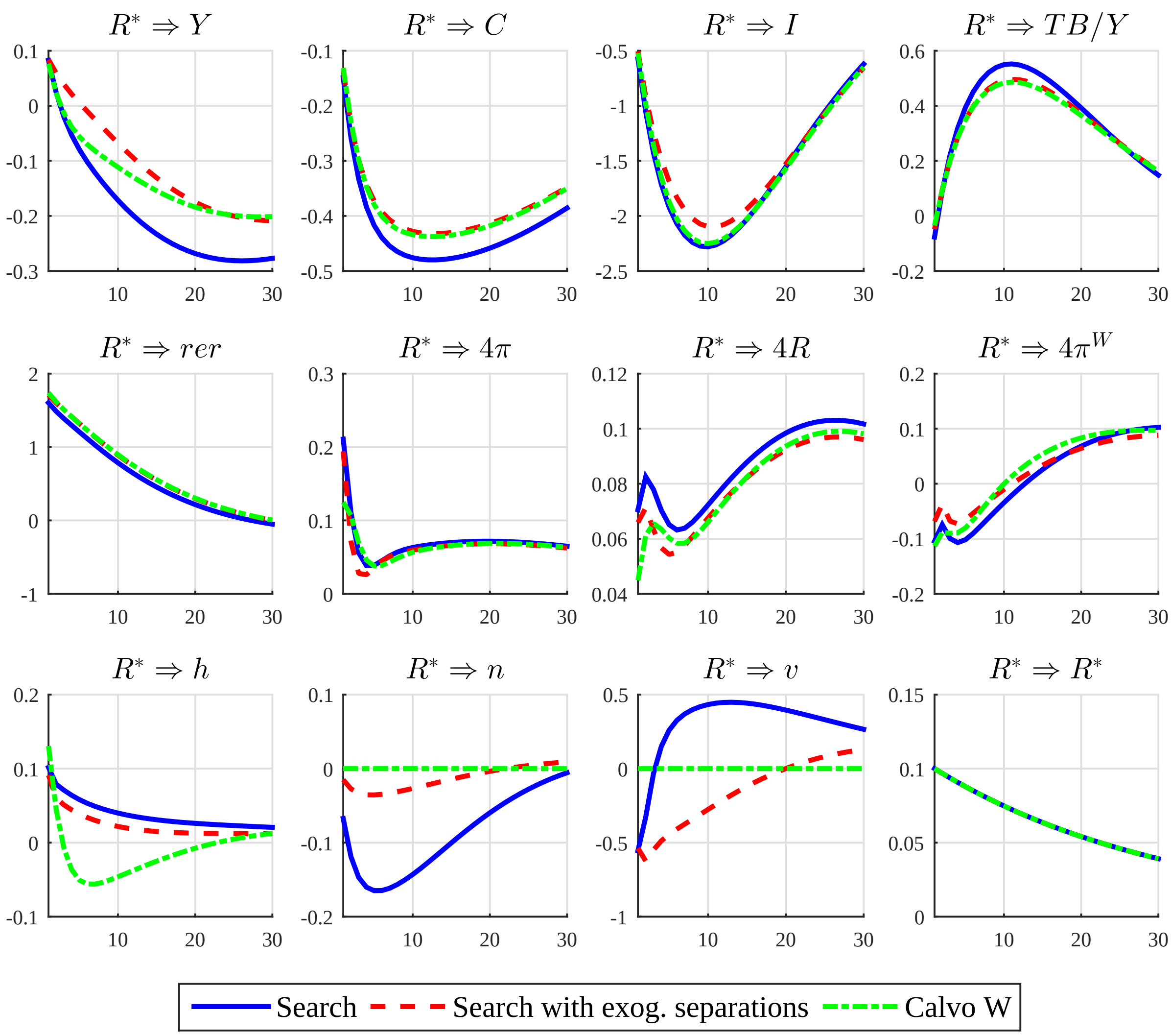
Note: The blue solid lines correspond to the model with search frictions, the red dashed lines to the model without endogenous separations, and the green dash-dotted lines to the model with Calvo wages. In all cases the estimated parameters (posterior mean) of the model with search frictions are used, setting $\theta_W = 0.915$ for the model with Calvo wages. The variables are real GDP (Y), private consumption (C), investment (I), the nominal trade balance as a ratio of GDP (TB/Y), the real exchange rate (rer), annualized CPI inflation (4π), the annualized monetary policy rate ($4R$), annualized nominal wage inflation ($4\pi^W$), hours per worker (h), employment (n), and vacancies (v). All variables are expressed as percentage deviations from steady state.

