Firm entry, Search and Matching in a Small Open Economy Faced with Uncertainty Shocks: The case of Korea

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May 2017

Abstract

Using Korean survey data, we first compute uncertainty index and worker flows. Using a VAR model, we then show that an increase in uncertainty lowers output and job finding rates, while raising job separations and unemployment. Our evidence put forward the importance of uncertainty shocks on the job separation margin, in contrast to US data. We also supplement the existing empirical evidence by looking at firm dynamics and current account behavior. We find that increased uncertainty generates current account surplus, real exchange rate depreciation and reduces the stock of firms in the economy. We then investigate the impact of uncertainty shocks in a small open economy with search and matching frictions, endogenous job separation and firm entry. The model's predictions are consistent with the empirical findings, as the option value channel affects labor adjustments as well as firm entry.

Keywords: small open economy, search and matching, firm entry, uncertainty shocks
JEL classification: E32, F41, F32, J64

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1 Introduction

This paper investigates the impact of uncertainty shocks in a small open economy with search and matching frictions, endogenous job separation, capital and firm entry. To our knowledge, this is the first paper that combines these elements. We develop our analysis in the context of the Korean economy, as all dimensions of the model are relevant in this country: Korea is a globalized economy with heavily regulated labor and product markets, in which the job separation margin appears empirically important.

Our work is related to the literature that has documented the relationship between uncertainty and the business cycle (Bloom (2014)). With respect to the literature on uncertainty shocks in an open economy setting (Fernandez-Villaverde et al. (2011), Kollmann (2016)), our originality lies in investigating the consequences of time-varying volatility on labor market adjustments and firm entry. With respect to the literature on uncertainty shocks in a search and matching environment (Leduc & Liu (2016), Guglielminetti (2015), Riegler (2015)), we lay stress on the endogenous separation and study the interaction between search and matching frictions and firm entry in an open economy setting, which has not been done in the existing work. In this paper, we study the macroeconomic effects of uncertainty shocks by allowing for richer and more realistic firm dynamics, in addition to labor market frictions. We are then able to highlight important transmission channels that are ignored in the literature on the macroeconomic effects of fluctuating uncertainty. Basu & Bundick (2012) stress that uncertainty shock generates recessionary effects in a rigid price environment. We argue that the interaction between search and matching and firm entry lead to sizeable macroeconomic effects of heightened uncertainty in a *flexible* price environment.

We first provide original empirical evidence on the effect of fluctuating uncertainty on economic activity, labor market adjustments, firm dynamics and current account on Korean data. Using survey data, we carefully compute the job finding and job separation rates. Using Shimer (2012)'s variance decomposition, unemployment inflows appears to be the main driver of unemployment cyclical behavior, which stresses the need for endogenous separation in the model. We then investigate the macroeconomic impact of time-varying volatility in a structural VAR. In doing so, we extend the literature by *i)* extending the empirical results previously found on US data, and *ii)* investigating the impact of increased volatility on firm dynamics, real exchange rate and current account fluctuations. We find that an increase in uncertainty lowers output, consumption, investment and job finding rates, while raising job separations and unemployment. These conclusions are consistent with the findings by Leduc

& Liu (2016), Guglielminetti (2015) and Riegler (2015) using US data. However, in US data, separation plays a minor in accounting for unemployment fluctuations (Shimer (2012)). In contrast, in Korean data, our evidence put forward the importance of uncertainty shocks on the separation margin. We also supplement the existing empirical evidence by looking at firm dynamics and current account behavior. We find that increased uncertainty generates current account surplus, real exchange rate depreciation and reduces the stock of firms in the economy.

We next develop a small open economy with search and matching frictions, endogenous job separation and firm entry. Uncertainty shocks do not affect technology as in Leduc & Liu (2016) and Guglielminetti (2015). Uncertainty shocks are defined as unexpected exogenous variations in the volatility of the technological process. In this paper, in order to compare our results to the existing literature, we focus on technological volatility shocks.

In order to take into account the effect of uncertainty shocks on agents' decisions, we use a third-order approximation. We show that the model is able to replicate the impulse response function of the structural VAR: an increase in uncertainty raises unemployment, job separation rates, and lowers output, consumption, investment, the stock of firms and job finding rates. The economy is also characterized by a current account surplus and real exchange rate depreciation. The model correctly reproduces the IRFs of the VAR. Let us stress that this is not a trivial result.

Indeed, as underlined by Basu & Bundick (2012), following uncertainty shocks, in the data, rising uncertainty result in a decline in output, consumption, investment *and* employment. However, macroeconomic models fail to generate such business-cycle co-movements among output, consumption, investment, and employment from changes in uncertainty. In a standard RBC model, the effect of uncertainty is actually expansionary, as rising uncertainty leads consumer to increase savings, resulting in lower consumption and higher investment. Basu & Bundick (2012) argue that the co-movement of these four macroeconomic variables can be obtained after an uncertainty shock in a demand-driven economy, with *price rigidity*. The fall in consumption reduces output. Firms cut their labor demand, which drives the demand for capital downward, hence investment. Endogenous rise in mark-ups help the sticky-price model generate data-consistent IRFs.

Guglielminetti (2015) explore the effects of uncertainty shocks in a search and matching model, with capital, in a *flexible* price environment. Uncertainty creates a precautionary saving motive that reduces consumption as well as the real interest rate. All else equal, a reduction in the real interest rate raises the present value of a job match and thus boosts employment and output. However, with labor market frictions, as hiring is an irreversible long-term employment relation, uncertainty gives rise to a contractionary real option-value effect. Facing higher uncertainty, the option value of waiting increases and the expected value of a job match drops. The option-value channel then dominates the precautionary saving motives. Faced with a lower expected return on the match, firms post fewer vacancies, unemployment goes up, making it harder for unemployed workers to find jobs. However, Guglielminetti (2015) finds that, in a search and matching setting, under flexible price, heightened uncertainty does not yield sizable recessionary effects. Leduc & Liu (2016) find sizeable recessionary effects of increased uncertainty in a search and matching model, *with price and wage rigidity*, but no capital. Leduc & Liu (2016) stress the quantitative importance of price rigidity in generating large macroeconomic impact of uncertainty shocks. However, Leduc & Liu (2016) develop a model without capital and endogenous separation, thereby neglecting two essential dimensions in the study of uncertainty shocks : Basu & Bundick (2012) argue that investment is an important dimension in the study of uncertainty shocks. We also argue in this paper that job separation is a key adjustment margin on the labor market, especially in Korea. As noted by Den Haan & Watson (2000), the combination of capital and endogenous separation provide an interesting interaction for the propagation of shocks.

In this paper, we find that a search and matching model with firm entry can also capture the co-movement feature stressed by Basu & Bundick (2012), in a *flexible price* environment, through the interaction between labor market frictions and firm entry. The originality of our paper is to stress that the co-movement feature can be obtained without price rigidity. In our model, real options apply to two key decisions: hiring decisions and firm entry. As firm entry incurs a fixed cost, the option value of waiting also affects entry decision. Following a positive uncertainty shock, the expected value of a firm falls, which drives firm entry down. The number of producers eventually declines. At the aggregate level, the drop in the number of firms is equivalent to a fall in the capital stock. This amplifies the initial decline in output. Korea is an interesting country as entry costs are large compared to the US. With heavy entry regulations, fixed entry costs are large enough to produce sizeable real-option value effects.

As for the open economy dimension, Kollmann (2016) finds that, following an unexpected rise in output volatility, Home net foreign assets increase, which is consistent with our IRFs. However, in Kollmann (2016)'s 2-country model, under complete financial markets, the international risk sharing implies that the rise in Home output volatility triggers a wealth transfer from the rest of the world to the Home country, such that Home consumption rises, and the Home real exchange rate appreciates. These features are counterfactual on Korea data. Fernandez-Villaverde et al. (2011) stress that rising uncertainty on foreign shocks triggers a fall in foreign debt, hence a current account surplus. They do not discuss the implications for real exchange rate dynamics. We echo their findings in the case of technological shocks and supplement their work by looking at real exchange rate fluctuations in response to fluctuating uncertainty. In our model, real exchange rate depreciates in response to increase in uncertainty, as Home relative prices decline. real exchange rate depreciation is consistent with the current account surplus as the real exchange rate depreciation makes imports more expensive.

The paper is organized as follows. We investigate the macroeconomic effects of uncertainty shocks in Korean data in Section 2, then develop a small open economy model with search and matching, endogenous separation and firm entry in Section 3. We explore the macroeconomic effects of uncertainty shocks in Section 4. Section 5 concludes.

2 Stylized facts: Impact of uncertainty shocks on labor market flows and current account

We provide new evidence of the macroeconomic effects of uncertainty shocks in a small open economy. In particular, we provide evidence of the effects of uncertainty shocks on GDP, current account, unemployment, job finding and job separation probabilities.

2.1 Measuring uncertainty

Our measure of uncertainty is forecast dispersion computed from the Korean economy forecasts in Consensus Economics. Periods when forecasters hold more diverse opinions are likely to reflect greater uncertainty. Since January 1995, Consensus Economics has surveyed over prominent financial and economic forecasters for their estimates of a range of Korean macroeconomic variables, including GDP, inflation, unemployment and interest rates over a 2 year forecast horizon. Among them, we use cross-sectional standard deviation of GDP forecasts.[1]

[1] To construct the series, we compute the average of cross-sectional standard deviations of GDP forecasts over a 2 year horizon. Bloom (2014) also checks that forecast dispersion provides a good proxy for perceived uncertainty. In the US Survey of Professional Forecasters, in 1992, forecasters provide probabilities for GDP growth (in percent) falling into ten different bins. Using the subjective uncertainty calculated using these probabilities, Bloom shows that disagreement across forecasters indeed captures changes in subjective

The monthly time series are seasonally adjusted using X-13-ARIMA-SEATS method and we quarterly average the series from 1995Q1 to 2015Q4. Figure 6 in Appendix A.1 displays our measure of uncertainty. Survey-based measures of uncertainty have been previously used in the empirical literature (Bachmann et al. (2013), Leduc & Liu (2016), Guglielminetti (2015)). Other commonly used measures of uncertainty are the volatility of financial markets (Bloom (2014), Riegler (2015)), newspaper or google-based indicators (Alexopoulos & Cohen (2009), Knotek & Khan (2011)) and cross-sectional measures of dispersion in TFP growth and level, profit and sales at the sector, industry. All measures point at macroeconomic uncertainty spikes in recessions. Our measure suggests that the stylized fact is relevant in Korea.

