SVERIGES RIKSBANK
WORKING PAPER SERIES

395

Macro Uncertainty and Unemployment Risk

Joonseok Oh and Anna Rogantini Picco

October 2020

WORKING PAPERS ARE OBTAINABLE FROM

www.riksbank.se/en/research
Sveriges Riksbank • SE-103 37 Stockholm
Fax international: +46 8 21 05 31
Telephone international: +46 8 787 00 00

Macro Uncertainty and Unemployment Risk[*]

Joonseok Oh[†] Anna Rogantini Picco[‡]

Sveriges Riksbank Working Paper Series

No. 395

October 2020

Abstract

This paper shows how uninsurable unemployment risk is crucial to qualitatively and quantitatively match macro responses to uncertainty shocks. Empirically, uncertainty shocks i) generate deflationary pressure; ii) have considerably negative consequences on economic activity; iii) produce a drop in aggregate consumption, which is mainly driven by the response of the households in the bottom 60% of the income distribution. Standard representative-agent New Keynesian models have difficulty to deliver these effects. A heterogeneous-agent framework with search and matching frictions and Calvo pricing allows us to jointly attain these results. Uncertainty shocks induce households' precautionary saving and firms' precautionary pricing behaviors, triggering a fall in aggregate demand and supply. These precautionary behaviors increase the unemployment risk of the imperfectly insured households, who strengthen precautionary saving. When the feedback loop between unemployment risk and precautionary saving is strong enough, a rise in uncertainty leads to i) a drop in inflation; ii) amplified negative responses of macro variables; iii) heterogeneous consumption responses of households, which are consistent with the empirical evidence.

Keywords: Uncertainty shock, Inflation, Unemployment risk, Precautionary savings

JEL Classification: E12, E31, E32, J64

---

[*] The opinions expressed in this article are the sole responsibility of the authors and should not be interpreted as reflecting the views of Sveriges Riksbank.

[†] Chair of Macroeconomics, School of Business and Economics, Freie Universität Berlin, Boltzmannstrasse 20, 14195 Berlin, Germany. Phone: +49 30 838 67525. E-mail: `joonseok.oh@fu-berlin.de`.

[‡] Monetary Policy Department, Research Division, Sveriges Riksbank, SE-103 37 Stockholm, Sweden. E-mail: `anna.rogantini@eui.eu`

1 Introduction

The Great Recession has sparked a wide debate on the impact of uncertainty on the macroeconomy. After the seminal paper of Bloom (2009), close attention has been devoted to study the consequences of uncertainty shocks over the business cycle. An increase in uncertainty has been empirically shown to cause a contraction of output and its subcomponents, as well as a drop in inflation, and an increase in unemployment.[1] Yet, the theoretical literature has found it challenging to generate a significant drop in output and its subcomponents in response to a rise in uncertainty.[2] In addition, it has not been successful in robustly explaining why inflation drops.[3] This paper shows how households' uninsurable unemployment risk is crucial to qualitatively and quantitatively match the drop in aggregate output and inflation generated by a positive uncertainty shock.

To corroborate the already existing empirical evidence on the propagation of macro uncertainty shocks, we estimate a vector autoregression (VAR) of macro variables, labor market variables, and the macro uncertainty index of Jurado et al. (2015). We use a recursive identification where macro uncertainty is ordered first. We show that a rise in macro uncertainty leads to a drop in output, the job finding rate, consumption, and inflation, and an increase in the unemployment rate and the separation rate. To gain a deeper understanding of what drives the aggregate macro responses, we then estimate a VAR by using consumption and income micro data from the Consumer Expenditure Surveys (CEX). This allows us to study the heterogeneous response of consumption across households' income distribution. We show that the response of aggregate consumption is driven by the response of households belonging to the bottom 60% of the income distribution. Instead, the consumption response of households in the top 40% of the income distribution is not significant.

To rationalize these empirical findings, we propose a theoretical mechanism whereby an increase in macro uncertainty results in a drop in inflation and generates responses of output, consumption, unemployment rate, job finding rate, and separation rate, which are quantitatively, as well as qualitatively in line with the empirical evidence. In particular, we develop a heterogeneous-agent New Keynesian (HANK) model with the following features: household heterogeneity induced by unemployment risk and imperfect risk sharing, labor market search and matching (SaM) frictions, and Calvo-type price rigidities. We model uncertainty as a second moment shock to technology.

---

[1] Following the macro literature, we use the word 'uncertainty' to refer to 'objective uncertainty' or 'risk', in which the probabilities are well understood by all agents. There could be an alternative source of uncertainty, that is ambiguity, in which the probabilities are not well understood.

[2] See Born and Pfeifer (2014), Cesa-Bianchi and Fernandez-Corugedo (2018), de Groot et al. (2018), and Katayama and Kim (2018).

[3] The result of Leduc and Liu (2016), who argue that an uncertainty shock resembles an aggregate demand shock as it increases unemployment, while decreasing inflation, has been shown to critically hinge upon the Taylor rule specification (Fasani and Rossi, 2018). In their setup, this result can be easily overturned by assuming some empirically plausible interest rate inertia.

Within this framework, we study how a positive uncertainty shock propagates throughout the economy. In representative-agent New Keynesian models such as Born and Pfeifer (2014), Fernández-Villaverde et al. (2015), and Mumtaz and Theodoridis (2015), uncertainty shocks have two effects. The first effect is on aggregate demand and works through the precautionary saving behavior of risk-averse households. Due to the convexity of the marginal rate of substitution between present and future consumption, higher uncertainty induces households to increase their savings. The second effect is on aggregate supply and works through the precautionary pricing behavior of firms. When uncertainty increases, firms that are allowed to reset their price, increase it to self-insure against the risk of being stuck with low prices in the future. Since the increase in prices induced by the precautionary pricing behavior of firms is stronger than the drop in prices induced by the precautionary saving behavior of risk-averse households, inflation increases after a positive uncertainty shock. Enhancing this framework with households' heterogeneity adds an indirect channel of precautionary savings, which has powerful implications on the propagation of uncertainty shocks. This channel works as follows. The drop in aggregate demand and aggregate supply induces firms to lower vacancy posting. This reduces households' job finding rate and increases unemployment risk. Since some households are borrowing constrained and subject to only partial risk sharing, an increase in unemployment risk pushes them to further strengthen their precautionary saving behavior. When the feedback loop between precautionary savings and unemployment risk sufficiently amplifies the negative demand effects of uncertainty shocks, the latter have deflationary effects. Moreover, this feedback effect is able to reinforce the responses of output, consumption, and unemployment rate so as to be quantitatively in line with the empirical evidence.

Importantly, we clarify that, were price rigidities assumed to be à la Rotemberg (1982) instead of à la Calvo (1983), there would be no precautionary pricing behavior of firms. We could therefore obtain a small drop in prices for some parametrizations of the Taylor rule. However, absent the precautionary pricing channel, we would not trigger any amplification mechanism for the response of the other macro variables, thus not being able to quantitatively match the empirical evidence on uncertainty propagation to output and its subcomponents. This result on the lack of amplification in absence of precautionary pricing confirms the difficulty that other studies have found in generating amplified macro responses, which are empirically consistent - see e.g. de Groot et al. (2018), who show that Basu and Bundick (2017)'s results become muted once the asymptote present in their preference specification is removed, Cesa-Bianchi and Fernandez-Corugedo (2018), and Katayama and Kim (2018). Differently from the existing literature, the presence of households who are imperfectly insured against unemployment risk, jointly with the precautionary pricing behavior of Calvo-price setters allows us to contemporaneously obtain a robust drop in inflation as well as a response in macro variables, which is empirically consistent.

We further show that our result on both the qualitative and quantitative response of inflation and the main macro variables cannot be obtained by introducing an alternative Taylor rule to representative-agent models such as Fernández-Villaverde et al. (2015), where the nominal interest rate directly reacts to an increase in uncertainty. This type of Taylor rule at best generates a mild drop in macro variables and inflation, which is certainly not in line with the empirical evidence. To obtain responses quantitatively consistent with the data it is thus necessary to assume households' heterogeneity.

In our baseline specification and in line with the vast majority of the literature on uncertainty propagation, we mainly focus on TFP uncertainty. Yet, the macro uncertainty index by Jurado et al. (2015), which we use in our empirical analysis, captures a broader concept of uncertainty affecting the macro economy. We therefore assess the sensitivity of our main result by showing that it is robust to other forms of uncertainty, like monetary policy uncertainty.

Related Literature The first stream of the literature our paper is related to is the one on uncertainty. This paper focuses specifically on macro uncertainty as estimated by Jurado et al. (2015). Based on a series of recent studies showing that macro uncertainty is exogenous to the business cycle (see e.g. Carriero et al., 2018a, Piffer and Podstawski, 2018, Angelini et al., 2019, and Angelini and Fanelli, 2019), this paper investigates how an exogenous shock to macro uncertainty affects the macroeconomy. Our main contribution is to highlight the importance of the interaction between households' heterogeneity, labor market SaM frictions, and Calvo pricing in the transmission of uncertainty shocks to the macroeconomy.[4] Critically, we show that it is this interaction that allows us to contemporaneously obtain a decrease in inflation as well as macro responses that are quantitatively in line with the empirical evidence. Papers like Born and Pfeifer (2014) and Mumtaz and Theodoridis (2015) obtain an increase in prices as a consequence of higher uncertainty. This increase is due to price rigidities à la Calvo, which trigger a precautionary pricing behavior of firms. Yet, the increase in inflation is not supported by empirical evidence, at least for the post-Volker period. Leduc and Liu (2016) and Basu and Bundick (2017), which assume price rigidities à la Rotemberg (1982), show that an increase in uncertainty can actually lead to a decrease in prices. Importantly, however, Fasani and Rossi (2018) show that the response of inflation to uncertainty shocks in Leduc and Liu (2016) is very much dependant on the Taylor rule specification. Namely, they argue that this response becomes positive once an empirically plausible degree of interest rate smoothing is considered. Also, the quantitative results of Basu and Bundick (2017) are shown by de Groot et al. (2018) to hinge upon their preference specification, which implies an asymptote. Once the asymptote is removed, their macro responses become muted and inconsistent with business cycle comovement. Other papers highlight how theoretically challenging it is to obtain quantitatively relevant responses of macro variables to uncertainty shocks (e.g. Born and Pfeifer,

---

[4] We also confirm Riegler (2019)'s results on the effect of higher uncertainty on the job finding rate and the job separation rate.

2014, Cesa-Bianchi and Fernandez-Corugedo, 2018, de Groot et al., 2018, and Katayama and Kim, 2018). Differently from the existing literature and thanks to the feedback mechanism due to uninsured risk and the precautionary pricing behavior of firms, we are able to jointly obtain a drop in inflation as well as macro responses that are quantitatively in line with the data.

Our paper is also related to the fast growing literature of HANK models, such as those developed by McKay and Reis (2016), Kaplan et al. (2018), and Bilbiie (2019). More specifically, it is part of the novel literature of HANK models with SaM frictions, which studies how labor market frictions interact with households' precautionary saving behavior (see e.g. Gornemann et al., 2016, McKay and Reis, 2017, Ravn and Sterk, 2017, 2020, Cho, 2019, Lagerborg et al., 2019, Dolado et al., 2020). More precisely, our paper is related to a specific stream of the HANK literature, which introduces households' heterogeneity in a simplified, but effective framework. This setup allows us to gain tractability, which is essential to study the propagation of uncertainty shocks, while at the same time retaining the main feature of introducing households' heterogeneity, which is the precautionary saving motive.[5] This framework is presented by Challe et al. (2017), who construct and estimate a tractable HANK model with SaM frictions, where the cross-sectional heterogeneity of households remains finite dimensional. A similar framework where households' heterogeneity is kept to the minimum to retain model tractability is the one of Challe (2020), who studies optimal monetary policy in the presence of uninsured unemployment risk and nominal rigidities. To our knowledge, our paper is the first to study aggregate uncertainty shocks in the context of a HANK model with SaM frictions and highlight how these features are crucial to explain the propagation of uncertainty throughout the economy. Outside the HANK literature with SaM frictions, Den Haan et al. (2018) and Heathcote and Perri (2018) examine how the interaction between market incompleteness and unemployment risk gives rise to precautionary saving motives, but the business cycle fluctuations that they study are not generated by an increase in aggregate uncertainty.

Another paper focusing on uncertainty and heterogeneity is Bayer et al. (2019). Our paper differs from it along several dimensions. While Bayer et al. (2019) study individual households' income volatility, we focus on the propagation of aggregate macro uncertainty. In addition, when solving for aggregate dynamics, Bayer et al. (2019) use a first-order perturbation. Instead, we solve the model at third order, which allows us to obtain a precautionary pricing motive for firms, which would not be present at a first order approximation. Third, we have a frictional labor market, which is necessary to explain the feedback effect between unemployment risk and precautionary saving, which is the one driving our main results.

The rest of the paper is structured as follows. Section 2.1 shows empirical evidence on the responses of

---

[5] Studying uncertainty shocks requires to solve the model to a third-order approximation or a fully global solution method. This gets extremely complicated in fully fledged heterogeneous models.

macroeconomic variables to an increase in macro uncertainty. Using the CEX micro data, Section 2.2 provides additional evidence that the aggregate response of consumption is driven by households' heterogeneous response across their income distribution. Taking stock of these empirically relevant features, Section 3 builds a New Keynesian model with uninsured unemployment risk and aggregate uncertainty. Section 4 displays our main quantitative results on the model dynamics in response to an increase in uncertainty. Section 5.1 illustrates how much each precautionary saving and pricing channel contributes to our quantitative results, Section 5.2 shows model responses using an alternative Taylor rule, Section 5.3 illustrates responses to a different type of uncertainty, and Section 5.4 conducts additional sensitivity analyses. Section 6 concludes.

2 Empirical Evidence

2.1 Macro Evidence

Recent papers such as Carriero et al. (2018a), Piffer and Podstawski (2018), Angelini et al. (2019), and Angelini and Fanelli (2019) argue that macroeconomic uncertainty is exogenous when evaluating its effects on the US macroeconomy.[6] Based on this extensive evidence, we consider macro uncertainty as exogenous to the business cycle. To show how the U.S. economy reacts to an exogenous increase in uncertainty, we estimate a quarterly frequency VAR with a constant and two lags suggested by the Hannan-Quinn information criterion. The variables included in our VAR are: macroeconomic uncertainty, log of per capita real GDP, the job finding rate, the separation rate, the unemployment rate, log of per capita real consumption (including nondurable goods and services), inflation (first-differenced logged consumer price index), and the policy rate. To measure macroeconomic uncertainty we use the macro uncertainty index estimated by Jurado et al. (2015).[7] For the job finding rate and the separation rate we use the series computed by Shimer (2012) and updated by Pizzinelli et al. (2018).[8] As for the policy rate, we use the quarterly average of the effective Federal funds rate. However, since the sample includes a period during which the Federal funds rate hits the zero lower bound (ZLB), from 2009Q1 to 2015Q3 we use the shadow Federal funds rate constructed by Wu and Xia (2016).[9] This shadow rate is not bounded below by zero and better summarizes the stance of monetary policy. The remaining series are retrieved from the FRED of St. Louis Fed.[10]

---

[6] For a thorough review on macro uncertainty and its exogeneity to the business cycle, see Castelnuovo (2019), Section 2.