Figure 2: Impulse Responses to a Monetary Policy Shock (e^R).



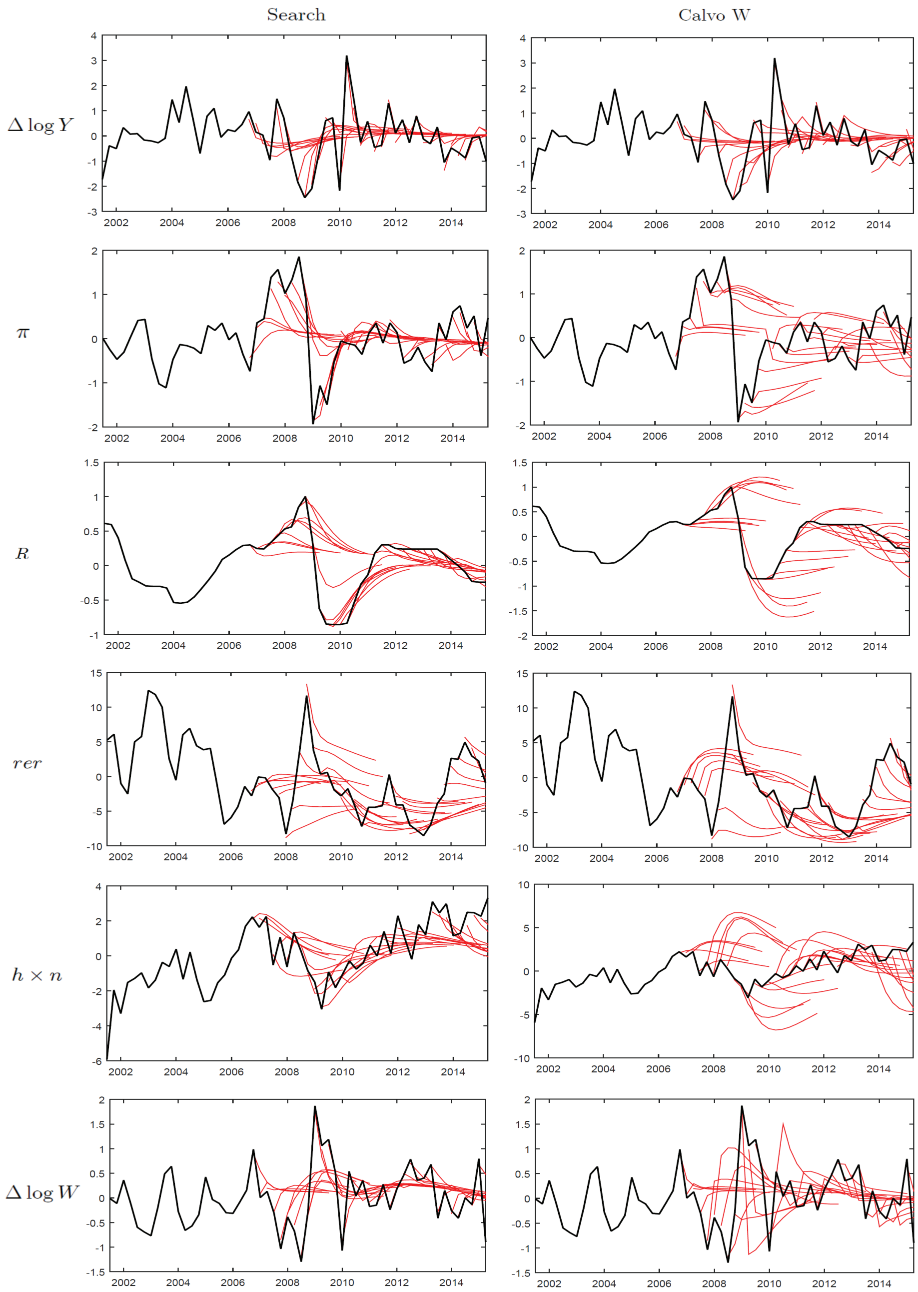
Note: See Figure 1.

Figure 3: Impulse Responses to a Foreign Interest Rate Shock (R^*).