2.2 Measuring worker flows: job separation and job finding probabilities using survey data

As in Shimer (2012), we measure the probability that an employed worker becomes unemployed and the probability that an unemployed worker finds a job, using EAPS survey data, between 1995Q1 and 2015Q4 (See Appendix A.2.2 for a full description of the microdata and the methodology). Job finding and employment exit probabilities are reported in Figure 7 in Appendix A.2.2. The job finding probability falls in recession, while employment exit probability rises in economic slumps. These cyclical features are also found in other OECD countries (Elsby et al. (2008), Shimer (2012)). The salient stylized fact in Korean data lies in the leading role of job separations in unemployment fluctuations. Based on Shimer (2012)'s variance decomposition, exit from employment accounts for nearly 80% of unemployment fluctuations (versus an upper bound of 50%-60% on US and French data (Fujita & Ramey (2009), Hairault et al. (2015)). See Appendix A.2.3 for details on the computation of Shimer (2012)'s variance decomposition.) As a result, the model developed in this paper includes endogenous separation.

Figure 1 displays our measure of uncertainty along with workers' flows and current account as % of GDP. Visual inspection suggests that increased uncertainty tends to be associated with lower job finding rate, higher separation and increases in current account. The correlation of the uncertainty measure with unemployment outflows, inflows and current account as % of GDP are respectively -0.52, 0.72 and 0.49.

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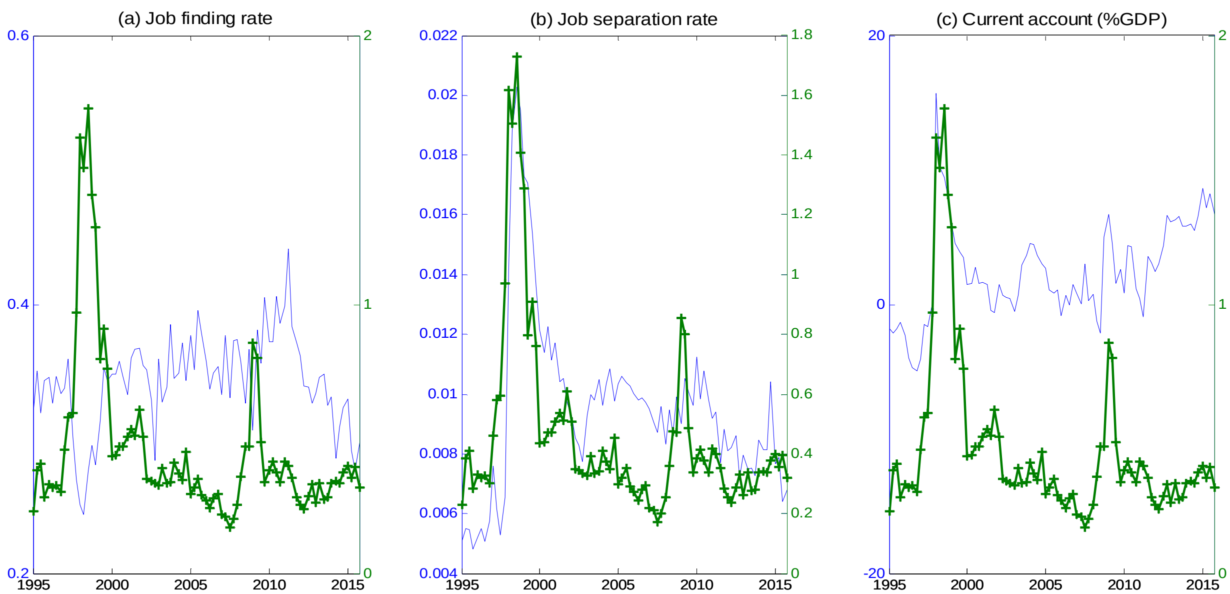
uncertainty.

Figure 1: Job finding rate, separation rate, current account and uncertainty index

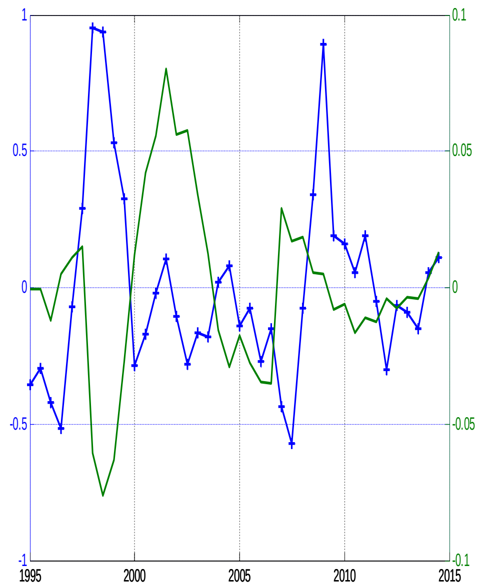


Source : Authors' calculations. See Appendix A. Solid line: the time series mentioned in the title of the graph. "+"-line Uncertainty measure

2.3 Firm dynamics

Korean firm data are available on a semi-annual basis. Firm data come from national tax statistics and span January 1995 to June 2014. We consider the stock of firms N, log and HP filter the time series using 400 as the smoothing parameter. Figure 2 displays the cyclical behavior of the stock of firms and uncertainty index. Figure 2 suggests that periods of high uncertainty are associated with a fall in the number of firms with a negative correlation of -0.44. In the next section, we go beyond the descriptive statistics using a structural VAR to identify the causal effect of uncertainty on macroeconomic dynamics.

Figure 2: Firm dynamics and uncertainty index



Source : Authors' calculations. See Appendix A. Solid line: Logged, HP-filtered, total number of firms. "+"-line Uncertainty measure, HP-filtered. Semi-annual data. Smoothing parameter 400.

2.4 VAR evidence: GDP, current account, labor market flows and firm dynamics

The structural VAR consists of four time-series; in the following order, a measure of uncertainty, one of the labor market or firm dynamics variables (the unemployment rate, the job finding rate, the job separation rate or the stock of firms [2]), real GDP (or one of GDP

[2]Semi-annual stock of firms is turned into quarterly data using spline

components such as real consumption or real private investment), and a measure related to the open economy dimension (current account, as percent of GDP, or real exchange rate defined as the relative price of US consumption basket with respect to the Korean one[3]). It is estimated with 2 lags according to Akaike's information criterion. All quarterly variables are in log (except current account), seasonally adjusted, and HP-filtered with smoothing parameter 1600. The sample ranges from 1995Q1 to 2015Q4.

As in Basu & Bundick (2012) and Leduc & Liu (2016), we assume that uncertainty does not respond to the state of the economy on impact, but labor variables, real GDP, and current account are allowed to react instantaneously to uncertainty. As in Leduc & Liu (2016), our identification strategy exploits the fact that, when answering questions at time t about their expectations, survey participants do not have complete information about the time t realizations of variables in our VAR model because the macroeconomic data have not yet been made public. Thus, the measure of uncertainty comes first in the Cholesky ordering[4].

Figure 3 plots the effects of the relevant variables to one-standard deviation shock to uncertainty with the 90% confidence bands. A one-standard deviation uncertainty shock increases the uncertainty measure by 17%. The responses of all macroeconomic variables appear statistically significant at the 90 percent level.[5] The peak decline in investment is 2.5 larger as the decline in total output, as in US data (Basu & Bundick (2012)). A one standard deviation increase in uncertainty produces a peak decline in output of about 0.5-1 percent, which falls within the range found in the US (0.2 percent in Basu & Bundick (2012), 2.5 percent in Bloom et al. (2012)).

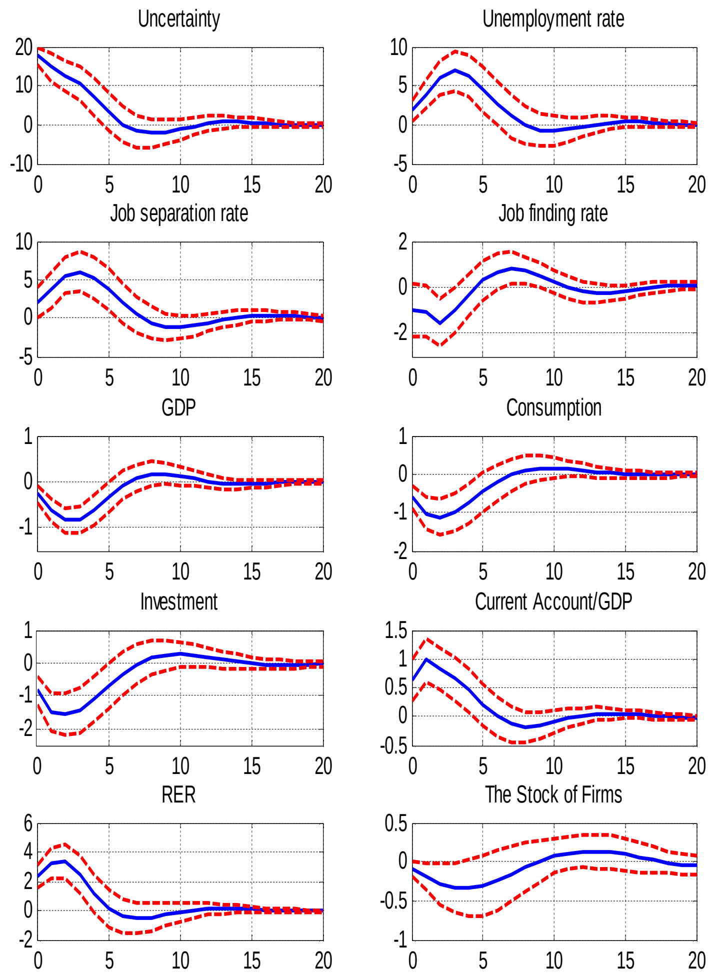
Heightened uncertainty lowers GDP, consumption and investment, as well as the job finding rate while job separation increases. Both effects on the job finding and separation rates contribute to an increase in unemployment. In particular, a one-standard-deviation increase in uncertainty leads to a peak increase of unemployment rate of about 6.9 percent relative to the sample average. The negative effects of higher uncertainty on labor variables are in line with the recent empirical studies on US data (Leduc & Liu (2016), Riegler (2015) and Guglielminetti (2015)). The difference is that the response of the separation rate is

[3]In the model as in the data, real exchange rate is the US CPI expressed in South Korean wons relative to Korean CPI. An increase in the real exchange rate captures a depreciation of the Korean currency.

[4]Appendix A.3 shows that the results are robust to alternative identification, to an alternative volatility measure, and to alternative specification.

[5]The results are robust to changing the Cholesky order. Other shocks in the structural VAR are consistent with economic mechanisms.

Figure 3: The effects of one-standard deviation shock to uncertainty: GDP, current account and labor market flows.



Quarterly data. 90% confidence band. The units of the horizontal axes are quarters. The units of the vertical axes are % change. Example : following a 1 standard deviation shock, the rise in unemployment rate peaks at 6.9%. Current account is % of GDP, IRF is then in percentage points.

initially stronger and more persistent than the job finding rate, which is not the case on US data. These findings echoes our variance decomposition on Korean data.

When it comes to firm dynamics, firm entry significantly drops following an uncertainty shock. In the subsequent section, we propose a model with firm entry, in which the number of firms actually captures the number of products available in the economy. In the current section, we look at data on business formation and establishment dynamics. As each firm produces at least one product, the empirical evidence presented in this section then provides a lower bound on the IRFs on firm dynamics we need to match with the model.