[7] The updated version of the macro uncertainty series is obtained from the author's website, `https://www.sydneyludvigson.com/data-and-appendixes`. We use the quarterly average of their monthly series with $h = 3$ (i.e., 3-month-ahead uncertainty).

[8] We are grateful to Carlo Pizzinelli for sharing with us the updated version of Shimer's series as can be found at `https://sites.google.com/site/robertshimer/research/flows`.

[9] The shadow Federal funds rate is obtained from the author's website, `https://sites.google.com/view/jingcynthiawu/shadow-rates`.

[10] The retrieved series are the following (FRED series IDs are in parentheses): Gross Domestic Product (GDP), Consumer Price Index for All Urban Consumers: All Items (CPIAUCSL), Civilian Unemployment Rate (UNRATE), Personal Consumption Expenditures: Nondurable Goods (PCND), Personal consumption expenditures: Nondurable goods (chain-type price index) (DNDGRG3M086SBEA), Personal Consumption Expenditures: Services (PCESV), Personal consumption expenditures:

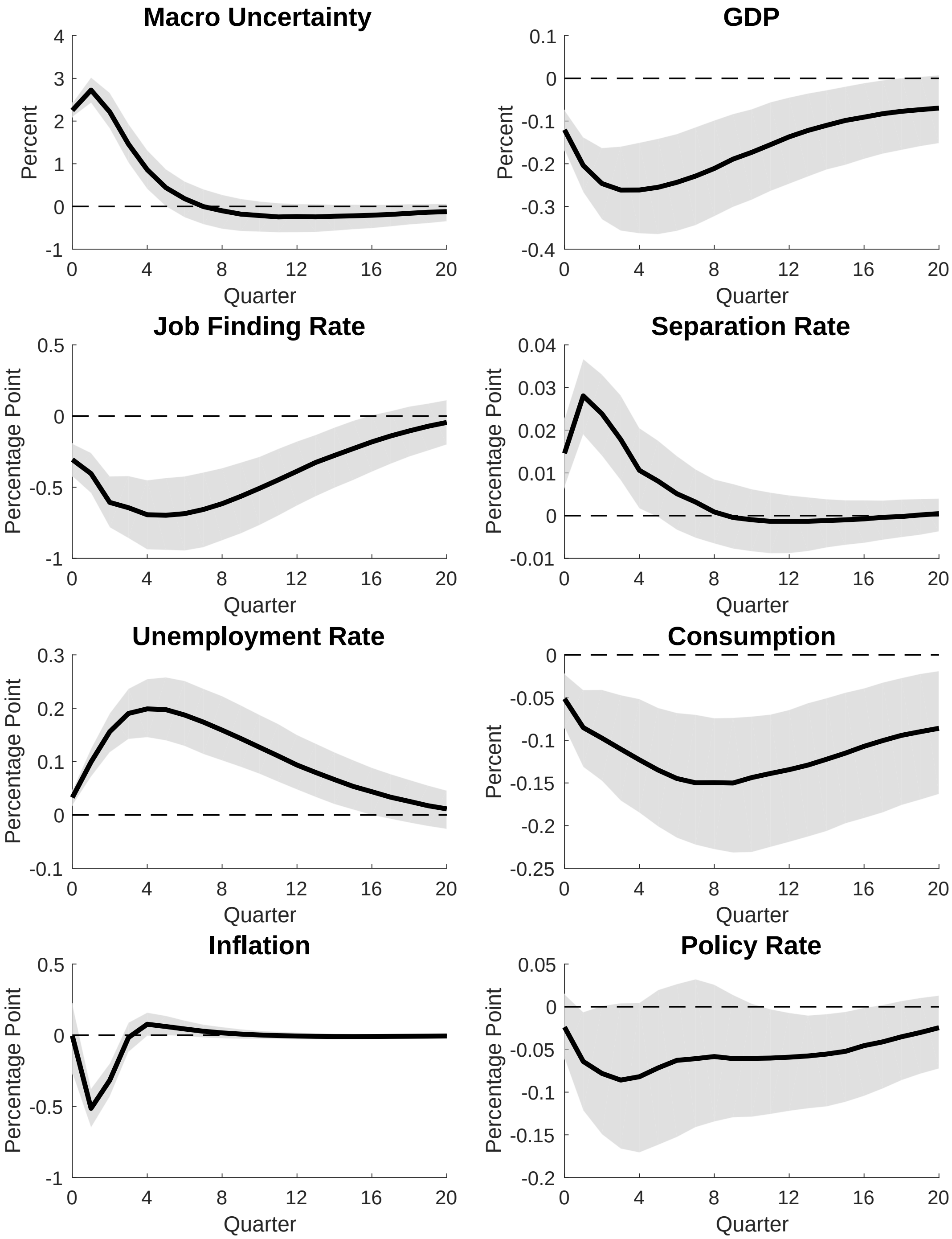

Figure 1: Empirical Responses to One-Standard Deviation Macro Uncertainty Shocks

Note: Grey areas indicate 68 percent bootstrap confidence bands.

Services (chain-type price index) (DSERRG3M086SBEA), and Effective Federal Funds Rate (FEDFUNDS). Then, we obtain the quantity indices by deflating the expenditures. Per capita variables are divided by Civilian Noninstitutional Population (CNP16OV).

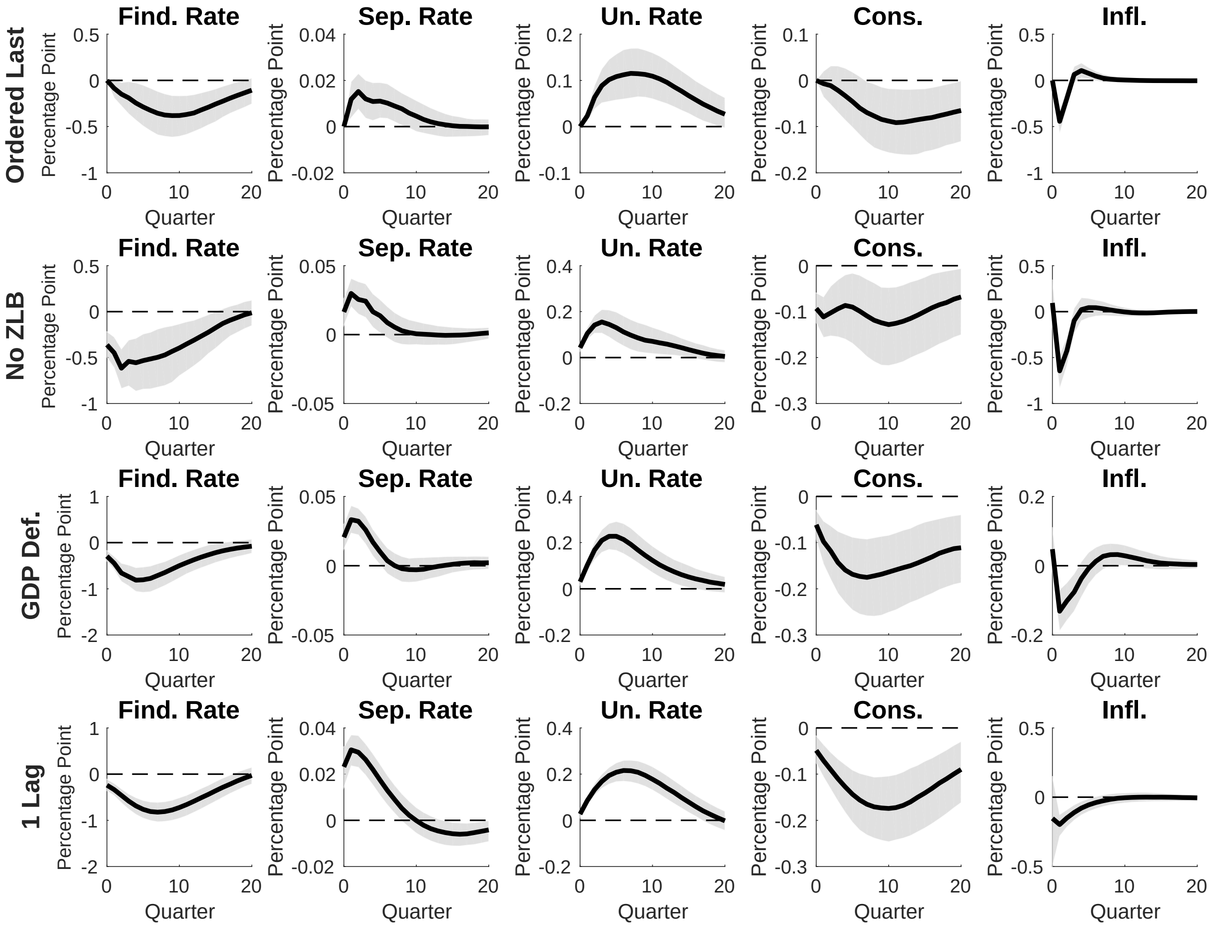

Figure 2: Robustness Checks for Empirical Responses to One-Standard Deviation Macro Uncertainty Shocks

Note: Grey areas indicate 68 percent bootstrap confidence bands.

We identify uncertainty shocks by using a Cholesky decomposition where macro uncertainty is ordered first. This ordering implies that uncertainty does not react contemporaneously to the other variables included in the VAR. We use US quarterly data over the sample period 1982Q1-2015Q3. As it is common practice in this literature, to avoid parameter instability we start our sample only after the beginning of Paul Volcker's mandate as the Federal Reserve Chairman.[11]

Figure 1 shows the impulse responses to a one standard deviation shock in the macro uncertainty index. GDP and the job finding rate drop significantly and persistently for sixteen quarters, while the separation rate rises significantly for four quarters. The response of the unemployment rate is positive and persistent and reaches a 0.2 percentage point increase at its peak. The unemployment rate response is in line with the linear specification results of Caggiano et al. (2014), who examine the impact of uncertainty on unemployment

---

[11] Paul Volcker started his mandate on August 6, 1979.

dynamics. Moving to the consumption response, we find that it declines at its minimum by more than 0.15 percent after seven quarters. The policy rate drops, but is only mildly significant. Importantly, inflation falls by 0.5 percentage points after one quarter. The response of inflation is in line with what other papers studying uncertainty shocks find - see Fernández-Villaverde et al. (2015), Bonciani and van Roye (2016), Leduc and Liu (2016), Basu and Bundick (2017), and Oh (2020).[12]

To make sure that our results are robust to different Cholesky ordering, sample periods, data series, and VAR specifications, we conduct several robustness checks, which are shown by Figure 2. The first row displays responses of a VAR where we put macro uncertainty as last in the recursive ordering of the variables. The second row reports the impulse responses when we exclude the ZLB period. The third row replaces the CPI inflation with the GDP deflator inflation. The last row shows responses of a VAR with one suggested by the Bayesian information criterion, instead of two lags. In all cases, following a positive uncertainty shock we get: a drop in the finding rate, an increase in the separation rate and the unemployment rate, and decrease in consumption and inflation.

Given this empirical evidence, Section 3 is going to build a model, which is able to replicate our empirical findings. In particular, our goal is to obtain a drop in inflation and a significant amplification in the response of macro and labor market variables following a positive uncertainty shock.

2.2 Suggested Micro Evidence: Heterogeneous Response of Consumption

To gain a deeper understanding of the mechanism driving the macroeconomic dynamics, we carry out a similar VAR exercise to Section 2.1, but we now use consumption micro data instead of aggregate consumption. This allows us to disentangle the responses of households' consumption across their income distribution. We use the Consumer Expenditure Survey (CEX) data on consumption and income over the period 1982Q1-2015Q3. We follow Heathcote et al. (2010), Anderson et al. (2016), and Ma (2019) in defining nondurable consumption. This comprises food and beverages, tobacco, apparel and services, personal care, gasoline, public transportation, household operation, medical care, entertainment, reading material, and education. As in Ma (2019), income is defined as before-tax income, which is the sum of wages, salaries, business and farm income, financial income, and transfers. To get income and nondurable consumption for households in real per capita values, we divide them by family size (the number of family members), deflate by CPI-U series, and seasonally adjust by X-12-ARIMA.[13]

Figure 3 exhibits the consumption responses to macro uncertainty shocks for the bottom 60% and the

---

[12] The few exceptions are Mumtaz and Theodoridis (2015), Katayama and Kim (2018), and Carriero et al. (2018b). The former finds an inflationary effect of uncertainty shocks, while the last two find a non-significant response of inflation to uncertainty shocks. However, they start their sample in 1975Q1, 1960Q3, and 1961M1 respectively, thus including the pre-Volcker period.

[13] We are grateful to Eunseong Ma for sharing with us his CEX data on consumption.

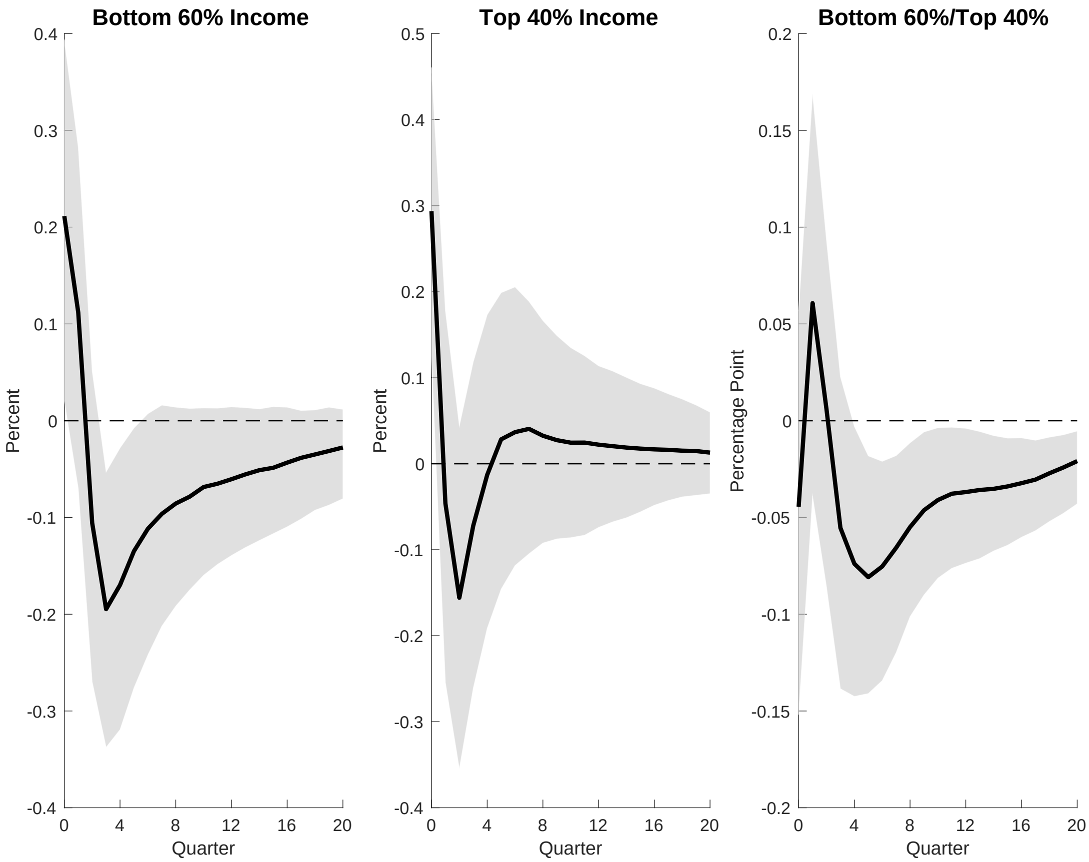

Figure 3: Empirical Responses of Consumption across Income Distribution to One-Standard Deviation Macro Uncertainty Shocks

Note: "Bottom 60% Income" and "Top 40% Income" denote the consumption response of households respectively in the lowest 60% and the highest 40% of the income distribution. Grey areas indicate 68 percent bootstrap confidence bands.

top 40% of the households' income distribution.[14] The response of consumption is heterogeneous between these two groups. In particular, what Figure 3 illustrates is that the drop in aggregate consumption is mainly driven by the consumption response of the bottom 60%. Instead, the consumption response of households in the top 40% is not significant. To show that the heterogeneity in the consumption responses is significant, the third plot of Figure 3 displays the response of the ratio between the consumption of the bottom 60% and the consumption of the top 40%. This response is negative and significant from the fourth quarter onward and remains persistently negative until the twentieth quarter. This indicates that the consumption response of households is heterogeneous: the most responsive to uncertainty are those who are at the bottom of the income distribution.[15]

---

[14] We chose the breakdown between the bottom 60% and the top 40% of the income distribution to match the calibration of our model in Section 3, as in Challe et al. (2017). However, we have also run the VAR across the five quintiles of the income distribution and we have found that the aggregate response is driven by the response of households in the three lowest quintiles. The response of households in the fourth quintile is only mildly significant, while the response of households in the fifth quintile is not significant.