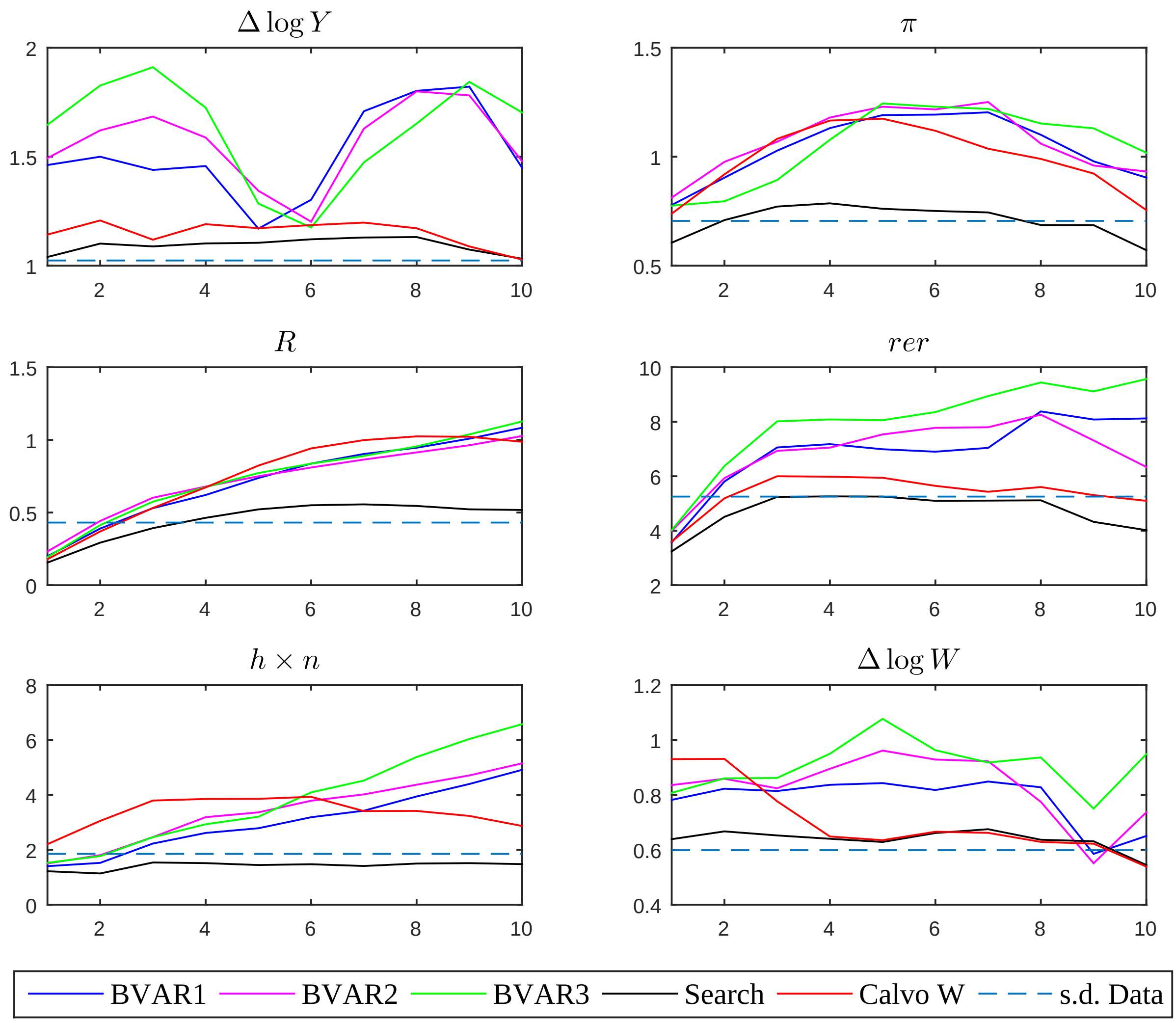
Note: See Figure 1.

Figure 4: Recursive Out-of-Sample Forecasts.



Note: The black thick lines show the observed data while the red thin lines show the recursive forecasts. The forecasts are based on recursive estimations of the posterior mode of each model. The first estimation sample is 2001Q3-2006Q4 and the last estimation sample is 2001Q3-2015Q1.

Figure 5: Root Mean Squared Errors of Out-of-Sample Forecasts.



Note: See Figure 4. BVAR1 includes real GDP growth, inflation, the monetary policy rate, total hours worked and real wage growth. BVAR2 includes the variables from BVAR1 plus the growth rates of real private consumption and investment, real government consumption, and the real exchange rate. BVAR3 includes the variables from BVAR1 plus commercial partners' real GDP, the foreign interest rate, the copper price, and commercial partners' inflation. The variable transformations for the BARs are the same as those adopted for the estimation of the DSGE models.

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