The novel feature of our paper is to investigate the impact of increased uncertainty on current account dynamics. Increased uncertainty is associated with current account surplus. This is consistent with the empirical result that heightened uncertainty reduces domestic absorption (consumption and investment fall). Korean real exchange depreciates. This is consistent with current account surplus as real depreciation makes imports more expensive.

3 Small open economy model with labor market frictions and firm entry

We model a small open economy. Foreign variables are denoted with a superscript star. The subscript d refers to quantities and prices of a country's own goods consumed domestically. x refers to quantities and prices of exports.

3.1 Household's preference

The economy is populated by a unit mass of households, where each household is an extended family. In each family, some members are employed, others are employed. This assumption is made to avoid heterogeneity across households, as in Andolfatto (1996). The representative household maximizes the expected intertemporal utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma_c}}{1-\sigma_c} \right]$$

where $\beta \in (0,1)$ is the discount factor, and $\sigma_c > 0$ risk aversion. C_t represents consumption of market and home-produced goods: $C_t = C_t^M + (1 - L_t)h_p$, where C_t^M is consumption of market goods, h_p is home production, and L_t is the number of employed workers. The aggregate market-consumption basket C_t^M is a CES aggregate of domestic ($C_{d,t}$) and foreign ($C_{x,t}^*$) goods with elasticity of substitution $\phi > 0$:

$$C_t^M = \left((1-\gamma)^{\frac{1}{\phi}} C_{d,t}^{\frac{\phi-1}{\phi}} + \gamma^{\frac{1}{\phi}} (C_{x,t}^*)^{\frac{\phi-1}{\phi}} \right)^{\frac{\phi}{\phi-1}}$$

with $0 < \gamma < 1$ the share of foreign goods in the consumption basket and ϕ the elasticity of substitution between Home and Foreign goods. The corresponding composite price index is:

$$P_t = \left((1-\gamma) P_{d,t}^{1-\phi} + \gamma (\varepsilon_t P_{x,t}^*)^{1-\phi} \right)^{\frac{1}{\phi-1}}$$

The domestic consumption basket $C_{d,t}$ is defined over a set Ω_t of available consumption goods. As in Bilbiie et al. (2012), we assume that $C_{d,t}$ and $C_{x,t}^*$ take a translog form as in Feenstra (2003) such that the elasticity of substitution across varieties ω in the subset $C_{d,t}$ increases with the number of available goods in the economy. The price index associated with translog preferences is

$$\begin{aligned} \ln P_{d,t} &= \frac{1}{2\sigma}\left(\frac{1}{N_t} - \frac{1}{\tilde{N}_t}\right) + \frac{1}{N_t}\int_{\omega \subset \Omega_{d,t}} \ln p_{d,t}(\omega) d\omega \\ &+ \frac{\sigma}{2N_t}\int_{\omega \subset \Omega_{d,t}} \int_{\omega' \subset \Omega_{d,t}} \ln p_{d,t}(\omega) \left(\ln p_{d,t}(\omega) - \ln p_{d,t}(\omega')\right) d\omega d\omega' \end{aligned}$$

with $\sigma > 0$ the price elasticity of demand on an individual good, $p_{d,t}(\omega)$ the price of a variety ω produced and sold at Home, N_t the total number of Home producers (the mass of Ω_t), and $\tilde{N}_t$ the maximum number of varieties (the mass of Ω). In a small open economy setting, P_t^* and $P_{x,t}^*$ are exogenous.

3.2 Production

Producer of variety ω There is a continuum of monopolistically competitive firms, each producing a different variety ω. As in Bilbiie et al. (2012), a firm is a producer of one product. The number of firms is endogenous, because of firm entry. Upon entry, firms pay a sunk entry cost $f_{E,t}$. Exit is exogenous, based on death shock $0 < \delta < 1$. Production uses labor and capital. Within each firm, there is a continuum of jobs, each job is executed by one worker. Capital is perfectly mobile across firms and jobs as in Den Haan & Watson (2000) and Cacciatore & Fiori (2016).

A filled job i at firm ω produces $Z_t z_{it} k_{i\omega t}^{\alpha}$ with Z_t aggregate productivity, z_{it} match-specific productivity, $k_{i\omega t}$ stock of capital allocated to the job. Within each firm, jobs with identical productivity z_{it} produce the same amount of output. As a result, i be can ignored. Each job is characterized by its match-specific productivity z_t. z_t is a per-period i.i.d. draw from a time-invariant distribution with c.d.f. $G(z)$, positive support, and density $g(z)$. When solving the model, we assume that $G(z)$ is lognormal with log-scale μ_{zi} and shape σ_{zi}. Total output for producer ω is

$$y_{\omega t} = Z_t l_{\omega t} \frac{1}{\left[1 - G\left(z_{\omega t}^c\right)\right]} \int_{z_{\omega t}^c}^{\infty} k_{\omega t}^{\alpha}(z) z g(z) dz$$

$z_{\omega t}^c$ endogenous threshold below which jobs that draw $z_t < z_{\omega t}^c$ are not profitable. As in Leduc & Liu (2016), the aggregate TFP shock Z_t follows the stochastic process

$$\ln Z_t = \rho_z \ln Z_{t-1} + \sigma_{zt} \epsilon_t^z \tag{1}$$

with $0 < \rho_Z < 1$. ϵ_t^z is an i.i.d.innovation to the technology shock and is a standard normal process, with mean zero and unit variance. The time-varying standard deviation of the innovation σ_{zt} captures technology uncertainty shock. σ_{zt} follows the stochastic process

$$\ln \sigma_{zt} = (1 - \rho_{\sigma_z}) \ln \sigma_z + \rho_{\sigma_z} \ln \sigma_{z,t-1} + \sigma_{\sigma_z} \epsilon_t^{\sigma_z} \tag{2}$$

with $0 < \rho_{\sigma_z} < 1$. $\epsilon_t^{\sigma_z}$ is an i.i.d.innovation to the technology uncertainty shock and is a standard normal process, with mean zero and unit variance. σ_{zt} and σ_{σ_z} respectively controls the degree of mean volatility and stochastic volatility in TFP.

Firms sells at home and abroad. The demand faced by producer ω is

$$y_{\omega t} = y_{d,t}(\omega) + y_{x,t}(\omega)$$

with

$$y_{d,t}(\omega) = (1-\gamma)\sigma \ln\left(\frac{\bar{p}_{d,t}}{p_{d,t}(\omega)}\right) \frac{P_{d,t}}{p_{d,t}(\omega)} \left(\frac{P_{d,t}}{P_t}\right)^{-\phi} Y_t^C$$

$$y_{x,t}(\omega) = \gamma\sigma \ln\left(\frac{\bar{p}_{x,t}}{p_{x,t}(\omega)}\right) \frac{P_{x,t}}{p_{x,t}(\omega)} \left(\frac{P_{x,t}}{\varepsilon_t P_t^*}\right)^{-\phi} Y_t^{C*}$$

where Y^C and Y_t^{C*} denote aggregate demand at Home and abroad. Notice that P_t^* expressed in Foreign currency, while P_x and $p_{x,t}(\omega)$ are in Home currency. ε_t is the nominal exchange rate. The maximum prices that a domestic producer can charge are

$$\ln \bar{p}_{d,t} = \frac{1}{\sigma N_t} + \frac{1}{N_t}\int_{\omega\subset\Omega_{d,t}} \ln p_{d,t}(\omega)d\omega$$
$$\ln \bar{p}_{x,t} = \frac{1}{\sigma N_t} + \frac{1}{N_t}\int_{\omega\subset\Omega_{x,t}} \ln p_{x,t}(\omega)d\omega$$

Search and matching frictions Labor markets are characterized by search and matching frictions. Hirings are subject to costs of posting vacancy κ. The number of matched workers M_t are such that

$$M_t = \chi U_t^{\varepsilon} V_t^{1-\varepsilon}$$

with $\chi > 0$, $0 < \varepsilon < 1$, U_t the total number of unemployed workers in the economy and V_t the aggregate number of vacancies. The probability of filling a vacancy is $q_t = \frac{M_t}{V_t}$ and labor market tightness is $\theta_t = \frac{V_t}{U_t}$. The timing of events follows Den Haan & Watson (2000). Firms select capital after observing aggregate and idiosyncratic shocks. Let $v_{\omega t}$ denote the vacancies posted by producer ω. Total capital stock for firm ω is $k_{\omega t} = l_{\omega t}\tilde{k}_{\omega t}$ where

$$\tilde{k}_{\omega t} = \frac{1}{\left[1 - G\left(z_{\omega t}^c\right)\right]}\int_{z_{\omega t}^c}^{\infty} k_{\omega t}^{\alpha}(z)g(z)dz$$

The inflow of new workers and the outflow of workers due to separations jointly determine the evolution of firm level employment.

$$l_{\omega t} = \left(1 - \lambda_{\omega t}\right)\left(l_{\omega t-1} + q_{t-1}v_{\omega t-1}\right) \tag{3}$$

where $\lambda_{\omega t} = \lambda_t^x + \left(1 - \lambda_t^x\right) G\left(z_{\omega t}^c\right)$ denotes total separations within the firm ω. λ_t^x is the fraction of jobs that are exogenously separated in each firm.

Profit maximization Producer ω's production function can be written as

$$y_{\omega t} = Z_t \tilde{z}_{\omega t} k_{\omega t}^{\alpha} l_{\omega t}^{1-\alpha}$$

with $k_{\omega t} = l_{\omega t}\tilde{k}_{\omega t}$, $\tilde{z}_{\omega t} = \frac{1}{[1-G(z_{\omega t}^c)]}\left[\int_{z_{\omega t}^c}^{\infty} z^{\frac{1}{1-\alpha}} g(z)dz\right]^{1-\alpha}$ and $\tilde{k}_{\omega t} = \frac{1}{[1-G(z_{\omega t}^c)]}\int_{z_{\omega t}^c}^{\infty} k_{\omega t}^{\alpha}(z)g(z)dz$. Let $\rho_{\omega t} = \frac{p_{\omega t}}{P_t}$ denote the relative price of good ω with respect to the consumer price index. The firm per-period profit (in units of consumption) is

$$d_{\omega t}=\rho_{d\omega t}y_{d,t}(\omega)+\rho_{x\omega t}y_{x,t}(\omega)-\tilde{w}_{\omega t}l_{\omega t}-r_t k_{\omega t}-\left(1-\lambda_t^x\right)G\left(z_{\omega t}^c\right)\left(l_{\omega t-1}+q_{t-1}v_{\omega t-1}\right)F-\kappa v_{\omega t} \tag{4}$$

where $\tilde{w}_{\omega t}=\frac{1}{[1-G(z_{\omega t}^c)]}\int_{z_{\omega t}^c}^{\infty}w_{\omega t}(z)g(z)dz$ is the average wage paid by the firm. When terminating a job, each job incurs a real cost F. Firing costs are not a transfer to workers, they refer to pure administrative losses. $\rho_{x\omega t}=\frac{p_{xt}}{P_t}$ as p_{xt} is the export price, expressed in Home consumption units.