[15] Figure 3 shows responses of consumption in three different VARs: in the first we insert the consumption of the bottom

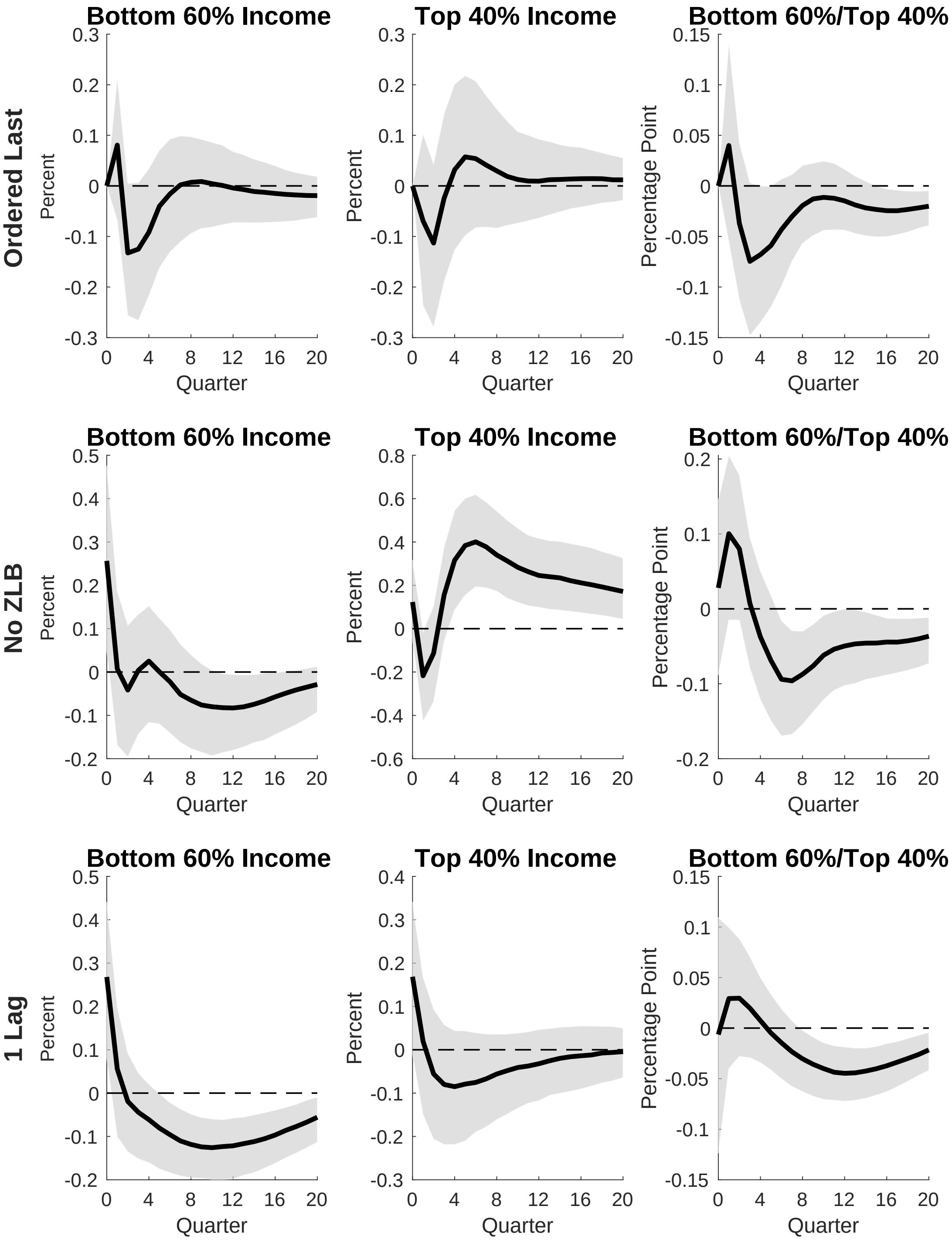

Figure 4: Robustness Checks for Empirical Responses of Consumption across Income Distribution to One-Standard Deviation Macro Uncertainty Shocks

Note: "Bottom 60% Income" and "Top 40% Income" denote the consumption response of households respectively in the lowest 60% and the highest 40% of the income distribution. Grey areas indicate 68 percent bootstrap confidence bands.

60%, in the second the consumption of the top 40%, and in the third the ratio between the two consumption series. We have also run a single VAR where we insert these three series at once and our results are robust.

We check the robustness of our results to the recursive ordering, the sample period, and the VAR specification. Results are shown by Figure 4. The first row reports responses to an uncertainty shock when the macro uncertainty is ordered last in the Cholesky recursion. The second row exhibits responses of the two income groups when we exclude the ZLB period. The last row displays responses when we run a VAR with only one lag. All robustness checks indicate that the aggregate response of consumption is driven by the response of households in the bottom 60%.

This micro data evidence suggests that households respond in a heterogeneous way across their income distribution. Therefore, households' heterogeneity is an important feature of the data that should not be overlooked when studying the propagation of uncertainty shocks. Hence, in Section 3 we build a tractable model with heterogeneous agents subject to uninsurable unemployment risk to study the propagation of uncertainty shocks throughout the economy.

3 The Model

To reproduce our empirical findings, we build a tractable New Keynesian model with imperfectly insured unemployment risk, where we introduce a technology process with stochastic volatility. We then simulate a temporary increase in the stochastic volatility of technology and study how the economy reacts. The reduced-form analysis conducted in Section 2 studies the impact of macro uncertainty. This is a comprehensive measure, which aims to capture 'uncertainty that may be observed in many economic indicators at the same time, across firms, sectors, markets, and geographic regions', Jurado et al. (2015). In our baseline theoretical analysis we capture macro uncertainty by focusing on a technology uncertainty shock. In the robustness checks, we also study the sensitivity of our main results to other sources of uncertainty shocks such as interest rate uncertainty.

Following Challe et al. (2017), the model features *imperfect* insurance against idiosyncratic unemployment risk in a New Keynesian framework with labor market frictions à la Mortensen and Pissarides (1994). There are two types of households, a perfectly and an imperfectly insured one. Only perfectly insured households can own firms. Both perfectly and imperfectly insured households participate in the labor and bond market and are subject to idiosyncratic unemployment risk. However, while perfectly insured households fully share risk among each other, imperfectly insured households cannot fully insure themselves against unemployment risk and face a borrowing constraint. The two latter features generate precautionary saving motives for employed households who are not perfectly insured.

To simplify the introduction of both labor market frictions and nominal rigidities, the production side is made of four types of firms as in Gertler et al. (2008). First, labor market intermediaries hire labor from both perfectly and imperfectly insured households, subject to search and matching frictions, and transform it into labor services. Second, wholesale goods firms buy labor services in a competitive market to produce wholesale goods used by intermediate goods firms. Third, intermediate goods firms buy wholesale goods, differentiate it, and sell it monopolistically while facing price stickiness à la Calvo (1983). Fourth, a competitive final good sector aggregates the intermediate good into a final good used for consumption and vacancy posting costs. The nominal interest rate is set by a central bank which follows a standard Taylor rule.

To specify the timing of events within a period, every period can be divided into three sub-periods: a labor market transition stage, a production stage and a consumption-saving stage. In the first stage, the exogenous state is revealed, workers are separated from firms, firms open vacancies and new matches are created. In the second stage, production takes place and the income components are paid out to the economy agents as wages, unemployment benefits, and profits. In the third stage, asset holding choices are made and the family heads redistribute assets across household members.

Challe et al. (2017)'s assumptions on imperfect risk sharing and a tight borrowing constraint faced by imperfectly insured households allow us to reduce the state space to a finite dimensional object. If we also assume that the borrowing constraint becomes binding after one period of unemployment spell, we can further reduce the heterogeneity of imperfectly insured households to three types. In Section 3.1 - 3.6, we are going to describe the model in detail by focusing on the specific case in which imperfectly insured households are reduced to three types. For notation purposes, aggregate variables are in bold characters. In addition, variables corresponding to the beginning of the labor transition stage are denoted with a tilde.

3.1 Households

There is a unit mass of households in the economy. Each household is endowed with one unit of labor. If at the beginning of the production stage the household is employed, she supplies her unit of labor inelastically. All households are subject to idiosyncratic changes to their employment status. A share $f \in [0,1]$ of the unemployed households at the beginning of the labor market transition stage finds a job by the beginning of the production stage, while a share $s \in [0,1]$ looses her job over the same period. There are two types of households: a measure $\Omega \in [0,1)$ of imperfectly insured ones and a measure $1-\Omega$ of perfectly insured ones. They have different subjective discount factors. In particular, the discount factor β^P of perfectly insured households is higher than the discount factor β^I of imperfectly insured ones. They all share the same period utility function $u(c) = \frac{(c-h\mathbf{c})^{1-\sigma}}{1-\sigma}$, where c is consumption, $\mathbf{c}$ is the level of consumption habits, and h is a constant habit parameter. Consumption habits are external. We define $\mathbf{c}^P$ as the common consumption habits of the perfectly insured households in the current period. These habits are assumed to be the average of the perfectly insured households' consumption in the previous period. Consumption habits of the imperfectly insured, instead, depend on their unemployment spell $N \geq 0$. Namely, we assume that imperfectly insured households with unemployment spell N are going to have consumption habits $\mathbf{c}^I(N)$. These habits are equal to the average consumption of the imperfectly insured households with unemployment spell N in the previous period.

3.1.1 Imperfectly Insured Households

Imperfectly insured households face idiosyncratic shocks to their employment state and are subject to a borrowing limit that prevents them from borrowing beyond a given threshold $\underline{a}$.

Employed households earn a wage w that gets taxed by a rate τ to pay for the unemployment benefit b^u that unemployed households receive. Since the unemployment insurance scheme is balanced every period, the following equation has to hold:

$$\tau w \mathbf{n}^I = b^u \left(1 - \mathbf{n}^I\right), \tag{1}$$

where $\mathbf{n}^I$ is the imperfectly insured households' employment rate at the end of the labor market transition stage. Following the literature, we adopt the family structure according to which every imperfectly insured household belongs to a representative family, whose head makes consumption and saving decisions to maximize the family current and expected utility.

There are two crucial assumptions that Challe et al. (2017) make to keep the model tractable, while still preserving the heterogeneity across imperfectly insured households: *i*) the borrowing limit is tighter than the natural debt limit; *ii*) there is only partial risk sharing across members of the imperfectly insured households. In particular, only employed members can fully insure each other by transferring assets. Instead, no transfer is admitted between employed and unemployed members or across unemployed members.

Because of idiosyncratic shocks and imperfect risk sharing, there is heterogeneity across imperfectly insured households. This heterogeneity implies a distribution $\mu\left(a^I, N\right)$ of imperfectly insured households over assets a^I and unemployment spells $N \geq 0$. Thanks to the two aforementioned assumptions, for every N the cross-sectional distribution $\mu(a^I, N)$ of imperfectly insured households can be summarized by the unique mass point $a^I(N)$ and the associated number of imperfectly insured households $n^I(N)$.

Given X the vector of aggregate states,[16] the head of a representative family of imperfectly insured households maximizes the family current and future utility with respect to assets $a'(N)$ and consumption

---

[16] See Section 3.6 for the aggregate state definition.

$c(N)$:

$$\begin{aligned} V^I\left(a^I(N), n^I(N), X\right) = \max_{\{a^{I\prime}(N), c^I(N)\}_{N \in Z_+}} & \left\{ \sum_{N \geq 0} n^I(N)\, u\left(c^I(N) - h\mathbf{c}^I(N)\right) \right. \\ & \left. + \beta^I \mathbb{E}_{\mu,X}\left[V^I\left(a^{I\prime}(N), n^{I\prime}(N), X'\right)\right] \right\}, \end{aligned} \tag{2}$$

subject to:

$$a^{I\prime}(N) \geq \underline{a}, \tag{3}$$

$$a^{I\prime}(0) + c^I(0) = (1-\tau)\, w + (1+r)\, A, \qquad N = 0, \tag{4}$$

$$a^{I\prime}(N) + c^I(N) = b^u + (1+r)\, a, \qquad N \geq 1. \tag{5}$$

Equation (3) is the borrowing constraint, where $\underline{a}$ is higher than the natural borrowing limit. Equation (4) is the budget constraint of an employed household (the unemployment spell N is zero). An employed household consumes $c^I(0)$ and buys assets $a^I(0)$, while receiving after tax income $(1-\tau)\, w$ and return from previously held assets $(1+r)\, A$. Equation (5) is the budget constraint of a household, who has been unemployed for N periods. This household consumes $c^I(N)$, buys assets $a^I(N)$, gets the unemployment benefit b^u and the return $(1+r)\, a$ from previously held assets (of course, if these are negative assets, i.e. debt, r is the interest paid on debt).