The firm's program is

$$Max \quad \Pi_t=E_t\sum_{s=t}^{\infty}\beta^t\frac{\lambda_{t+s}}{\lambda_t}\left(1-\delta\right)^{s-t}\frac{\lambda_{t+s}}{\lambda_t}d_{\omega s}$$

subject to

$$\begin{aligned}
l_{\omega t} &= \left(1-\lambda_{\omega t}\right)\left(l_{\omega t-1}+q_{t-1}v_{\omega t-1}\right) \qquad (\psi_{\omega t})\\
y_{\omega t} &= y_{x,t}(\omega)+y_{d,t}(\omega)=Z_t l_{\omega t}\frac{1}{\left[1-G\left(z_{\omega t}^c\right)\right]}\int_{z_{\omega t}^c}^{\infty}k_{\omega t}^{\alpha}(z)zg(z)dz \qquad (\varphi_{\omega t})\\
y_{\omega t} &= y_{x,t}(\omega)+y_{d,t}(\omega)=\sigma\ln\left(\frac{\bar{p}_{d,t}}{p_{d,t}(\omega)}\right)\frac{P_{d,t}}{p_{d,t}(\omega)}\left(\frac{P_{d,t}}{P_t}\right)^{-\phi}\left[(1-\gamma)Y_t^C+Q_t^{\phi}\gamma Y_t^{C*}\right] \qquad (\mu_{\omega t})\\
y_{x,t}(\omega) &= \gamma\sigma\ln\left(\frac{\bar{p}_{x,t}}{p_{x,t}(\omega)}\right)\frac{P_x}{p_{x,t}(\omega)}\left(\frac{P_{x,t}}{\varepsilon_t P_t^*}\right)^{-\phi}Y_t^{C*} \qquad (\mu_{x\omega t})\\
y_{d,t}(\omega) &= (1-\gamma)\sigma\ln\left(\frac{\bar{p}_{d,t}}{p_{d,t}(\omega)}\right)\frac{P_{d,t}}{p_{d,t}(\omega)}\left(\frac{P_{d,t}}{P_t}\right)^{-\phi}Y_t^C \qquad (\mu_{d\omega t})
\end{aligned}$$

with the real exchange rate $Q_t\equiv\frac{\varepsilon_t P_t^*}{P_t}$ and $\varphi_{\omega t}$ the marginal cost of a job. The FOC with respect to $k_{\omega t}$ equate the marginal productivity of capital to capital rental rate r_t.

Job creation

$$\frac{\kappa}{q_t}=\beta\left(1-\delta\right)\left(1-\lambda^x\right)E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\left(\begin{array}{c}\left(1-G\left(z_{\omega t+1}^c\right)\right)\left(\frac{y_{\omega t+1}}{l_{\omega t+1}}\varphi_{\omega t+1}\left(1-\alpha\right)-\tilde{w}_{\omega t+1}+\frac{\kappa}{q_{t+1}}\right)\\ -G\left(z_{\omega t+1}^c\right)F\end{array}\right)\right]$$

The firm determines the optimal number of vacancies such that the cost of vacancy posting (κ incurred during an average number of periods of $\frac{1}{q_t}$) equal the expected return of a filled vacancy (which includes, if the job is not destroyed, future labor productivity and vacancy costs costs saved on next period's job, net of wage cost, and, for lost jobs, firing costs)

Job destruction The job destruction equation defines a productivity threshold $z^c_{\omega t}$ below which a job is destroyed

$$\frac{\kappa}{q_t} - w_{\omega t}\left(z^c_{\omega t}\right) + (1-\alpha)\,\varphi_{\omega t}\frac{y_{\omega t}}{l_{\omega t}}\left[\frac{z^c_{\omega tit}}{\tilde{z}_t}\right]^{\frac{1}{1-\alpha}} = -F$$

The job destruction equation states that, at productivity level $z^c_{\omega t}$, the firm's outside option (firing the worker, thereby incurring the firing cost F) equals its profit (marginal product, net of labor costs) in addition to the recruitment costs the firm saves by keeping the worker.

Price Without price rigidity, the relative prices are such that $\rho_{d\omega t} = \mu_{\omega t}\varphi_{\omega t}$ and $\rho_{x\omega t} = \mu_{\omega t}\varphi_{\omega t}$. Let $\theta_{\omega t} = \frac{-\partial ln y_{\omega t}}{\partial ln p_{\omega t}}$ denote the price elasticity of total demand for variety ω. Then the firm's mark up over marginal cost $\mu_{\omega t} = \frac{\theta_{\omega t}}{1-\theta_{\omega t}} = 1 + ln(\frac{\overline{p_t}}{p_{\omega t}})$ endogenously responds to changes in the number of firms. The larger the number of competitors, the lower the mark-up.

3.2.1 Wage-setting

The wage is the solution of the maximization of the generalized Nash product HERE in units of consumption. with $\Delta^F_{\omega t}$ the firm's marginal value of a job and $\Delta^W_{\omega t}(z)$ the worker's marginal value of a job, η the worker's bargaining power. At the symmetric equilibrium, all firms ω behave similarly. The average wage is then

$$\tilde{w}_{\omega t} = (b + h_p)(1-\eta) + \eta\begin{bmatrix} (1-\alpha)\,\varphi_t\frac{y_t}{l_t} + \kappa\theta_t \\ +\left(1-(1-\delta)(1-\lambda^x)(1-s_t)\,\beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\right]\right)F \end{bmatrix}$$

with $s_t = \frac{M_t}{U_t}$ the job finding rate. The wage is a weighted sum of the worker's outside option and the value of the match for the firm, which includes the expected marginal product of labor, the search costs saved by the firms because she kept the worker within the firm. Firing costs have two opposing effects on the current wage. On the one hand, the firm saves today the firing costs, which increases the current wage. On the other hand, the firm will pay future firing costs, in case of job separation in the next period, which lowers the current wage.

3.2.2 Firm entry

As in Cacciatore & Fiori (2016), prior to entry, firms pay a sunk entry cost

$$f_{Et} = f_{Rt} + f_{Tt} + \kappa v^e_{\omega t} \tag{5}$$

The first two terms represent, respectively, the costs in terms of goods and services imposed by regulatory and administrative barriers to market entry (f_{Rt}) and technological requirements for business creation (f_{Tt}) such as research and development ($R\&D$), nonresidential structures, etc. $f_{Rt} + f_{Tt}$ are paid in terms of the final good Y_t. New entrants choose the same amount of labor as incumbent. New entrants post v^e_t vacancies such that $v^e_t = \frac{l_t + q_t v_t}{q_t}$. Prospective entrants compute their expected post-entry value, such that is the present discounted value of their expected profit stream

$$e_{\omega t} = E_t \sum_{s=t}^{\infty} \beta^t (1-\delta)^{s-t} \frac{\lambda_{t+s}}{\lambda_t} d_{\omega s}$$

The free entry condition is $e_t = f_{Et}$. As in Bilbiie et al. (2012), we introduce a one-period time-to-build lag. New and incumbent firms can be hit by a death shock with probability $\delta \in (0,1)$ at the end of the period. The law of motion is given by

$$N_t = (1-\delta)(N_{t-1} + N_{Et-1})$$

Upon exit, the firm's workers join the unemployment pool.

3.3 Household budget constraints

Household accumulates physical capital and rent it to firms. Investment consists of domestic and foreign goods, in the same fashion as the consumption basket. As in Cacciatore & Fiori

(2016), capital accumulation is subject to adjustment costs, such that

$$K_{t+1} = (1-\delta_K)K_t + I_t \left[1 - \frac{\nu}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right]$$

with scale parameter $\nu > 0$. On the international financial market, households have access to foreign-currency risk-free bonds. Let us define $b_t^* = \frac{B_t^*}{P_t^*}$ real holdings of Foreign-currency bonds (in units of Foreign consumption). We assume a quadratic cost of adjusting Foreign bond holding, as in Benigno (2009). In addition, households hold shares in a mutual fund of firms. As in Bilbiie et al. (2012), household savings are made available to prospective entrants to cover their entry costs through the mutual fund. x_t denotes the share in the mutual fund held by the household at the beginning of period t. The representative household receives each period, $N_t d_t$, the total profit of all firms that produce in that period (in units of consumption). Each period t, the household buys x_{t+1} shares in a mutual fund of $N_t + N_{Et}$ firms.

Household's budget constraint (in units of consumption basket) is

$$\begin{aligned} & C_t + b_t + Q_t b_t^* + \frac{\xi}{2} Q_t \left(b_t^*\right)^2 + \left(N_t + N_{E,t}\right) e_t x_{t+1} + I_t \\ = \quad & r_t K_t + \mathcal{W}_t + Q_t \frac{P_{t-1}^*}{P_t^*} b_{t-1}^* \left(1 + i_{t-1}^*\right) + N_t x_t \left(d_t + e_t\right) + \left(1 + i_{t-1}\right) \frac{P_{t-1}}{P_t} b_{t-1} \\ & + \left(b + h_p\right)\left(1 - L_t\right) + \Pi_t + T_t \quad (\lambda_t) \end{aligned}$$

where T_t are lump-sum transfers, $\xi > 0$ the scale parameter on adjustment costs on Foreign bond holding.

Timing of events is the following: at the beginning of period t, exogenous separations occur. Macroeconomic and microeconomic shocks are realized. Firms can then determine the productivity threshold below which jobs are terminated. Firing costs are paid. Wage bargaining takes place. Entry decisions are made. New entrants join the good market. Firms then post vacancies, choose the capital stock. Hiring takes place. Firm-level employment then evolves according to the law of motion (equation 3). Exogenous death shock occurs.

3.4 Equilibrium

In the symmetric equilibrium, the elasticity of substitution across varieties is $\theta_t = 1 + \sigma N_t$ and the mark-up $\mu_t = 1 + \frac{1}{\sigma N_t} = \frac{\theta_t}{\theta_t - 1}$. Total employment is $L_t = N_t l_t$, the law of motion of employment is $L_t = (1-\lambda_t)(1-\delta)[L_{t-1} + q_{t-1}V_{t-1}]$ while the mass of unemployed workers is $U_t = 1 - L_t$. Total vacancies are $V_t = (N_t + N_{E,t})\, v_t + N_{E,t}\frac{l_t}{q_t}$ while aggregate capital is $K_t = N_t k_t$. Total output, total output for all producing firms, in terms of consumption units is $Y_t = \rho_t Z_t \tilde{z}_t K_t^{\alpha} L_{\omega t}^{1-\alpha}$. Current account dynamics is given by

$$Q_t b_t^* - Q_t \frac{P_{t-1}^*}{P_t^*} b_{t-1}^* = Q_t \frac{P_{t-1}^*}{P_t^*} b_{t-1}^* i_{t-1}^* + \rho_t N_t y_t - Y_t^C$$

with

$$Y^C = C^M + N_{E,t}(f_{Rt} + f_{Tt}) + \kappa V_t + I_t + F L_t \frac{G(z_t^c)}{[1 - G(z_t^c)]} + \frac{\xi}{2} Q_t (b_t^*)^2$$

Because of the love for variety, measures in units of consumption are not data-consistent. The aggregate price index in the model takes into account changes in the number of available products, which is not the case in CPI data. Ghironi & Melitz (2005) suggest to solve this problem by deflating all variables using an average price index. When we assess the model's fit with the data, we make sure to consider data-consistent variables.