If $N = 0$, the value of assets and the employed households' law of motion are given by:

$$A' = \frac{1}{n^{I\prime}(0)} \left[(1-s')\, a^{I\prime}(0) + f' \sum_{N \geq 1} a^{I\prime}(N)\, n^I(N) \right], \tag{6}$$

$$n^{I\prime}(0) = (1-s')\, n^I(0) + f'\left(1 - n^I(0)\right). \tag{7}$$

Equation (6) says that the next period value of assets that each employed imperfectly insured household gets is the total of assets that next period employed imperfectly insured households bring divided by the total number of employed imperfectly insured households $n^{I\prime}(0)$, who belong to the family. The total of assets that next period employed imperfectly insured households bring is given by the fraction of assets that households who *remain* employed bring to the family $(1-s')\, a^{I\prime}(0)$, plus the fraction of assets that households, who *become* employed bring to the family $f' \sum_{N \geq 1} a^{I\prime}(N)\, n^I(N)$. Equation (7) says that next period employed imperfectly insured households are given by the fraction of this period employed imperfectly insured households who *remain* employed $(1-s')\, n^I(0)$, plus the fraction of this period unemployed imperfectly insured households who *become* employed $f'\left(1 - n^I(0)\right)$.

If $N \geq 1$, the value of next period assets and next period unemployed households' law of motion are given by:

$$a^{I}\left(N\right)=a^{I\prime}\left(N-1\right), \tag{8}$$

$$n^{I\prime}\left(1\right)=s^{\prime}n^{I}\left(0\right)\;\text{ and }\;n^{I\prime}\left(N\right)=\left(1-f^{\prime}\right)n^{I}\left(N-1\right)\;\text{ if }N\geq2. \tag{9}$$

Equation (8) says that the value of next period assets of an imperfectly insured household, who has been unemployed for $N-1$ periods is equal to the value of this period assets of an imperfectly insured household, who has been unemployed for N periods. Equation (9) says that next period unemployed people with one period unemployment spell are the fraction of this period employed households, who become unemployed, while next period unemployed with more than one period unemployment spell are the fraction of this period unemployed households, who stay unemployed.

Imperfectly insured households face a binding borrowing limit after $\hat{N}$ consecutive periods of unemployment. This problem has a particularly easy solution for the case of $\hat{N}=1$, which, following Challe et al. (2017), is supported by empirical evidence (liquid wealth is fully liquidated after one period). When $\hat{N}=1$, in every period there are *three* types of imperfectly insured households: $N=0$, $N=1$, and $N\geq2$. To these three types, there are the three following associated consumption levels $c^{I}\left(0\right)$, $c^{I}\left(1\right)$, and $c^{I}\left(2\right)$ for all $N\geq2$, and the two following assets levels $a^{I}\left(0\right)$, and $\underline{a}$. $a^{I}\left(0\right)$ is the asset level of employed households, while $\underline{a}$ is the asset level of unemployed households. Since all unemployed households face a binding borrowing constraint, their asset level is the same regardless of their unemployment spell. These three types of imperfectly insured households are in number $\Omega\mathbf{n}^{I}$, $\Omega s\tilde{\mathbf{n}}^{I}$, and $\Omega\left(1-\mathbf{n}^{I}-s\tilde{\mathbf{n}}^{I}\right)$. In equilibrium, for any $N\geq0$ the Euler condition for imperfectly insured households is:

$$\mathbb{E}_{\mu,X}\left[M^{I\prime}\left(N\right)\left(1+r^{\prime}\right)\right]=1-\frac{\Gamma(N)}{u_{c}\left(c^{I}\left(N\right)-\mathbf{c}^{I}\left(N\right)\right)n\left(N\right)}, \tag{10}$$

where $M^{I}(N)$ is the intertemporal marginal rate of substitution (IMRS) and $\Gamma(N)$ is the Lagrange multiplier associated to the borrowing limit. When the household is employed ($N=0$), the borrowing limit is not binding. Therefore, $\Gamma\left(N\right)=0$ and the Euler condition holds with equality:

$$\mathbb{E}_{\mu,X}\left[M^{I\prime}\left(0\right)\left(1+r^{\prime}\right)\right]=1. \tag{11}$$

Instead, when the household is unemployed ($N\geq1$), the borrowing limit is binding, $\Gamma\left(N\right)>0$, and $\mathbb{E}_{\mu,X}\left[M^{I\prime}\left(N\right)\left(1+r^{\prime}\right)\right]<1$. The IMRS is the ratio of the next-period and the current period marginal utility:

$$M^{I\prime}\left(0\right)=\beta^{I}\frac{\left(1-s^{\prime}\right)u_{c}^{I\prime}\left(0\right)+s^{\prime}u_{c}^{I\prime}\left(1\right)}{u_{c}^{I}\left(0\right)},\qquad N=0, \tag{12}$$

$$M^{I\prime}(N) = \beta^I \frac{(1-f')\, u_c^{I\prime}(N+1) + f' u_c^{I\prime}(0)}{u_c^I(N)}, \qquad N \geq 1. \tag{13}$$

Equation (12) is the IMRS of an employed household. The denominator is the current period marginal utility. The numerator is the next period marginal utility, which is a weighted average of the household's marginal utility if she remains employed $u_c^{I\prime}(0)$ times the probability of remaining employed $1-s'$, and her marginal utility if she becomes unemployed $u_c^{I\prime}(1)$ times the probability of becoming unemployed s'. Similarly, Equation (13) is the IMRS of an unemployed household. In this case, the numerator is the weighted average of the household's marginal utility if she remains unemployed $u_c^{I\prime}(N+1)$ times the probability of remaining unemployed while already being unemployed $1-f'$, and her marginal utility if she becomes employed $u_c^{I\prime}(0)$ times the probability of becoming employed f'.

3.1.2 Perfectly Insured Households

The fraction of employed members within every family of perfectly insured households before and after the labor-market transitions stage are denoted by $\tilde{n}^P$ and n^P, respectively. We thus have:

$$n^{P\prime} = (1-s')\, n^P + f'\left(1-n^P\right), \tag{14}$$

$$n^P = \tilde{n}^{P\prime}. \tag{15}$$

As before, these are family-level variables. The corresponding aggregate variables are denoted by $\tilde{\mathbf{n}}^P$ and $\mathbf{n}^P$. Employed perfectly insured households earn after tax wage $(1-\tau)w^P$, while unemployed perfectly insured households get unemployment benefit b^{uP}. Also the unemployment insurance scheme of perfectly insured households is balanced every period, thus the following equation holds:

$$\tau w^P \mathbf{n}^P = b^{uP}\left(1-\mathbf{n}^P\right). \tag{16}$$

Besides having a higher discount factor, what differentiates perfectly insured households from imperfectly insured ones is that there is full risk sharing among their family members, regardless of their employment status. This implies that all family members are symmetric, consume c^P and save $a^{P\prime}$. The family head of perfectly insured households solves:

$$V^P\left(a^P, n^P, X\right) = \max_{a^{P\prime}, c^P} \left\{u\left(c^P - h\mathbf{c}^P\right) + \beta^P \mathbb{E}_{n^P, X}\left[V^P\left(a^{P\prime}, n^{P\prime}, X'\right)\right]\right\}, \tag{17}$$

subject to:

$$c^P + a^{P\prime} = w^P n^P + (1+r)\, a^P + \Pi, \tag{18}$$

where w^P is the real wage that perfectly insured households get and Π is the profit from intermediate goods firms and labor intermediaries, which are owned by perfectly insured households.

Since all perfectly insured households are homogeneous, they have the same Euler equation:

$$\mathbb{E}_X \left[M^{P\prime} (1 + r') \right] = 1, \tag{19}$$

where the IMRS $M^{P\prime}$ is given by:

$$M^{P\prime} = \beta^P \frac{u_c^{P\prime}}{u_c^P}. \tag{20}$$

3.2 Firms

There are four types of firms in the economy. Labor intermediaries hire labor in a frictional labor market and sell labor services to wholesale goods firms. Wholesale goods firms buy labor to produce wholesale goods in a competitive market. Intermediate goods firms buy wholesale goods and sell them to the final goods firms while facing Calvo (1983) price rigidities. Final goods firms aggregate intermediate goods into a final good.

3.2.1 Final Goods Firms

A continuum of perfectly competitive final goods firms combine intermediate goods, which are uniformly distributed on the interval $[0, 1]$, according to the production function:

$$y = \left(\int_0^1 y_i^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{21}$$

where ε is the elasticity of substitution between two intermediate goods. Let p_i denote the real price of intermediate good variety i in terms of final good price. The final goods firm solves:

$$\max_y y - \int_0^1 p_i y_i di, \tag{22}$$

subject to Equation (21). The solution of the maximization gives the final firm's demand of intermediate good:

$$y_i (p_i) = p_i^{-\varepsilon} y, \tag{23}$$

while the zero-profit condition for final goods firms gives:

$$\left(\int_0^1 p_i^{1-\varepsilon} di\right)^{\frac{1}{1-\varepsilon}} = 1. \tag{24}$$

3.2.2 Intermediate Goods Firms

Intermediate goods firm i produces x_i with a linear technology $y_i = x_i$. Firm i's profit is then given by $\Xi = (p_i - p_m)y_i$, where p_m is the real price of intermediate goods in terms of final goods. Intermediate goods firms choose p_i to maximize the present discounted value of future profits subject to the demand curve (23). They face pricing frictions à la Calvo (1983). Therefore, every period only a share $1-\theta \in [0,1]$ of firms is allowed to reoptimize over the price. The value of an intermediate goods firm $V^R(X)$ that is allowed to reoptimize is:

$$V^R(X) = \max_{p_i} \left\{\Xi + \theta \mathbb{E}_X\left[M^{P\prime} V^N(p_i, X')\right] + (1-\theta)\mathbb{E}_X\left[M^{P\prime} V^R(X')\right]\right\}. \tag{25}$$

The value of an intermediate goods firm $V^N(p_{i,-1}, X)$ that is not allowed to reoptimize is:

$$V^N(p_{i,-1}, X) = \Xi + \theta \mathbb{E}_X\left[M^{P\prime} V^N(p_i, X')\right] + (1-\theta)\mathbb{E}_X\left[M^{P\prime} V^R(X')\right]. \tag{26}$$

Intermediate goods firms which do not reoptimize set their price by fully indexing it to steady state inflation $\bar{\pi}$:

$$p_i = \frac{1+\bar{\pi}}{1+\pi} p_{i,-1}. \tag{27}$$

Instead, optimizing firms set their price as:

$$p^\star = \frac{\varepsilon}{\varepsilon - 1}\frac{p^A}{p^B}, \tag{28}$$

where

$$p^A = p_m y + \theta \mathbb{E}_X\left[M^{P\prime}\left(\frac{1+\pi'}{1+\bar{\pi}}\right)^{\varepsilon} p^{A\prime}\right], \tag{29}$$

$$p^B = y + \theta \mathbb{E}_X\left[M^{P\prime}\left(\frac{1+\pi'}{1+\bar{\pi}}\right)^{\varepsilon-1} p^{B\prime}\right]. \tag{30}$$

The inflation law of motion associated with the optimal price $p^\star$, the indexation rule (27) and the zero profit condition (24) is

$$\pi = \frac{\theta(1+\bar{\pi})}{(1-(1-\theta)p^{\star 1-\varepsilon})^{\frac{1}{1-\varepsilon}}} - 1. \tag{31}$$

This pricing generates price dispersion. The price dispersion index $\Delta = \int_0^1 p_i^{-\varepsilon} di$ evolves according to the following law of motion:

$$\Delta = (1-\theta)\, p^{\star -\varepsilon} + \theta \left(\frac{1+\pi}{1+\bar{\pi}} \right)^{\varepsilon} \boldsymbol{\Delta}_{-1}. \tag{32}$$

3.2.3 Wholesale Goods Firms

The wholesale good y_m is produced by a continuum of perfectly competitive identical firms, which use a linear technology in labor $y_m = z\check{n}$, where $\check{n}$ is labor demand and z is technology. These firms solve:

$$\max_{n^d} \{p_m z \check{n} - Q\check{n}\}. \tag{33}$$

The real unit price Q of labor services n is given by the first order condition:

$$Q = p_m z. \tag{34}$$

3.2.4 Labor Intermediaries

Labor intermediaries hire labor from both perfectly and imperfectly insured households in a frictional labor market and sell labor services to wholesale goods firms. Every period there is exogenous separation rate ρ between employers and workers. At the same time, labor intermediaries post vacancies at the unit cost κ. There is a skill premium for perfectly insured households over imperfectly insured ones.[17] In particular, while an employed imperfectly insured household provides one unit of labor services and earns a wage w, an employed perfectly insured household provides $\psi > 1$ units of labor services and earns $w^P = \psi w$. Hence, the values for a labor intermediary of a match with imperfectly and perfectly insured households are:

$$J^I = Q - w + \mathbb{E}_X \left[(1-\rho')\, M^{I\prime} J^{I\prime} \right], \tag{35}$$

$$J^P = \psi Q - \psi w + \mathbb{E}_X \left[(1-\rho')\, M^{P\prime} J^{P\prime} \right], \tag{36}$$

which implies that $J^I = \psi J^P$. Moreover, given the vacancy filling rate λ, the free entry condition of labor intermediaries implies that the value of opening a vacancy has to equalize its cost:

$$\lambda \left(\Omega J^I + (1-\Omega)\, J^P \right) = \kappa. \tag{37}$$

---

[17] We follow Challe et al. (2017) in introducing a skill premium for the perfectly insured. As a matter of fact, consumption heterogeneity in the U.S. cannot be fully imputed to the heterogeneity in asset income. Some heterogeneity in labor income is needed to match the heterogeneity in consumption. We test the sensitivity of our results to the skill premium in Section 5.

The aggregate employment rate at the beginning and at the end of the labor market transition stage are given respectively by

$$\tilde{\mathbf{n}} = \Omega \tilde{\mathbf{n}}^I + (1 - \Omega)\psi \tilde{\mathbf{n}}^P, \tag{38}$$

$$\mathbf{n} = \Omega \mathbf{n}^I + (1 - \Omega)\psi \mathbf{n}^P, \tag{39}$$

which implies that $\tilde{\mathbf{n}}' = \mathbf{n}$.

The aggregate unemployment rate $\mathbf{u}$ is given by the unemployed households $\mathbf{1} - \tilde{\mathbf{n}}$ at the beginning of the labor market transition stage plus the fraction ρ of employed households, who loose their job over the period:

$$\mathbf{u} = 1 - \tilde{\mathbf{n}} + \rho \tilde{\mathbf{n}}. \tag{40}$$

Firm-worker matches are created through the following matching technology

$$m = \mu \mathbf{u}^{\chi} v^{1-\chi}, \tag{41}$$

where v are the posted vacancies, μ is the matching efficiency parameter, and χ is the elasticity of matches with respect to unemployed households. The aggregate job finding and job filling rates are given by:

$$f = \frac{m}{\mathbf{u}}, \tag{42}$$

$$\lambda = \frac{m}{v}. \tag{43}$$

Since the workers who loose their job at the beginning of the labor market transition period can be rematched within the same period, the period-to-period separation rate is:

$$s = \rho \left(1 - f\right). \tag{44}$$

Given the job finding rate f and the job separation rate s, the law of motion of aggregate labor is:

$$\mathbf{n} = f \tilde{\mathbf{n}} + \left(1 - s\right) \tilde{\mathbf{n}}. \tag{45}$$

We assume that wages are set according to the following wage rule:

$$w = \bar{w} \left(\frac{\mathbf{n}}{\bar{n}}\right)^{\phi_w}, \tag{46}$$

where ϕ_w indicates the elasticity of wages to deviations of employment from its steady-state value $\bar{n}$ and $\bar{w}$ is the steady state wage.