4 Macroeconomic effects of uncertainty shocks

4.1 Solution method and calibration

4.1.1 Solution method

Uncertainty shocks, which are the second-moment shocks in our model only enter the model's policy functions independently from the level shocks at third order. Hence, the model is solved using a third-order approximation around the deterministic steady state. We then simulate the model and compute moments of endogenous variables using pruning[6]. The Dynare is used for that purpose (Adjemian et al. (2014)).

As argued in Fernandez-Villaverde et al. (2011), higher order approximation moves the economy away from its deterministic steady state. This implies responses as deviations of the deterministic steady state are not informative. To overcome this problem, we simulate the model for 4000 periods conditioning on future shocks by setting them to 0 and consider the values reached after the simulation as the "stochastic steady state"[7]. All IRFs are then

[6] To ensure stable sample paths, pruning discards higher order terms when iteratively computing simulations of the solution. At third order, Dynare 4.4.3 uses the pruning algorithm of Andreasen et al. (2013)

[7] Born & Pfeifer (2014) use the term EMAS (the ergodic mean in the absence of shocks). It is the point of the state space where, in absence of shocks in that period, agents would choose to remain although they are taking future volatility into account.

computed as deviations from the stochastic steady state.

4.1.2 Calibration

We calibrate the model at a quarterly frequency and choose parameter values from the literature to match features of the Korean economy. However, as data is not always available for Korea, we use data for countries that share the same institutional settings (high regulation on product and labor markets). The benchmark calibration is summarized in Table 1 . We choose standard values for all the parameters that are conventional in the literature: the discount factor β, risk aversion σ_C, the capital share in the Cobb-Douglas production function α, and the capital depreciation rate δ_K. We set $\beta = 0.99$, $\sigma_C = 1$, $\alpha = 0.33$, and $\delta = 0.025$. Moreover, we set workers' bargaining power parameter η to 0.6 following Petrongolo & Pissarides (2001). Using Hosios (1990) condition, we set also the elasticity of matches to unemployment ε to 0.6. Adjustment costs on capital are set such that the model matches the relative volatility of investment (leading to $\nu = 0.5$).

Concerning the parameters related to the product market, we set regulation entry cost f_R following the procedure described in Ebell & Haefke (2009). Djankov et al. (2002)'s assessment of entry costs in Korea amounts to 27% of annual GDP per capita. We then infer the entry costs in terms of months of lost output. We add this measure to Pissarides (2001)' index of entry costs (converted in the same unit of months of lost output).[8]

We set the technological entry cost f_T such that aggregate R and D expenditures are 1.7 percent of GDP as in Cacciatore & Fiori (2016). In order to get the calibrated value of f_T, we convert the empirical target in terms of quarterly output per capita. The calibrated value is a lower bound for the Korean economy as Korea is characterized by the largest growth in R and D expenditures over the recent years (OECD (2015)).

To pin down the firm exit rate δ, we target the portion of worker separation due to firm exit equal to 26 percent, within the range of estimates reported by Haltiwanger et al. (2006). We set the price elasticity of demand on an individual good, σ, such that the steady state markup is 10 percent, a benchmark value in the literature.

We now turn to the parameters that are specific to the search and matching framework.

[8] Korea does not appear in Pissarides (2001)' sample. However, according to Nicoletti & Scarpetta (2003)'s index of product market regulation, Korea's level of product market regulation is similar to Italy, Portugal and Spain. These countries appear in Pissarides (2001)' sample. We consider the Italian measure as a proxy for Korea. The implied regulation cost amount to 3.28 quarters of firm-level steady state output. Korea indeed ranks high in the OECD PMR index and in Djankov et al. (2002)'s listing of heavily regulated markets.

Unemployment benefit b, are equal to 61 percent of the steady state wage (OECD, Benefits and Wages Database, Korea)[9]. We choose the exogenous separation rate, λ^x, so that the percentage of jobs counted as destroyed in a given year that fail to reappear in the following year is 71 percent as in Cacciatore & Fiori (2016). We set home production, h_p, the matching efficiency parameter, χ, and firing costs, F, to match the total separation rate, λ, the unemployment rate, U, and the probability of filling a vacancy, q. We set $U = 11.2$, $q = 0.6$, and $\lambda = 0.027$, in line with the estimates in Appendix A.2.2. The resulting firing costs and home production appear to be, respectively, 3 percent of average wage and 31 per cent of average wage, at the steady state. For the lognormal scale and shape parameters, μ_{zi} and σ_{zi}, we normalize μ_{zi} to zero, and choose σ_{zi} such that the model reproduces the variability of the job separation rate. Hiring costs as a fraction of steady-state average wage is $\frac{\kappa}{w} = 0.10$, close to the estimates by Abowd & Kramarz (1997) on French data.

As for the open economy dimension, as in Cacciatore et al. (2016), elasticity of substitution between domestic and foreign goods ϕ is 3.8, and adjustment costs on Foreign bonds $\xi = 0.0025$. The share of imports in total consumption γ is set to 0.3, which is consistent with OECD data on Korean imports. Foreign interest rate i^* is pinned down by the Euler equation on Foreign bonds.

We calibrate the parameters in the first-moment shock. As for the technology shock, we set the persistence parameter to $\rho_z = 0.9$ and choose the average standard deviation, σ_z, to match the absolute standard deviation of GDP in the data. We calibrate the parameters in the second-moment shock based on AR(1) estimation. Using our uncertainty series, we estimate a simple AR(1) model and set the standard deviation of the uncertainty shock to $\sigma_{\sigma z} = 0.22$ and the persistence parameter to $\rho_{\sigma z} = 0.88$.

4.2 Technology uncertainty shock

Figures 4 and 5 display the impulse responses of macroeconomic variables to a one-standard deviation technology uncertainty shock.

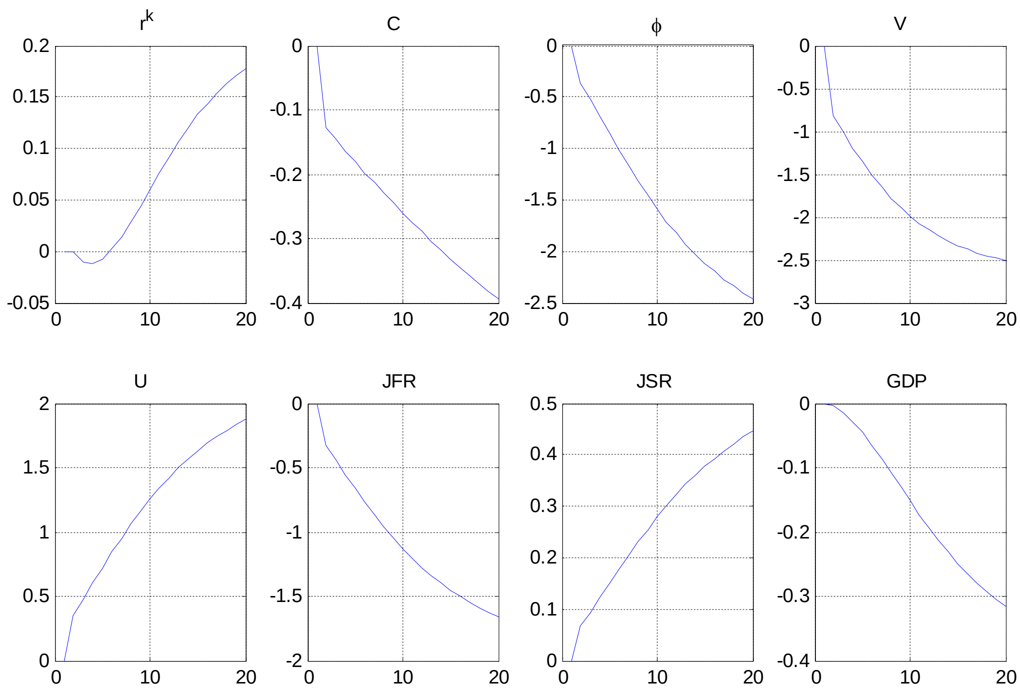
Mechanisms at work Uncertainty creates a precautionary saving motive that reduces consumption as well as the real interest rate. All else equal, a reduction in the real interest rate raises the present value of a job match and thus pushes employment and output upward. The fall in the real interest rate also raises the present value of firm entry. This expansionary

[9] We consider net replacement rates during the initial phase of unemployment

Table 1: Calibration

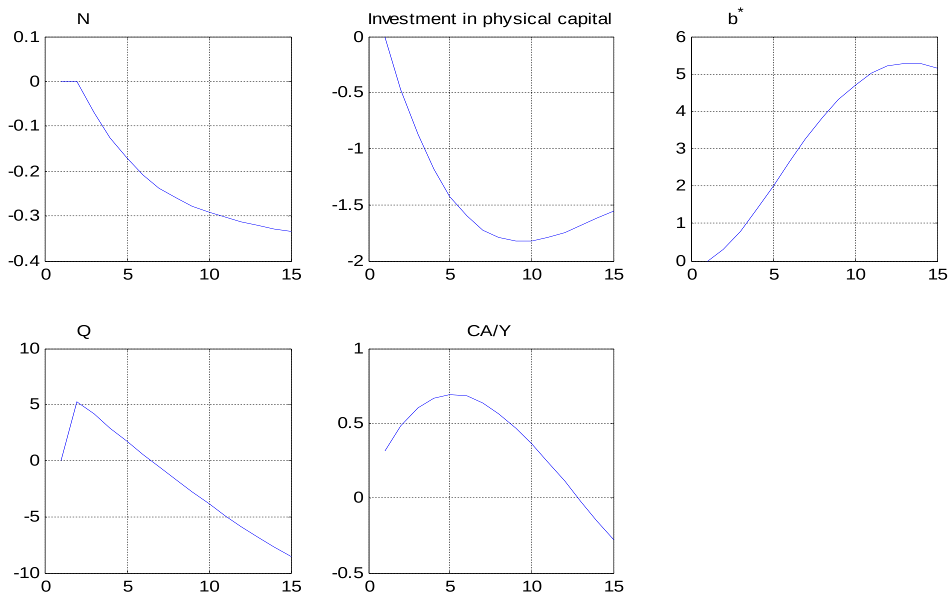
Parameter	Description	Value
β	Discount factor	0.99
σ_C	Risk aversion	1
α	Capital share	0.33
δ_K	Capital depreciation rate	0.025
σ	Variety elasticity	13.5
δ	Plant exit	0.007
f_R	Regulation entry cost	7.9
f_T	Technology entry cost	7.8
v	Investment adjustment costs	0.5
λ^x	Exogenous separation rate	0.019
b/w	Unemployment benefit replacement ratio	0.61
F	Firing costs	0.0483
ε	Matching function elasticity	0.6
η	Worker's bargaining power	0.6
χ	Matching efficiency	0.32
κ	Vacancy cost	0.0966
σ_{zi}	Lognormal shape	0.08
ρ_z	TFP, persistence	0.9
σ_z	TFP, standard deviation	0.0105
$\rho_{\sigma z}$	TFP uncertainty, persistence	0.88
$\sigma_{\sigma z}$	TFP uncertainty	0.17

Figure 4: Impulse responses of macroeconomic variables to a one-standard deviation technology uncertainty shock (1)



The units of the vertical axes are % change. Example: following a 1 standard deviation shock, C goes down by 0.4%. r^k real interest rate. C data-consistent consumption. ϕ value of a match to the firm. V aggregate vacancies. U unemployment. JFR Job finding rate is $s_t = \frac{M_t}{U_t}$. $JSR = \lambda_t^x + G(z_t^c)(1-\lambda_t^x) + \delta(1-\lambda_t^x)(1-G(z_t^c))$ total separation rate, including separations due to firm exit. GDP data-consistent GDP.

Figure 5: Impulse responses of macroeconomic variables to a one-standard deviation technology uncertainty shock (2)



The units of the vertical axes are % change. Example : following a 1 standard deviation shock, N goes down by 0.35%. N Number of products. b^* Foreign asset holding by Home household. Q real exchange rate. CA/Y Current account as % of GDP.

effect of uncertainty is similar to that found in a standard RBC model.

The effect of rising uncertainty on macroeconomic variables also operate through real options. Uncertainty makes economic agents cautious about actions like investment and hiring, which adjustment costs can make expensive to reverse. In our model, real options apply to 2 key decisions: hiring decisions and firm entry.

As for hirings, as a job match is an irreversible long-term employment relation, uncertainty gives rise to a contractionary real option-value effect. Facing higher uncertainty, the option value of waiting increases and the expected value of a job match drops. ϕ the marginal value of a match to the firm goes down. The option-value channel then dominates the precautionary saving motives. Faced with a lower expected return on the match, firms post fewer vacancies, unemployment goes up, making it harder for unemployed workers to find jobs. Firms also use the separation margin to lay off the least productive workers. The decline in employment drives the marginal product of capital downward, which triggers fall in capital investment. As in Den Haan & Watson (2000), the interaction between capital and endogenous separation make the propagation of the shock stronger. The decline in private investment is larger than the peak fall in output, as in the VAR evidence reported in Section

2.

Let us now have a look at firm entry. As entry is costly, the option value of waiting increases. The expected value of a firm falls, which drives firm entry down. The number of producers eventually declines. At the aggregate level, the reduction in the number of firms is equivalent to a fall in the capital stock. This amplifies the initial fall in output. With respect to Leduc & Liu (2016) and Guglielminetti (2015), our model predicts long-lasting macroeconomic effects, due to the interaction between labor and firm dynamics. The option-value channel also operates on firm entry, which amplifies the effects of increased uncertainty.

Households are also driven by a strong precautionary motive, leading to invest more in foreign bonds, the gradual increase in foreign bonds holdings is also the driver for the current account surplus. The current account surplus is consistent with the drop in domestic absorption (consumption and investment). Real exchange rate depreciates in response to increase in uncertainty because of the fall in Home relative prices. This is not a trivial result as two opposing forces affect real exchange rate dynamics. On the one hand, Home relative price goes down due to the large fall in the marginal cost of production (associated with the reduced value of a filled vacancy), which tends to generate real exchange rate depreciation. On the other hand, there is an upward pressure on Home relatives prices from the rising mark-ups (as the stock of firms fall). Under the benchmark calibration, Home relative price decline, which makes the model correctly predict an immediate real exchange rate depreciation. The latter is consistent with the current account surplus as the real exchange rate depreciation makes imports more expensive.

The effects of increased uncertainty on macroeconomic variables are consistent with the empirical evidence reported in Section 2. The predicted IRFs from the model display more persistence responses than the empirical IRFs, as the theoretical mechanisms are linked to the slow evolution of the stock of firms in the economy.

Originality with respect to economic mechanisms found in the literature As stressed by Basu & Bundick (2012), following uncertainty shocks, in the data, rising uncertainty result in a decline in output, consumption, investment *and* employment. However, macroeconomic models fail to generate such business-cycle co-movements among output, consumption, investment, and employment from changes in uncertainty. Indeed, in a standard RBC model, rising uncertainty leads consumer to increase savings, resulting in lower consumption. If labor supply is inelastic, total output remains constant as capital and level

TFP are unchanged immediately after an uncertainty shocks. In a closed-economy model, unchanged output and falling consumption imply that investment must rise. In this case, increased uncertainty result in unchanged output and employment, falling consumption, and rising investment. If labor supply is allowed to change over the business cycle, faced with rising uncertainty, workers are willing to work more ("precautionary labor supply"), which results in higher output, employment and investment after a rise in uncertainty.

Basu & Bundick (2012) stress that this macroeconomic co-movement is a key empirical feature of the economy's response to an uncertainty shock. Basu & Bundick (2012) argue that the co-movement of these four macroeconomic variables can be obtained after an uncertainty shock in a demand-driven economy, with price rigidity. The fall in consumption reduces output. Firms reduce their labor demand, which drives the demand for capital downward, hence investment. Endogenous rise in mark-ups help the sticky-price model generate data-consistent IRFs, as only increasing mark-ups triggers a drop in labor demand.

In this paper, we find that a search and matching model with firm entry can also capture the co-movement feature, in a flexible price environment. The originality of our paper is to stress that the co-movement feature can be obtained without price rigidity. We also add to the literature devoted to uncertainty shocks under search and matching. Indeed, Leduc & Liu (2016) develop a search and matching model without capital. However, investment is key in the comovement puzzle. In addition, Leduc & Liu (2016) also consider price and wage rigidity. They stress that search and matching alone does not generate sizeable quantitative impact of uncertainty shocks. Guglielminetti (2015) develops a search and matching model with capital, under flexible prices. Her model generates limited quantitative effects and predicts a *rise* in investment following a rise in uncertainty. Indeed, a simple search and matching model does not display any non-convexities in investment decisions. Guglielminetti (2015) and Leduc & Liu (2016) consider exogenous separation. We explore the impact of uncertainty shocks on the separation margin.

In our model, the predicted IRFs show sizeable declines in output, employment, consumption *and* investment, in a flexible price environment. Indeed, as stressed by Bloom et al. (2012), non-convex adjustment costs in both capital and labor imply that firms become more cautious in investing and hiring when uncertainty increases. In our model, as noted by Ghironi & Melitz (2005), with sunk costs and time-to-buiild, the number of firms in the model plays a role similar to a capital stock in the economy. Due to fixed entry costs, non-convexities are introduced in the investment in new line of products N_e. Firm entry provides an interesting propagation mechanism as the real option value also applies to the entry decision, thereby magnifying the macroeconomic effect of this mechanism.

Korea is an interesting country as entry costs are large compared to the US (see calibration section for a discussion). With heavy entry regulations, fixed entry costs are large enough to produce sizeable real-option value effects of entry decisions. Notice that, as in Basu & Bundick (2012)'s paper, a positive uncertainty shock generates a rise in firms' mark-up, which is key in generating a decline in labor demand. However, while in Basu & Bundick (2012)'s paper, endogenous mark-up response is due to price rigidity, in our paper, the rise in mark-up is linked to the fall in the number of firms. This fall in the aggregate number of firms is key in generating a decline in labor demand.

Leduc & Liu (2016) and Guglielminetti (2015) develop search and matching model with exogenous separation. In contrast, in this paper, we take into account endogenous separations. Let us notice that the positive shock on TFP volatility give rise to a negative correlation between unemployment and vacancies. This is an interesting feature as search and matching models with endogenous separation are well-known for their failure to predict a negative correlation between unemployment and vacancies (Krause & Lubik (2007), Costain & Reiter (2008), Shimer (2005), Cole & Rogerson (1999)). Indeed, in booms, as firms can instantaneously adjust the separation margin, they increase employment by keeping more workers, even less productive ones, rather than waiting for new workers to arrive from the matching market. Job destruction immediately falls. The concomitant fall in unemployment reduces the likelihood of filling a vacancy, which tends to dampen the rise in job creation. Unemployment goes down in booms, so does vacancies (or the rise in vacancies is limited), such that the correlation between unemployment and vacancies is no longer negative. The Beveridge curve disappears. With firm entry, after a positive shock on TFP volatility, job destruction increases at the firm level. Higher unemployment increases the probability to increase vacancies at the firm level, which entices firms to post more vacancies (thereby generating a positive correlation between vacancies and unemployment, at the firm level). However, as firm entry falls, the decline in the number of firms results, at the aggregate level, in a fall in vacancies in the economy.

As for the open economy dimension, Kollmann (2016) finds that, following an unexpected rise in output volatility, Home net foreign assets increase, which is consistent with our IRFs. However, in Kollmann (2016)'s 2-country model, under complete financial markets, the international risk sharing implies that the rise in Home output volatility triggers a wealth transfer from the rest of the world to the Home country, such that Home consumption rises, and the Home real exchange rate appreciates. These features are counterfactual on

Korea data. Fernandez-Villaverde et al. (2011) stress that rising uncertainty on foreign shocks triggers a fall in foreign debt, hence a current account surplus. They do not discuss the implications for real exchange rate dynamics. We echo their findings in the case of technological shocks and supplement their work by looking at real exchange rate fluctuations in response to fluctuating uncertainty.

4.3 Business cycle statistics: Model versus data

Finally, we check that the model provides a good fit of the data, with respect to business cycle statistics. Table 2 displays the simulated moments and the moments computed from Korean data from 1986Q4 to 2015Q4. All quarterly data are seasonally adjusted, logged, and HP-filtered with smoothing parameter 1600. See Appendix A.4 for a description of data sources. As mentioned in the calibration section, some of the model's parameters were chosen to make the model match output volatility, investment and job separation relative volatility.

Table 2: Business cycle statistics: Model versus data

	Volatility		Cyclicality	
	(1) Data	(2) Model	(3) Data	(4) Model
Y (i)	2.07	2.07	1 (iii)	1
C (ii)	1.44	0.59	0.86	0.75
I	2.42	2.20	0.83	0.90
JSR	8.74	8.78	-0.73	-0.68
JFR	4.13	3.77	0.48	0.76
U	8.44	9.70	-0.81	-0.77
V	8.54 (iv)	8.73	0.9 (iv)	0.35
corr(U,V)			-0.80 (iv)	-56.4

(i). Output std. in %, in columns (1) and (2).