3.3 Monetary Authority

The monetary authority follows a standard Taylor rule, where the nominal interest rate R reacts to inflation and output growth. The rule is:

$$\frac{1+R}{1+\bar{R}} = \left(\frac{1+\pi}{1+\bar{\pi}}\right)^{\phi_\pi} \left(\frac{y}{\mathbf{y}_{-1}}\right)^{\phi_y}, \tag{47}$$

where $\bar{R}$ is the steady-state nominal interest rate, and ϕ_π and ϕ_y are the reaction coefficients to inflation and output growth.

The real interest rate is determined as follows:

$$1+r = \frac{1+\mathbf{R}_{-1}}{1+\pi}. \tag{48}$$

3.4 Exogenous Processes

The technology z used by wholesale goods firms is subject to first and second moment shocks according to the following stochastic processes:

$$\log z = \rho_z \log z_{-1} + \sigma^z \varepsilon^z, \tag{49}$$

$$\log \sigma^z = (1-\rho_{\sigma^z}) \log \bar{\sigma}^z + \rho_{\sigma^z} \log \sigma^z_{-1} + \sigma^{\sigma^z} \varepsilon^{\sigma^z}. \tag{50}$$

In particular, $\varepsilon^z \sim N(0,1)$ is a first-moment shock capturing innovations to the level of technology, while $\varepsilon^{\sigma^z} \sim N(0,1)$ is a second moment shock capturing innovations to the standard deviation σ^z of technology. ρ_z and ρ_{σ^z} indicate the persistence of the two processes and σ^{σ^z} is the standard deviation of σ^z. The second moment shock is how we introduce uncertainty into the model.[18] We interpret a positive second moment shock as an increase in uncertainty in the economy.

3.5 Market Clearing

3.5.1 Labor Market

All households face the same job finding rate f and job separation rate s. Since we assume that employment is symmetric between perfectly and imperfectly insured households at the beginning of period zero, for the law of large numbers it remains symmetric at every point in time. Hence, the share of perfectly and

---

[18] Oh (2020) shows that responses of macro variables do not qualitatively depend on the source of uncertainty.

imperfectly insured agents which is employed is the same, and family-level variables are equal to aggregate variables:

$$\tilde{n}^P = \tilde{n}^I = \tilde{\mathbf{n}}^P = \tilde{\mathbf{n}}^I \equiv \tilde{\mathbf{n}}, \tag{51}$$

$$n^P = n^I = \mathbf{n}^P = \mathbf{n}^I \equiv \mathbf{n}. \tag{52}$$

Moreover, the aggregate labor supply is:

$$\Omega \mathbf{n}^I + (1-\Omega)\,\psi \mathbf{n}^P = (\Omega + (1-\Omega)\,\psi)\,\mathbf{n}, \tag{53}$$

and the labor market clearing condition is:

$$(\Omega + (1-\Omega)\,\psi)\,\mathbf{n} = \check{n}. \tag{54}$$

3.5.2 Assets Market

All households participate in the assets market, which is in zero net supply:

$$\Omega\,(A + (1-\mathbf{n})\,\underline{a}) + (1-\Omega)\,a^P = 0. \tag{55}$$

There are Ω imperfectly insured households and $1-\Omega$ perfectly insured households. Imperfectly insured households own either A if their budget constraint is not binding or $\underline{a}$ if it is binding.[19] Perfectly insured households own assets a^P.

3.5.3 Goods Market

The final good production y has to be equal to the final good aggregate consumption c plus the cost of posting vacancies:

$$c + \kappa v = y. \tag{56}$$

Aggregate consumption is the share Ω of imperfectly insured households' consumption plus the share $1-\Omega$ of perfectly insured households' consumption c^P. The former is made of the consumption of imperfectly insured households who are employed $n^I\,(0)\,c^I\,(0)$, who have been unemployed for one period $n^I\,(1)\,c^I\,(1)$,

---

[19] Since we have assumed that the borrowing constraint of unemployed imperfectly insured households becomes binding after one period of unemployment spell, the assets that they own is equal to the borrowing limit $\underline{a}$ regardless of the length of their unemployment spell N. This would not be the case if the borrowing limit became biding after more than one period of unemployment spell.

and who have been unemployed for at least two periods $n^I(2)\, c^I(2)$:

$$c \equiv \Omega \left(n^I(0)\, c^I(0) + n^I(1)\, c^I(1) + n^I(2)\, c^I(2) \right) + (1-\Omega)\, c^P. \tag{57}$$

Intermediate goods market is in equilibrium when the intermediate goods demand Δy is equal to its supply $y_i - \Phi$:

$$\Delta y = y_m - \Phi. \tag{58}$$

Finally, the market clearing condition for the wholesale goods is:

$$\int_0^1 x_i di = y_m = z\check{n}. \tag{59}$$

3.6 Aggregate State and Equilibrium

We focus on symmetric equilibrium, where variables at family-level are identical. The aggregate state X is then given by:

$$X = \left\{ \tilde{\boldsymbol{\mu}}(\cdot), a^P, a^I(0), \mathbf{c}^P, \mathbf{c}^I(N)_{N\geq 0}, \mathbf{R}_{-1}, \mathbf{y}_{-1}, \boldsymbol{\Delta}_{-1}, \tilde{\mathbf{n}}, z, \sigma^z \right\}. \tag{60}$$

When $\hat{N} = 1$, i.e. when the borrowing constraint becomes binding after one period of unemployment spell, the heterogeneity of the imperfectly insured households can be reduced to three types: the employed type $N = 0$, the unemployed type for one period $N = 1$, and the unemployed type for more than one period $N \geq 2$. These types are in shares of respectively: $\Omega\mathbf{n}$, $\Omega s\tilde{\mathbf{n}}$, and $\Omega(1 - \mathbf{n} - s\tilde{\mathbf{n}})$. In this specific case, a symmetric equilibrium is given by the following conditions:

1. the Euler condition (19) and the IMRS (20) for the perfectly insured households hold, and the Euler condition (11) and the IMRS (12) for the imperfectly insured households hold;
2. the budget constraint for the perfectly insured households (18) and the budget constraints for the three types of imperfectly insured households (4) and (5) with assets determined by (6) and (7);
3. the price set by optimizing firms, the inflation rate and the price dispersion are determined by (28) to (32), and the real unit price of labor services by (34);
4. the aggregate employment and unemployment rates are given by (38), (39), and (40), the job finding rate, the job filling rate, the period-to-period separation rate, and the matching function technology by (42), (43), (44) and (41), the aggregate labor law of motion by (45), the value of a match and the value of opening a vacancy are given by (35) to (37);

5. wages are determined according to (46), social contributions to (1) and (16), and nominal and real interest rates to (47) and (48);

6. the market clearing conditions (51) to (59) hold;

7. consumption habits are as follows: $\mathbf{c}^{P\prime} = c^P$, $\mathbf{c}^{I\prime}(0) = c^I(0)$, $\mathbf{c}^{I\prime}(1) = c^I(1)$, and $\mathbf{c}^{I\prime}(2) = c^I(2)$.

3.7 Precautionary Savings

The model features precautionary savings induced by positive uncertainty shocks through two different channels, a direct and an indirect one. The direct channel works through households' risk aversion. Because of its convexity, the IMRS of all households under uncertainty is larger than under certainty. A higher IMRS induces households to substitute out of consumption towards savings in a precautionary manner.

The indirect channel is due to uninsured unemployment risk. While both perfectly and imperfectly insured households bear unemployment risk, perfectly insured households fully share this risk, while imperfectly insured households face partial risk sharing. Partial insurance further strengthens the precautionary saving behavior of imperfectly insured households. This indirect channel works as follows. Higher uncertainty triggers a drop in aggregate demand, which, in turn, generates a fall in production and a decrease in posted vacancies. Less vacancies lead to a drop in the finding rate f, which increases the endogenous separation rate $s = \rho(1 - f)$. A lower finding rate and a higher separation rate increase the imperfectly insured households' propensity to save. The last implication can be derived from the IMRS of imperfectly insured households. In particular, if imperfectly insured households are employed ($N = 0$), their IMRS is as follows:

$$M^{I\prime}(0) = \beta^I \frac{(1 - s')\, u_c^{I\prime}(0) + s' u_c^{I\prime}(1)}{u_c^I(0)}, \qquad N = 0. \tag{61}$$

Their marginal utility of consumption when becoming unemployed $u_c^{I\prime}(1)$ is higher than their marginal utility of consumption when remaining employed $u_c^{I\prime}(0)$, as falling into unemployment generates a drop in consumption and marginal utility is decreasing in consumption. Therefore, whenever the separation rate s' rises, the IMRS increases, thus pushing imperfectly insured households to save more. A similar reasoning applies to the IMRS of imperfectly insured households who are unemployed ($N \geq 1$):

$$M^{I\prime}(N) = \beta^I \frac{(1 - f')\, u_c^{I\prime}(N + 1) + f' u_c^{I\prime}(0)}{u_c^I(N)}, \qquad N \geq 1. \tag{62}$$

Whenever the finding rate f' drops, the IMRS increases as the marginal utility of consumption when remaining unemployed $u_c^{I\prime}(N + 1)$ is higher than the marginal utility of consumption when becoming employed.

Notice that since throughout the paper we assume that the borrowing limit becomes binding after one period of unemployment spell, only the Euler condition for $N = 0$ will hold with equality, while the Euler condition for $N > 0$ will be slack. This implies that the precautionary saving motive will only concern *employed* imperfectly insured households, who are the only type of imperfectly insured households allowed to save. To the contrary, *unemployed* imperfectly insured households will be at their borrowing limit, so their asset position will simply be $\underline{a}$.

4 Quantitative Results

4.1 Calibration and Solution Method

Table 1 reports the parameter values for a quarterly calibration to the U.S. economy over the period 1982Q1-2015Q3. We mainly follow Challe et al. (2017). The share of imperfectly insured households Ω is calibrated to 0.60. Risk aversion σ is set to the standard value of 1.00 to have log utility, while the habit persistence is in the range estimated by Challe et al. (2017). The discount factor of perfectly insured households β^P is set to match an annual interest rate of 3%, while the discount factor of imperfectly insured households β^I is set to target a 21% consumption drop when falling into unemployment. The unemployment benefits are calibrated to target a replacement rate of 33%. As for parameters related to firms, we set the elasticity of substitution between goods to get a 20% markup. The price stickiness θ is calibrated to have a price resetting spell of four quarters. Moving to labor market parameters, the matching efficiency μ is set to target a job filling rate of 71%, which follows Den Haan et al. (2000). The job separation rate ρ targets a job loss rate of 6.1% and a job finding rate of 73%. The former follows Challe et al. (2017). The latter is computed following Shimer (2005) by using unemployment and short-term unemployment data from the Current Population Survey. The matching function elasticity χ is set according to Petrongolo and Pissarides (2001). The vacancy posting cost κ is calibrated to being 1% of output following Challe et al. (2017). The skill premium ψ is set to 2.04 so as to match the consumption share (42%) of the poorest 60% of the households. The wage elasticity with respect to employment ϕ_w is in the range estimated by Challe et al. (2017). As far as monetary policy parameters are concerned, we set the steady-state inflation $\bar{\pi}$ to target a 2% annual inflation, the interest rate responsiveness to inflation ϕ_π to 1.50 and the interest rate responsiveness to output growth ϕ_y to 0.25. Moving to the shock processes, we set the persistence ρ_z and the steady-state volatility $\bar{\sigma}^z$ of the technology shock to the standard values of 0.95 and 0.007. As for the uncertainty shock process, we follow Katayama and Kim (2018) in modelling our counterpart to the macro uncertainty used in Section 2 as stochastic volatility to technology. We set the persistence ρ_{σ^z} and the volatility σ^{σ^z} to 0.85 and 0.37, values which are also in line with Leduc and Liu (2016).

Table 1: Quarterly Calibration

Parameter	Description	Value	Target/Source
Households			
Ω	Share of imp. insured HHs	0.60	Challe et al. (2017)
$\underline{a}$	Borrowing limit	0	Challe et al. (2017)
σ	Risk aversion	1.00	Log utility
h	Habit persistence	0.60	Challe et al. (2017)
β^I	Discount factor of imp. insured HHs	0.961	21% consumption loss
β^P	Discount factor of perf. insured HHs	0.993	3% annual real interest rate
b^u	Unemployment benefits	0.27	33% replacement rate
Firms			
ε	Elasticity of substitution btw goods	6.00	20% markup
θ	Price stickiness	0.75	4-quarter stickiness
Labor Market			
μ	Matching efficiency	0.72	71% job filling rate
χ	Matching function elasticity	0.50	Petrongolo and Pissarides (2001)
ρ	Job separation rate	0.23	73% job finding & 6.1% job loss rates
κ	Vacancy posting cost	0.037	1% of output
ψ	Skill premium	2.04	Bottom 60% consumption share (42%)
ϕ_w	Wage elasticity wrt employment	1.50	Challe et al. (2017)
Monetary Authority			
$\bar{\pi}$	Steady-state inflation	1.005	2% annual inflation rate
ϕ_π	Taylor rule coefficient for inflation	1.50	Standard
ϕ_y	Taylor rule coefficient for output	0.25	Standard
Exogenous Processes			
ρ_z	Persistence of technology shock	0.95	Standard
$\bar{\sigma}^z$	Volatility of technology shock	0.007	Standard
ρ_{σ^z}	Persistence of uncertainty shock	0.85	Katayama and Kim (2018)
σ^{σ^z}	Volatility of uncertainty shock	0.37	Katayama and Kim (2018)

To study the effects of uncertainty shocks, we solve the model using a third-order perturbation method, as suggested by Fernández-Villaverde et al. (2011). The third-order perturbation moves the ergodic means of the endogenous variables of the model away from their deterministic steady-state values. Hence, we compute the impulse responses in percent deviation from the stochastic steady state of each endogenous variable. For that, we use the Dynare software package developed by Adjemian et al. (2011) and the pruning algorithm designed by Andreasen et al. (2018).

4.2 Baseline Results

Figure 5 shows the impulse responses of the variables of interest to a one standard deviation shock in technology uncertainty. The solid blue line shows the responses of the model with imperfectly insured unemployment risk as described in Section 3. The dashed red line shows the responses of the corresponding representative agent New Keynesian model where unemployment risk is fully insured. This model is identical to the former model except that there are no imperfectly insured households, that is $\Omega = 0$. In this case, there is only one type of households, the perfectly insured ones, who fully share risk. As a benchmark, we first describe the responses of the model with perfect insurance (PI), before illustrating the responses generated by the model with imperfect insurance (II).