(ii). For all variables except output, std. relative to output, in columns (1) and (2)

(iii). Correlation with output in columns (3) and (4)

(iv). For want of Korean data, US value

With respect to labor market variables, the model is able to produce volatile job finding and separations rates. In particular, separation are more volatile than job findings, which is a specific feature of the Korean economy. The model's predicted volatility of unemployment and vacancies is consistent with the data. For vacancies, there is no available data on Korean vacancies, we then report the business cycle statistics on US data.

Consumption is more volatile than output in Korean data. It is a well-known feature in emerging economies (Aguiar & Gopinath (2007) among others). The model fails to capture this feature. Capturing the high consumption volatility is beyond the scope of the paper. Furthermore, the high consumption volatility is not a robust stylized fact in Korean data. From 1980Q1 to 1995Q4, the relative volatility of consumption was 0.67. The relative consumption volatility prevailing during this period is closer to the model's predicted consumption volatility.

Finally, the model predicts a negative correlation between unemployment and vacancies. This is an interesting feature as a positive correlation between unemployment and vacancies is a well-known feature of Mortensen & Pissarides (1994)'s model with endogenous destruction. Indeed, with the separation margin, firms can quickly adjust the employment level, which is preferred by the firm as hiring is costly and takes time. Following a positive TFP shock, firm can increase employment by keeping more workers, even less productive ones, rather than waiting for new workers to arrive from the matching market. Vacancies can go down, so does unemployment, thereby generating a positive correlation between unemployment and vacancies. With firm entry, unemployment and vacancies can display a negative correlation in spite of endogenous separation. Indeed, as firm entry falls, with the decline in the number of firms actually result in a fall in aggregate vacancies.

5 Conclusion

Using Korean survey data, we first compute uncertainty index and worker flows. Using a VAR model, we then show that an increase in uncertainty lowers output, consumption, investment and job finding rates, while raising job separations and unemployment. Our evidence put forward the importance of uncertainty shocks on the separation margin, in contrast to US data. We also supplement the existing empirical evidence by looking at firm dynamics, real exchange rate and current account behavior. We find that increased uncertainty generates real exchange rate depreciation, current account surplus and reduces the stock of firms in the economy.

We then investigate the impact of uncertainty shocks in a small open economy with search and matching frictions, endogenous job separation and firm entry. The model's predictions are consistent with the empirical findings, as the option value channel affects labor adjustments as well as firm entry. The model also correctly predicts a current account surplus and a real exchange rate depreciation in the aftermath of the positive shock on technological volatility.

References

Abowd, J. M. & Kramarz, F. (1997). *The cost of hiring and separations*. Technical Report Working Paper 6110, NBER.

Adjemian, S., Bastani, H., Karame, F., Juillard, M., Maih, J., Mihoubi, F., Perendia, G., Pfeifer, J., Ratto, M., & Villemot, S. (2014). *Dynare*. Reference manual, Cepremap.

Aguiar, M. & Gopinath, G. (2007). Emerging market business cycles: The cycle is the trend. *Journal of Political Economy*, 115(1), 69–102.

Alexopoulos, M. & Cohen, J. (2009). *Uncertain Times, Uncertain Measures*. Technical Report Working Paper 352, University of Toronto, Department of Economics.

Andolfatto, D. (1996). Business cycles and labor-market search. *The American Economic Review*, (1), 112–132.

Andreasen, M., Fernandez-Villaverde, J., & Rubio-Ramirez, J. (2013). *The Pruned State-Space System for Non-Linear DSGE Models: Theory and Empirical Applications*. Technical Report Working Paper 18983, NBER.

Bachmann, R., Elstner, S., & Sims, E. (2013). Uncertainty and economic activity: evidence from business survey data. *AEJ.:Macroeconomics*, 5(2).

Basu, S. & Bundick, B. (2012). *Uncertainty shocks in a model of effective demand*. Working Paper 18420, NBER.

Benigno, P. (2009). Price stability with imperfect financial integration. *Journal of Money, Credit and Banking*, 41, 121–149.

Bilbiie, F., Ghironi, F., & Melitz, M. (2012). Endogenous entry, product variety, and business cycles. *Journal of Political Economy*, 120(2), 304–345.

Bloom, N. (2014). Fluctuations in uncertainty. *Journal of Economic Perspectives*, 28(2), 153–176.

Bloom, N., Floetotto, M., Jaimovich, N., Saporta, I., & Terry, S. (2012). *Really Uncertain Business Cycles*. NBER working paper 18245, NBER.

Born, B. & Pfeifer, J. (2014). Risk matters: The real effects of volatility shocks: Comment. *American Economic Review*, 104(12), 4231–39.

Cacciatore, M. & Fiori, G. (2016). The macroeconomi effets of good and labor markets deregulation. *Review of Economic Dynamics*, 20, 1–24.

Cacciatore, M., Fiori, G., & Ghironi, F. (2016). Market deregulation and optimal monetary policy in a monetary union. *Journal of International Economics*, 99.

Cole, H. & Rogerson, R. (1999). Can the mortensen-pissarides matching model match the business cycle facts? *International Economic Review*, 40(4), 933–959.

Costain, J. & Reiter, M. (2008). Business cycles, unemployment insurance, and the calibration of matching models. *Journal of Economic Dynamics and Control*, 32, 1120–1155.

Den Haan, W. Ramey, G. & Watson, J. (2000). Job destruction and propagation of shocks. *American Economic Review*, 90, 482–498.

Djankov, S., La Porta, R., Lopez-de Silanes, F., & Shleifer, A. (2002). The regulation of entry. *Quarterly Journal of Economics*, 117, 1–37.

Ebell, M. & Haefke, C. (2009). Product market deregulation and the us employment miracle. *Review of Economic Dynamics*, 12, 479–504.

Elsby, M., Hobijn, B., & Sahin, A. (2008). *Unemployment Dynamics in the OECD*. NBER Working Paper 14617, NBER.

Feenstra, R. (2003). A homothetic utility function for monopolistic competition models, without constant price elasticity. *Economics Letters*, 78(1), 79–86.

Fernandez-Villaverde, J., Guerron-Quintana, P., Rubio-Ramirez, J., & Uribe, M. (2011). Risk matters: The real effects of volatility shocks. *American Economic Review*, 101, 2530–2561.

Fujita, S. & Ramey, G. (2009). The cyclicality of separation and job finding rates. *International Economic Review*, 50(2), 415–430.

Ghironi, F. & Melitz, M. (2005). International trade and macroeconomic dynamics with heterogeneous firms. *Quarterly Journal of Economics*, 120, 856–915.

Guglielminetti, E. (2015). *The Effects of Uncertainty Shocks on the Labor Market: A Search Approach*. Mimeo.

Hairault, J.-O., LeBarbanchon, T., & Sopraseuth, T. (2015). The cyclicality of the separation and job finding rates in france. *European Economic Review*, 76, 60–84.

Haltiwanger, J., Scarpetta, S., & Schweiger, H. (2006). Assessing job flows across conntries: The role of industry, firm size and regulations. (2450).

Hosios, A. (1990). On the efficiency of matching and and related models of search and unemployment. *Review of Economic Studies*, 57, 279?98.

Kim, S. & Lee, J. (2014). Accounting for ins and outs of unemployment in korea. *Korea and the World Economy*, 15(1), 17–44.

Knotek, E. & Khan, S. (2011). How do households respond to uncertainty shocks? *Federal Reserve Bank of Kansas City Economic Review*, (Second Quarter), 63–92.

Kollmann, R. (2016). International business cycles and risk sharing with uncertainty shocks and recursive preferences. *Journal of Economic Dynamics and Control*, 72, 115–124.

Krause, M. & Lubik, T. A. (2007). The (ir)relevance of real wage rigidity in the new keynesian model with search frictions. *Journal of Monetary Economics*, 54(4), 706–727.

Leduc, S. & Liu, Z. (2016). Uncertainty shocks are aggregate demand shocks. *Journal of Monetary Economics*, 82, 20–35.

Mortensen, D. & Pissarides, C. (1994). Job creation and job destruction in the theory of unemployment. *Review of Economic Studies*, 61, 397–415.

Nicoletti, G. & Scarpetta, S. (2003). Regulation, productivity and growth: Oecd evidence. *Economic Policy*, 18, 9–72.

OECD (2015). *OECD Science, Technology and Industry Scoreboard 2015:Innovation for growth and society*. Technical report, OECD, Paris.

Petrongolo, B. & Pissarides, C. (2001). Looking into the black box : A survey of the matching function. *Journal of Economic Literature*, 39, 390–431.

Pissarides, C. (2001). *Pissarides, C.* Technical report, LSE.

Riegler, M. (2015). *The Impact of Uncertainty Shocks on the Job-Finding Rate and Separation Rate*. Mimeo.

Shimer, R. (2005). The cyclical behavior of equilibrium unemployment and vacancies. *American Economic Review*, 95(1), 25–49.

Shimer, R. (2012). Reassessing the ins and outs of unemployment. *Review of Economic Dynamics*, 15, 127–148.

A Data

A.1 Measuring uncertainty

Figure 6 displayed the measure of uncertainty. Our measure looks similar to alternative proxies of uncertainty. The VKOSPI index is the option-implied expected volatility on the Korean stock market (KOSPI200). Implied volatility of exchange rates is a measure of the market expected future volatility of Korean Won to US dollar exchange rates. Moreover, it also displays a similar pattern to the VIX index, implied volatility on the S&P 500 stock market index, except 1997 Asian financial crisis.

A.2 Measuring worker flows

A.2.1 Economically Active Population Survey

We employ the Economically Active Population Survey (EAPS) conducted by Statistics Korea. It is cross-sectional monthly household survey, and the sample size consists of approximately 33,000 households per period (about 70,000 adult individuals). The main goal of EAPS is to reveal the characteristics of that population with regards to the labor market. In particular, based upon the main activities indicated for the reference week, Statistics Korea classifies respondents as follows: those working or absent from work as employed, those looking for work as unemployed, and all others as inactive. Among inactive, those who worked for the money more than 1 hour or worked more than 18 hours as non-paid family worker are classified as employed and those who searched for job during last 4 weeks are classified as unemployed.