4.2.1 Responses of the Model with Perfect Insurance

In the PI model, a positive uncertainty shock in technology has both an aggregate demand effect through households' saving decisions and an aggregate supply effect through firms' pricing decisions. On the one hand, higher uncertainty induces a negative wealth effect on risk-averse households, who increase savings and decrease consumption (see Fernández-Villaverde et al., 2015, Leduc and Liu, 2016, Basu and Bundick, 2017, and Oh, 2020 for this precautionary saving channel). This causes a drop in aggregate demand. The decrease in aggregate demand reduces the marginal cost that firms are facing and pushes them to lower prices to stimulate demand. On the other hand, an increase in uncertainty triggers a precautionary pricing behavior of firms, which are subject to Calvo pricing. When uncertainty increases, optimizing firms increase their prices to self-insure against the risk of being stuck with low prices in the future (see Born and Pfeifer, 2014, Fernández-Villaverde et al., 2015, and Oh, 2020 for this precautionary pricing channel). Since the increase in prices induced by the precautionary pricing behavior of firms is stronger than the drop in prices induced by the precautionary saving behavior of households, inflation increases after a positive uncertainty shock.

4.2.2 Responses of the Model with Imperfect Insurance

The II model adds a new channel of transmission and amplification of the uncertainty shock to the precautionary saving and pricing behavior described above for the PI model. This is graphically illustrated by Figure 6.

As explained for the PI model, an uncertainty shock causes a drop in aggregate demand triggered by the precautionary saving behavior of households. The drop in demand induces firms to lower their vacancy posting, thus reducing the job finding rate and increasing the unemployment rate. At this point

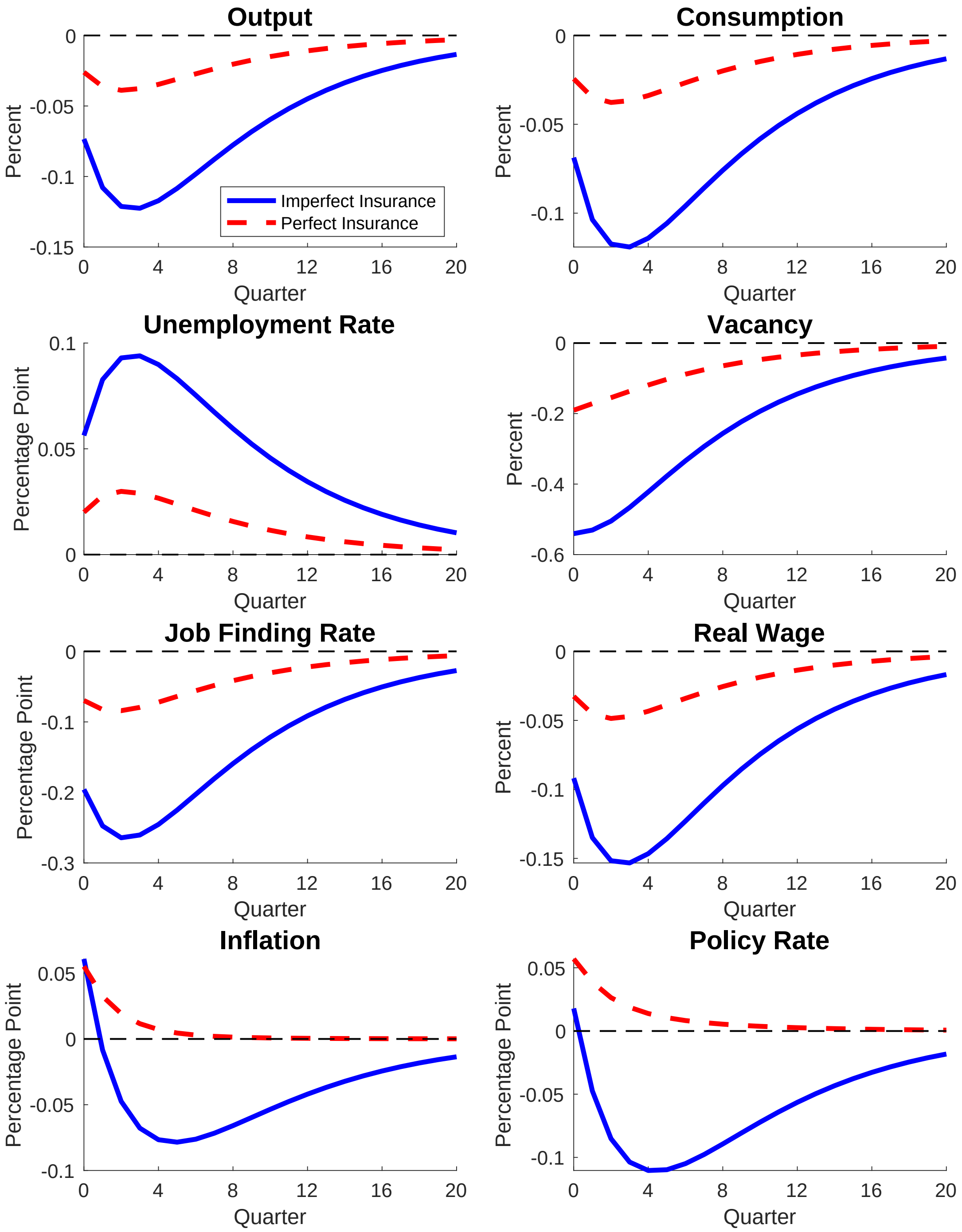

Figure 5: Impulse Responses to One-Standard Deviation Technology Uncertainty Shocks

Note: Impulse responses of output, consumption, vacancy, and real wage are in percent deviation from their stochastic steady state, impulse responses of unemployment rate and job finding rate are in percentage point deviations from their stochastic steady state, while inflation and policy rate are in annualized percentage point deviations from their stochastic steady state.

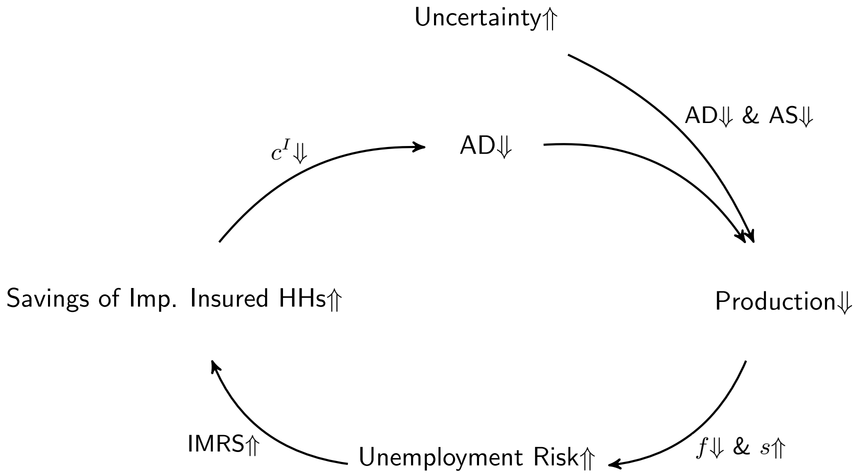

Figure 6: Propagation Mechanism of a Positive Uncertainty Shock

the presence of imperfectly insured households becomes key to explain the dynamics of the model. Since imperfectly insured households cannot fully insure against unemployment as they are subject to *imperfect* risk sharing, a higher unemployment risk induces them to further increase savings and decrease consumption. The imperfectly insured households' precautionary saving behavior triggers a feedback loop, which reinforces the drop in aggregate demand. At the same time, firms precautionary pricing behavior generates a reduction in vacancy posting and an increase in unemployment. This further reinforces the precautionary saving behavior of imperfectly insured households and strengthen the feedback loop. Figure 7 illustrates the responses of consumption for both imperfectly (dashed line) and perfectly (dotted line) insured households. Because of the precautionary saving behavior that partial risk sharing induces on imperfectly insured households, their consumption response is much stronger than the one of perfectly insured households.

The presence of heterogeneous agents bears two consequences on the propagation mechanism of uncertainty shocks. First, the feedback loop triggered by the precautionary saving behavior of imperfectly insured households is strong enough to induce a drop in prices that outweighs the increase in prices due to the precautionary pricing behavior of optimizing firms. This is the reason why, after two quarters, inflation response becomes negative, which is in line with our empirical results as shown by Figure 1. Second, the feedback loop amplifies all the responses. The precautionary behavior of imperfectly insured households triggers a drop in aggregate demand, which is much stronger than in the PI model. In parallel, the decrease in vacancy posting and the increase in unemployment rate are sharper.

It is worth noticing that our results hinge upon the interaction between the precautionary saving behavior of agents induced by imperfect risk sharing and the precautionary pricing behavior of firms induced

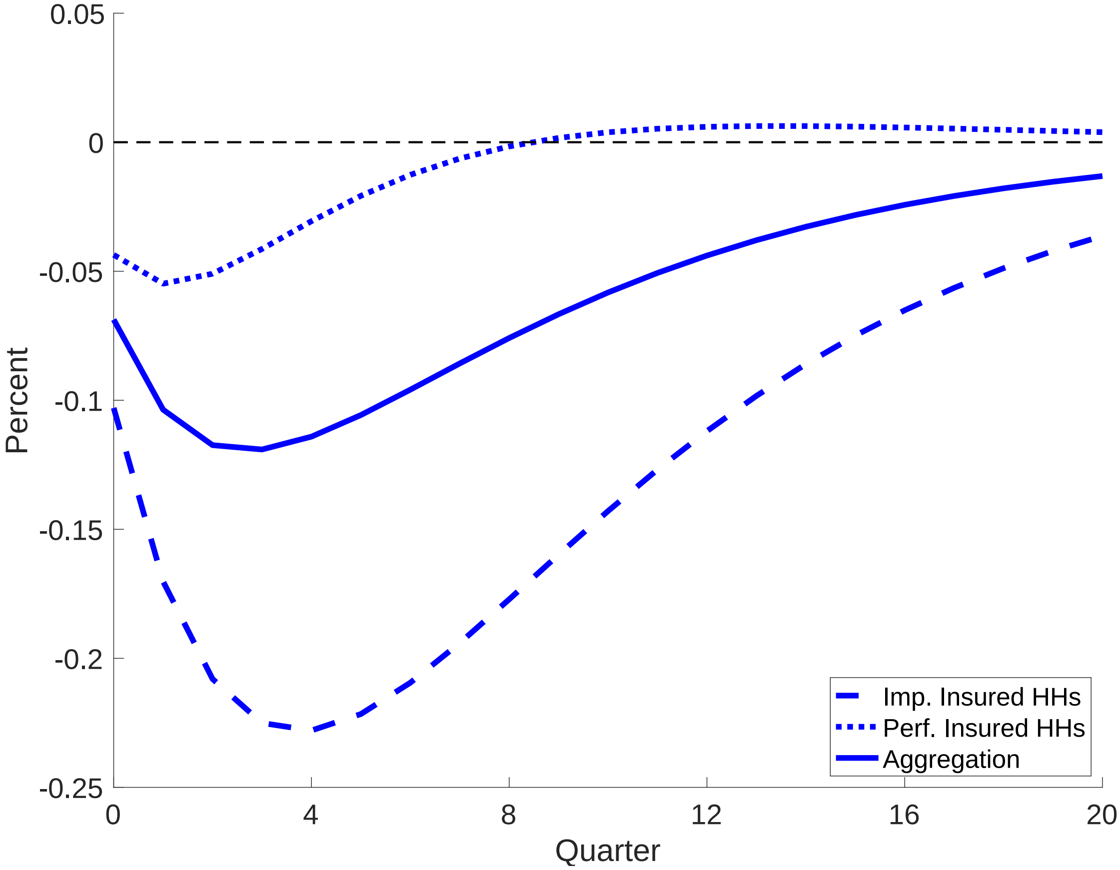

Figure 7: Consumption Heterogeneity

Note: Impulse responses of consumption are in percent deviation from their stochastic steady state.

by price rigidities à la Calvo (1983). It is the interaction between these two features that allows us to obtain a drop in inflation and an amplification of responses, which quantitatively match the empirical evidence.

Since the presence of imperfectly insured households is crucial both to determine the response of inflation and to amplify the responses of the other variables, Figure 8 shows how the impulse responses vary when varying the share of imperfectly insured households. On impact, inflation increases regardless of the share of imperfectly insured households. As soon as the negative feedback loop on aggregate demand induced by the precautionary saving behavior of imperfectly insured households kicks in, inflation decreases. Indeed, the higher is the share of imperfectly insured households, the stronger the feedback effect becomes and the more inflation drops. Figure 8 also shows that a bigger share of imperfectly insured households amplifies the responses of the other variables. In particular, output, consumption, vacancies, job finding rate, and wages drop more, while unemployment rate increases more, the higher is the share of imperfectly insured households.

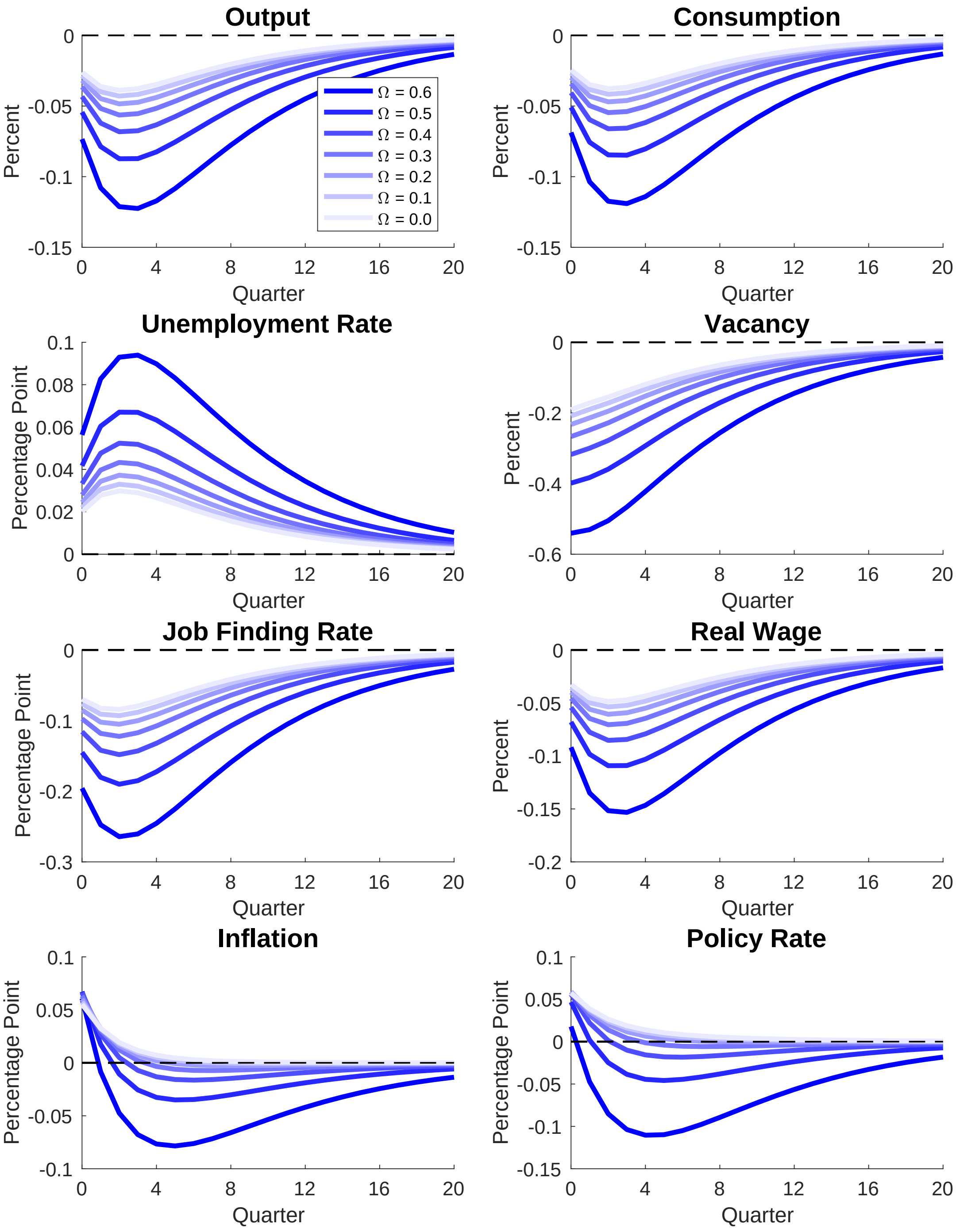

Figure 8: Different Degrees of Heterogeneity

Note: Impulse responses of output, consumption, vacancy, and real wage are in percent deviation from their stochastic steady state, impulse responses of unemployment rate and job finding rate are in percentage point deviations from their stochastic steady state, while inflation and policy rate are in annualized percentage point deviations from their stochastic steady state.

5 Robustness Checks

5.1 Rotemberg Pricing

To decompose how much of our results is driven by the direct and the indirect precautionary saving channel as well as by the precautionary pricing channel, this section compares the PI and the II models studied in the previous sections to identical models where we substitute the Calvo (1983)-type price rigidity with the Rotemberg (1982)-type price rigidity. As the Rotemberg pricing assumption does not feature any precautionary pricing effect, comparing the responses of models with the two different pricing assumptions allows us to quantify how much of the uncertainty shock propagation is due to the precautionary pricing effect. Before exploring in detail how comparing II and PI models with Calvo and Rotemberg pricing is helpful in disentangling the three precautionary channels, let us discuss what changes need to be made to the model when we substitute Rotemberg pricing to Calvo pricing.

As before, an intermediate good firm chooses price p_i to maximize the present discounted value of future profits subject to the demand curve (23). Now, its value is given by:

$$V^{Rotem}(p_{i,-1}, X) = \max_{p_i} \left\{ \Xi - \frac{\eta}{2} \left(\frac{(1+\pi)\, p_i}{(1+\bar{\pi})\, p_{i,-1}} - 1 \right)^2 y + \mathbb{E}_X \left[M^{P\prime} V^{Rotem}(p_i, X') \right] \right\}, \tag{63}$$

where $\frac{\eta}{2}\left(\frac{(1+\pi)p_i}{(1+\bar{\pi})p_{i,-1}} - 1\right)^2 y$ is a quadratic price adjustment cost. Imposing a symmetric equilibrium across firms implies that $p_i = 1$ and $y_i = y$. The optimal Calvo price equilibrium conditions (28), (29), and (30) are now replaced with the following equation:

$$\eta \left(\frac{1+\pi}{1+\bar{\pi}} - 1 \right) \frac{1+\pi}{1+\bar{\pi}} = \eta \mathbb{E}_X M^{P\prime} \left(\frac{1+\pi'}{1+\bar{\pi}} - 1 \right) \frac{1+\pi'}{1+\bar{\pi}} \frac{y'}{y} + 1 - \varepsilon + \varepsilon p_m. \tag{64}$$

Moreover, the intermediate goods market clearing condition (58) is replaced with

$$y = y_m - \Phi, \tag{65}$$

as Rotemberg-type frictions do not generate price dispersion. On the other hand, they generate price adjustment costs, which appear in the final good market clearing condition. Hence, condition (56) is replaced with

$$c + \kappa v + \frac{\eta}{2} \left(\frac{1+\pi}{1+\bar{\pi}} - 1 \right)^2 y = y. \tag{66}$$

Except for the equations mentioned above, all the other equilibrium conditions stay the same.

Figure 9 plots impulse responses to a positive uncertainty shock for the II ($\Omega = 0.6$) and the PI ($\Omega = 0$)

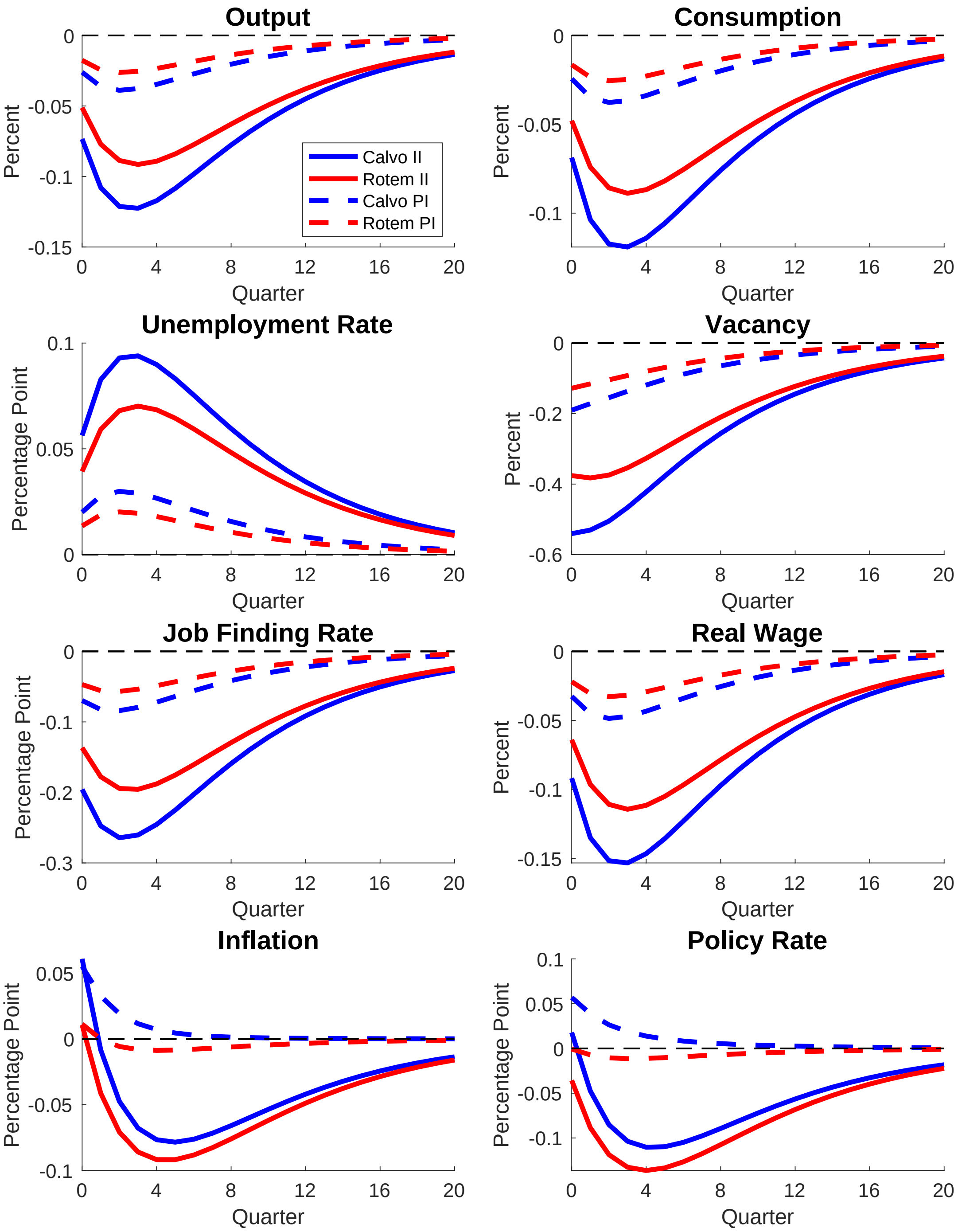

Figure 9: Comparison to Rotemberg Pricing

Note: Impulse responses of output, consumption, vacancy, and real wage are in percent deviation from their stochastic steady state, impulse responses of unemployment rate and job finding rate are in percentage point deviations from their stochastic steady state, while inflation and policy rate are in annualized percentage point deviations from their stochastic steady state.

model with Calvo and Rotemberg pricing. By comparing the four models we can precisely isolate the three precautionary channels: the direct precautionary saving channel, the indirect precautionary saving channel, and the precautionary pricing channel.

Let's first focus on the PI models. The PI model with Rotemberg pricing only features the direct precautionary saving channel. Through this channel, a positive uncertainty shock generates a negative wealth effect on risk-averse households, who decrease their consumption and increase their savings, thus lowering aggregate demand. While the only precautionary channel at play in the PI model with Rotemberg pricing is the direct precautionary saving one, the PI model with Calvo pricing adds the precautionary pricing channel. Hence, the difference between the responses of the PI model with Calvo pricing and the PI model with Rotemberg pricing helps us gauging the strength of the precautionary pricing channel.

As explained in Section 4.2.1, with Calvo-type frictions firms engage in a precautionary pricing behavior. This behavior leads them to increase prices to such an extent to overcompensate the downward pressure that the aggregate demand drop exerts on prices. That is the reason why the inflation response is positive on impact in the Calvo PI model. On the contrary, the precautionary pricing motive is absent in the Rotemberg pricing model, where all firms are symmetric and are allowed to reset their price every period, even though subject to an adjustment cost - see Oh (2020) for a thorough comparison between the Calvo and Rotemberg pricing models in response to uncertainty shocks. The absence of the precautionary pricing motive results in a drop in the inflation response to an increase in uncertainty. In addition to the opposite response of inflation, a further difference between the two PI models is that the Calvo pricing model generates more amplified responses. This difference is again induced by the precautionary pricing behavior of firms. Higher prices reduce consumption and push firms to cut their vacancy posting, thus decreasing the job finding rate and increasing the unemployment rate more than in the Rotemberg model. To generate even more amplification and a response of inflation fully in line with the data, a II model with Calvo pricing is necessary. This model features all three precautionary channels: the direct precautionary saving, the indirect precautionary saving and the precautionary pricing channel. Comparing the responses of the II model with Calvo pricing to the PI model with Calvo pricing allows us to isolate the effect of the indirect precautionary saving channel, which is the only precautionary channel that differentiates the two models. The heterogeneity of households in the II model enriches the dynamics of the PI model with the precautionary saving behavior of imperfectly insured households, who reduce their consumption more when unemployment risk rises. This depresses aggregate demand more than in the PI model. This indirect precautionary saving channel is necessary to contemporaneously obtain a drop in inflation as well as an amplification in the responses of the other variables that is quantitatively in line with the empirical evidence.

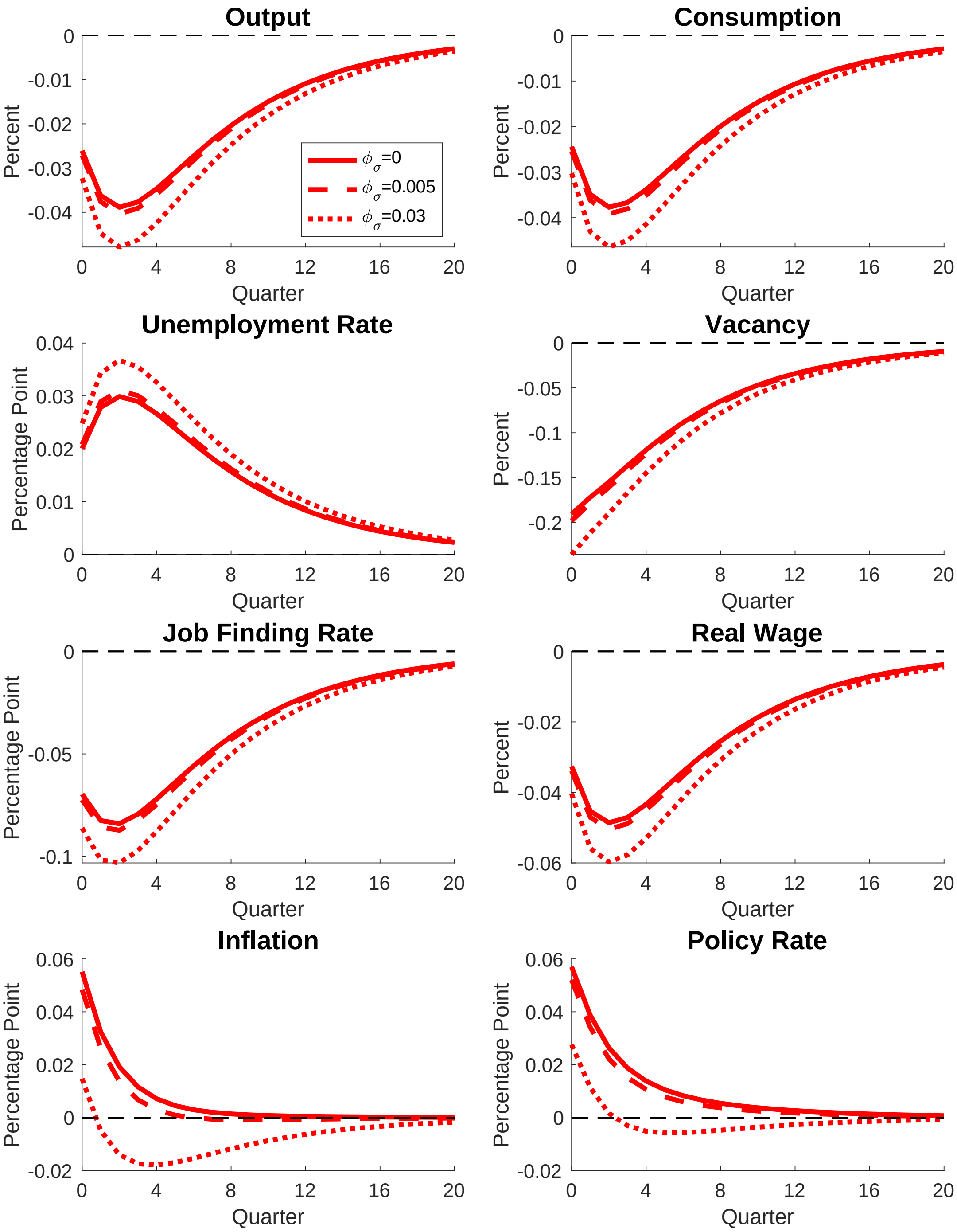

Figure 10: Alternative Monetary Policy Rule in Perfect Insurance Model

Note: Impulse responses of output, consumption, vacancy, and real wage are in percent deviation from their stochastic steady state, impulse responses of unemployment rate and job finding rate are in percentage point deviations from their stochastic steady state, while inflation and policy rate are in annualized percentage point deviations from their stochastic steady state.