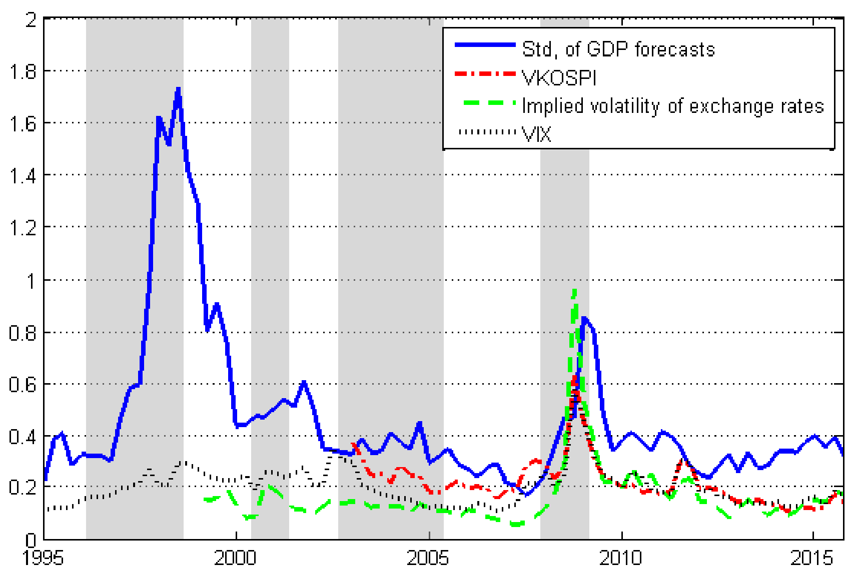
A.2.2 Measuring transition rates

We use EAPS from January 1986 through December 2015 to construct the series of worker flows.[10] According to survey design, each household remains in the sample for 36 months, and 1/36 of total households is renewed each month.[11] EAPS's rotation scheme allows us to match individuals across two consecutive months, and obtain gross flows across labor market

[10] The EAPS has been in existence since 1963, but microdata in which information on individual characteristics is available have been collected since 1986.

[11] The survey was redesigned in 2005. Prior to 2005, EAPS maintained a fixed sample over 5 years.

Figure 6: Uncertainty measures



Note: Shaded areas indicate recessions by Statistics Korea.

states.[12] Note that our analysis focuses on monthly transitions between employment (E) and unemployment (U), and never consider transition from and to inactivity (I). To calculate the transition rates, we first consider the gross flow N_t^{AB} of workers that transit from the state A to the state B over the month. Let $n_t^{EU}(n_t^{UE})$ denote the share of employed (unemployed) workers in period t-1 who are unemployed (employed) in period t:

$$n_t^{EU} = \frac{N_t^{EU}}{N_t^{EE} + N_t^{EU}}$$

$$n_t^{UE} = \frac{N_t^{UE}}{N_t^{EE} + N_t^{EU}}$$

Then, we seasonally adjust the series using X-13-ARIMA-SEATS method, and corrects the time aggregation bias converting these monthly series to quarterly frequency as in Shimer (2012). Figure 7 displays the job finding (f_t) and separation (s_t) rates in Korea. The correlation of the corresponding steady-state unemployment $u = \frac{s_t}{s_t + f_t}$ with actual unemployment

[12] We match individuals by household ID, person ID, sex, and date of birth for the 1986-2004 period. Since 2005, however, Statistics Korea has not provided household ID and person ID. Thus, we use sex, date of birth, relation with the head of household, and level of education for the 2005-2015 period.

rate is very high (0.96), which tends to validate our method for measuring worker flows.

A.2.3 Contribution of the transition rates to unemployment

We next consider the cyclicality of the job finding and separation rates following Shimer (2012). If the economy were in steady state at some date t, the unemployment rate would be determined by the job finding and separation rates, $\frac{s_t}{s_t+f_t}$. In quarterly-averaged data, the correlation between this steady state measure and actual unemployment is 0.96. We use this strong relationship to calculate the contribution of changes in each of the two transition rates to fluctuations in unemployment rate.

Let $\bar{f}$ and $\bar{s}$ denote the average values of f_t and s_t during the sample period and compute the hypothetical unemployment rates $\frac{\bar{s}}{\bar{s}+f_t}$ and $\frac{s_t}{s_t+\bar{f}}$ as measures of the contribution of fluctuations in the job finding and separation rates to overall fluctuation in the unemployment rate. Figure 8 shows the contribution of fluctuations in the job finding and separation rates to the fluctuations in the unemployment rate. This exercise finds that the separation rate contributes much more to accounting for the fluctuation in the unemployment in Korea.

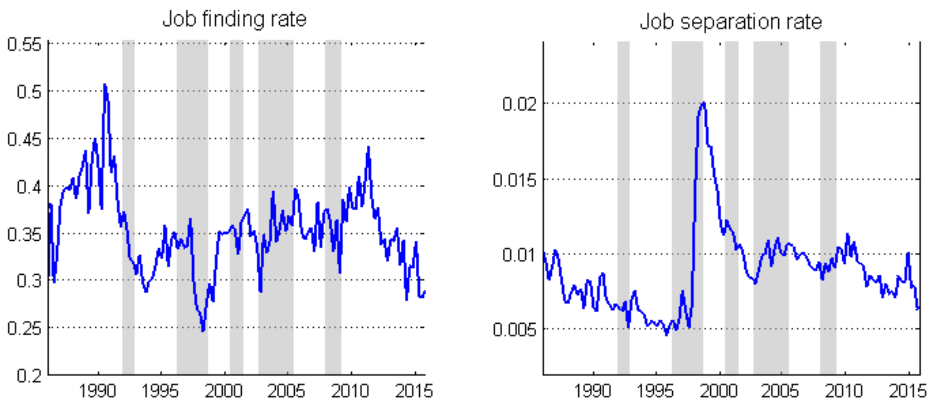
In order to quantify this, Shimer (2012) looks at the comovement of detrended data. Therefore, we use the Hodrick-Prescott filter for detrending with a smoothing parameter of 1600. Over the sample periods, the correlation of the cyclical components of unemployment and $\frac{\bar{s}}{\bar{s}+f_t}$ is 0.209, while the correlation of unemployment and $\frac{s_t}{s_t+\bar{f}}$ is 0.796. It shows that the job separation rate is the main driver of the fluctuation in the unemployment rate. These findings are consistent with Kim & Lee (2014) who show that inflows into unemployment contributes substantially to unemployment fluctuations in Korea.

A.3 Robustness checks

This section shows that the impulse response function in Figure 3 is robust to alternative identification, to an alternative volatility measure, and to alternative specification.

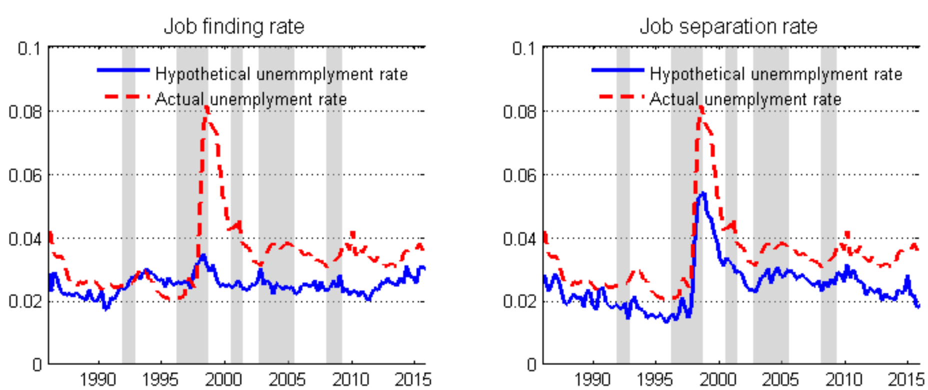
Our assumptions to identify uncertainty shocks imply that uncertainty does not respond to macroeconomic shocks in the impact period. To check the extent to which this assumption may affect our results, uncertainty is placed last in our vector. Uncertainty may reflect the forecasters' perceptions of bad economic times rather than an uncertain future. To control for potential effects from changes in consumer sentiment, we estimate a five-variable VAR that includes a consumer sentiment index as an additional variable. Our uncertainty measure is constructed to take a value 1 for each quarter that uncertainty exceeds the threshold

Figure 7: The job finding and separation rates



Note: Shaded areas indicate recessions by Statistics Korea.

Figure 8: Contribution of fluctuations in the job finding and seperation rates to the fluctuations in the unemployment rate



Note: Shaded areas indicate recessions by Statistics Korea.

and a 0 otherwise. This indicator function is used to ensure identification comes only from these large, and arguably exogenous, uncertainty shocks rather than the smaller ongoing fluctuations.

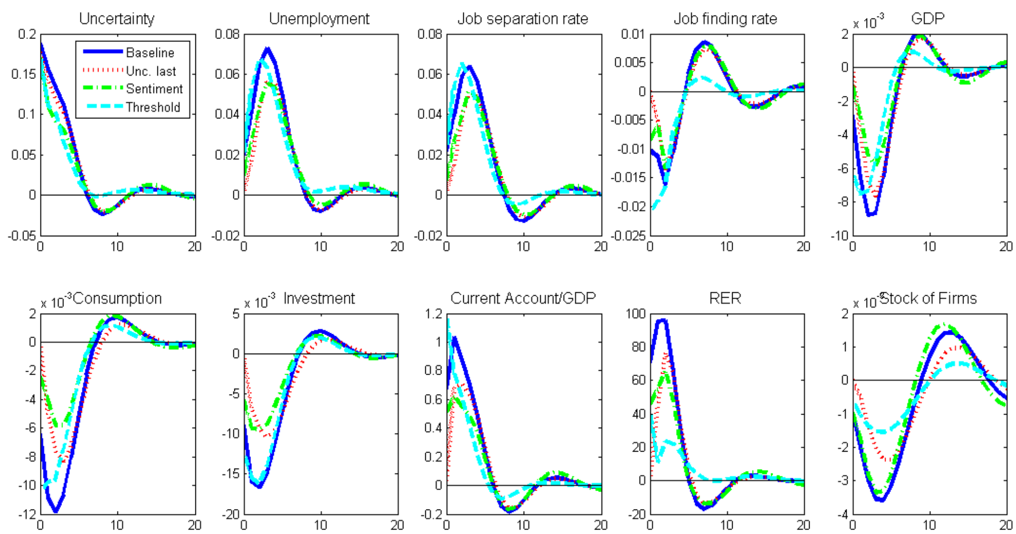
The outcome of all robustness checks are reported in Figure 9. In all cases, the responses are comparable to the baseline.

A.4 Macroeconomic data

The data coverage is 1986Q1-2015Q4.

- Output: real gross domestic product, seasonally adjusted, 2010 reference year, Statistics Korea.
- Consumption: private consumption expenditure, seasonally adjusted, 2010 reference year, Statistics Korea.
- Investment: the sum of gross capital formation and changes in inventories, seasonally adjusted, 2010 reference year, Statistics Korea.
- Unemployment rate: official unemployment rate, job-search for 4 weeks standard, seasonally adjusted, Statistics Korea.
- Number of firms: the number of corporations in operation as of end of the relevant period, semi-annual frequency from 1995H1 to 2014H2, National Tax Statistics.
- Current account as a % of GDP: seasonally adjusted, OECD Dataset.

Figure 9: The effects of one-standard deviation shock to uncertainty: robustness checks



Baseline: baseline VAR. Unc. last: uncertainty placed last in the otherwise baseline VAR. Sentiment: consumer sentiment index placed on top of the baseline VAR. Threshold: uncertainty measure constructed to take a value 1 for each quarter that uncertainty exceeds the threshold and a 0 otherwise.