5.2 Alternative Monetary Policy Rule

A potential concern regarding the response of inflation to uncertainty shocks might be that our result is dependant on the specification of the Taylor rule. In particular, it could be argued that, already in a representative agent model with only perfectly insured households, a direct response of monetary policy to uncertainty would not lead to a rise in inflation.

As a matter of fact, Fernández-Villaverde et al. (2015) modify the standard Taylor rule to address the counterfactual result that inflation increases in response to higher fiscal policy uncertainty. They assume that the nominal interest rate directly respond to fiscal volatility shocks. To assess how our result on inflation is robust to a Taylor rule specification à la Fernández-Villaverde et al. (2015), we modify the Taylor rule as follows:

$$\frac{1+R}{1+\bar{R}} = \left(\frac{1+\pi}{1+\bar{\pi}}\right)^{\phi_\pi} \left(\frac{y}{\mathbf{y}_{-1}}\right)^{\phi_y} \left(\frac{\exp\left(\sigma^z\right)}{\exp\left(\bar{\sigma}^z\right)}\right)^{\phi_\sigma}, \tag{67}$$

where σ^z is the TFP volatility, and $\phi_\sigma \geq 0$ is the responsiveness of the nominal interest rate to that volatility. Figure 10 shows the impulse responses of the main variables in our model under the assumption that there are only perfectly insured households, i.e. $\Omega = 0$.

The Figure reports three calibrations for ϕ_σ: $\phi_\sigma = 0$, which is our baseline case when the Taylor rule does not respond to uncertainty; $\phi_\sigma = 0.005$, which is the value calibrated by Fernández-Villaverde et al. (2015); and $\phi_\sigma = 0.03$, which captures a much stronger responsiveness to uncertainty. The Figure shows that with the Fernández-Villaverde et al. (2015) calibration inflation still rises in our setup with only perfectly insured households. Moreover, even with a much stronger monetary response to uncertainty, inflation drops only mildly at its trough. In addition, the responses of the other variables are quantitatively much smaller and not in line with the empirical evidence. This shows that a Taylor rule that reacts to uncertainty is not enough to obtain responses quantitatively in line with the data. To this end, it is necessary to assume heterogeneous agents to introduce a powerful enough amplification mechanism to the propagation of uncertainty.

5.3 Different Source of Macro Uncertainty

In line with the vast majority of the literature on uncertainty propagation, we have focused so far on TFP uncertainty. Yet, the macro uncertainty index by Jurado et al. (2015) that we use in our empirical analysis captures a broader concept of uncertainty affecting the macro economy. Thus, in this section we extend our analysis to study how the economy reacts to an increase uncertainty on the demand side of the economy. In particular, we modify Equation (47) by assuming that there is a monetary policy shock z^R, subject to time

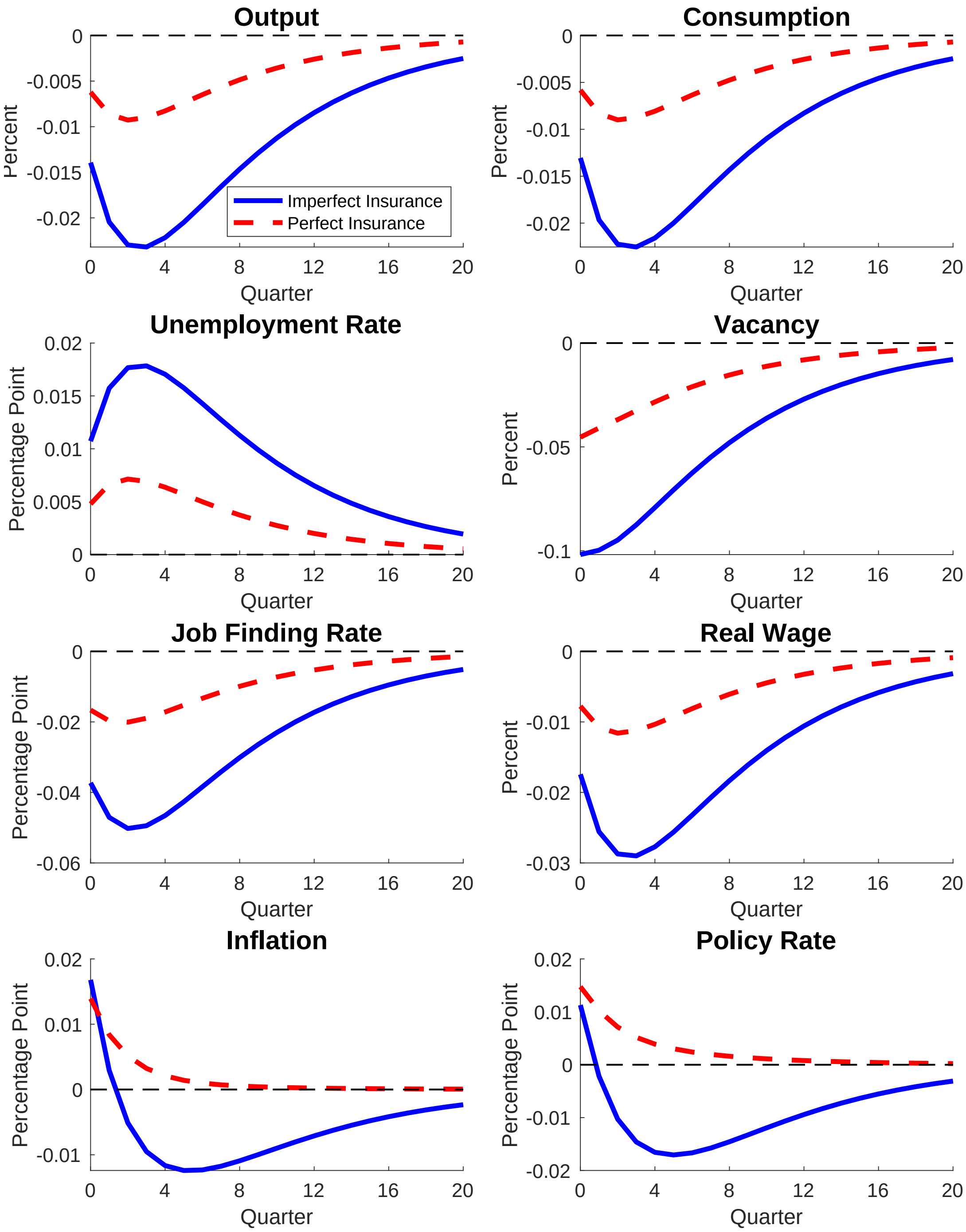

Figure 11: Impulse Responses to One-Standard Deviation Interest Rate Uncertainty

Note: Impulse responses of output, consumption, vacancy, and real wage are in percent deviation from their stochastic steady state, impulse responses of unemployment rate and job finding rate are in percentage point deviations from their stochastic steady state, while inflation and policy rate are in annualized percentage point deviations from their stochastic steady state.

varying volatility σ^R as follows:

$$\frac{1+R}{1+\bar{R}} = \left(\frac{1+\pi}{1+\bar{\pi}}\right)^{\phi_\pi} \left(\frac{y}{\mathbf{y}_{-1}}\right)^{\phi_y} z^R, \tag{68}$$

$$\log z^R = \rho_R \log z^R_{-1} + \sigma^R \varepsilon^R, \tag{69}$$

$$\log \sigma^R = (1-\rho_{\sigma^R}) \log \bar{\sigma}^R + \rho_{\sigma^R} \log \sigma^R_{-1} + \sigma^{\sigma^R} \varepsilon^{\sigma^R}. \tag{70}$$

We parametrize the persistence and the volatility of the monetary policy shock to $\rho_R = 0.7$ and $\bar{\sigma}^R = 0.0025$, while we set the persistence and volatility of the monetary policy uncertainty shock to $\rho_{\sigma^R} = 0.85$ and $\sigma^{\sigma^R} = 0.37$, consistently with the persistence and volatility of the TFP uncertainty shock. Figure 11 shows the responses to the monetary policy uncertainty shock. As can be seen, when there are only perfectly insured households inflation increases both on impact and in the following quarters. Only the presence of imperfectly insured households, who amplify the drop in demand triggered by the rise in uncertainty, allows us to obtain a persistent drop in inflation from the second quarter onward. Moreover, as in the case of TFP uncertainty shocks, imperfectly insured households generate an amplification of the responses of the other macro variables.

5.4 Additional Sensitivity Analyses

This section illustrates sensitivity exercises on various parameters, which affect the strength of the precautionary saving motive for imperfectly insured households.

The first row of Figure 12 shows how consumption and inflation respond when we vary households' risk aversion σ. A higher risk aversion generates a stronger precautionary response of imperfectly insured households, who cannot fully insure against risk. Hence, the more risk-averse imperfectly insured households are, the bigger the shift of their response out of consumption and towards savings. At the same time, inflation, which increases on impact, drops faster the higher the risk aversion is. This is due to the feedback effect that the precautionary saving behavior of households has on aggregate demand.

The second row of Figure 12 shows sensitivity of consumption and inflation response to various consumption differences between employed and unemployed households. Indeed, the bigger the consumption differential is between the two employment states, the stronger the precautionary saving motive that leads employed imperfectly insured households to save more, thus triggering a sharper drop in consumption and inflation.

The third sensitivity exercise that we carry out is on imperfectly insured households' consumption share ($C60/C$). This share is important as it negatively affects the skill premium ψ of perfectly insured households over imperfectly insured ones (as shown in Table 1, we calibrate the skill premium by targeting

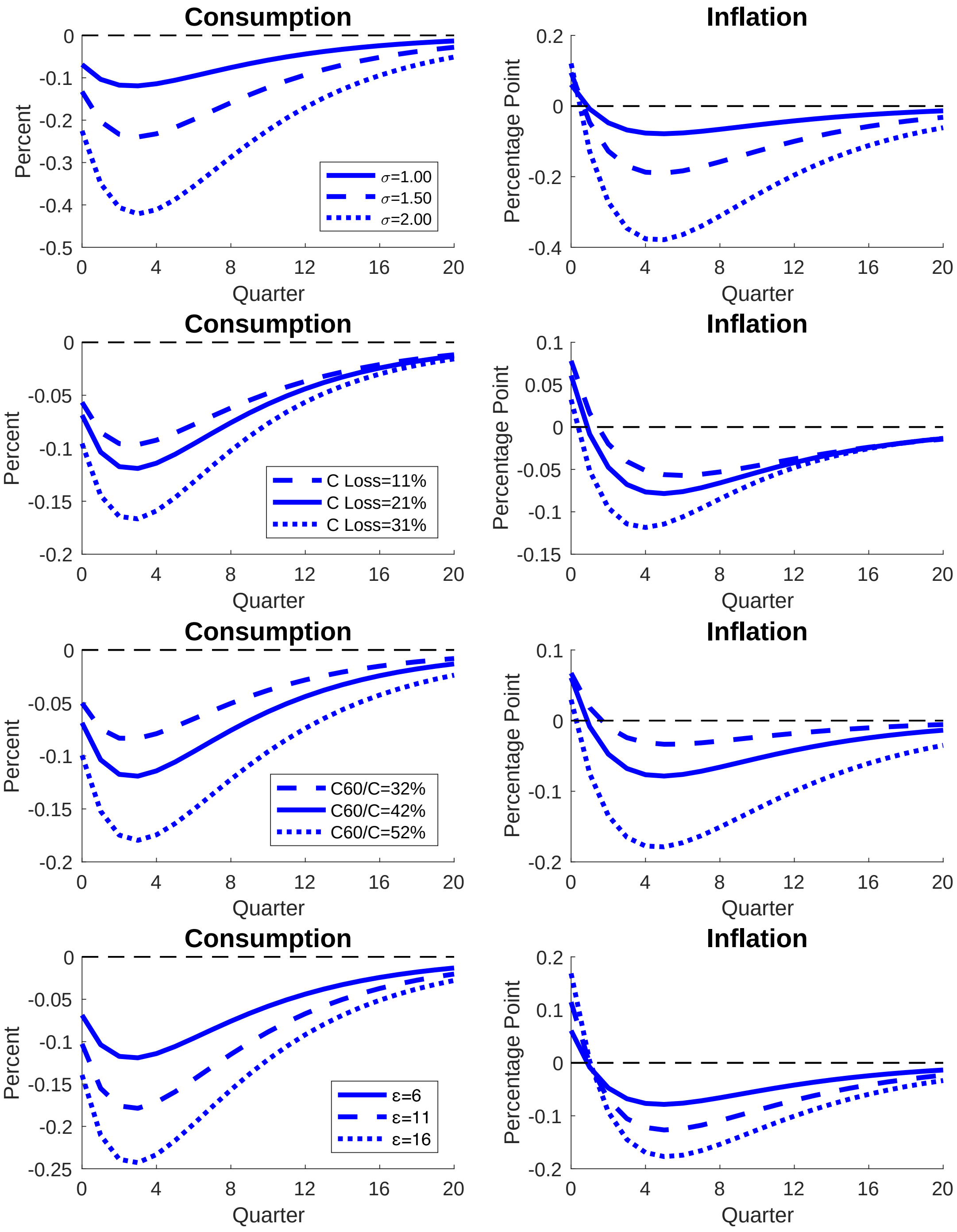

Figure 12: Sensitivity Analyses 1

Note: Impulse responses of consumption are in percent deviation from their stochastic steady state, while impulse responses of inflation are in annualized percentage point deviations from their stochastic steady state.

the share of imperfectly insured households' consumption). The bigger the imperfectly insured households' consumption share, the more the precautionary saving behavior of imperfectly insured households affects aggregate consumption, thus amplifying the drop in consumption and inflation caused by an uncertainty shock.

The next sensitivity exercise is on the elasticity of substitution between two intermediate goods ε. As shown in Oh (2020), a higher elasticity makes the marginal profit curve of intermediate firms more convex, thus strengthening the precautionary pricing behavior of firms. This is why, on impact, a higher elasticity causes a sharper increase in inflation. On the contrary, as soon as the higher prices set by intermediate firms trigger an increase in unemployment, the amplification effect of imperfectly insured households' precautionary saving behavior on aggregate demand kicks in, thus counteracting the price increase and leading to a sharper fall in inflation.

In our baseline model, we have assumed that there is no wage rigidity. Nevertheless, some degree of wage inertia may affect the consumption response of the households as well as the pricing behavior of firms. We therefore check what happens when we modify Equation (46) to introduce some wage rigidity:

$$w = \mathbf{w}_{-1}{}^{\gamma_w} \left(\bar{w} \left(\frac{\mathbf{n}}{\bar{n}} \right)^{\phi_w} \right)^{1-\gamma_w}, \tag{71}$$

where γ_w indicates the indexation to previous period wage. The first row of Figure 13 shows the sensitivity of consumption and inflation responses to different levels of wage rigidity. The effect of more rigid wages on consumption is not particularly strong. In response to stickier wages, firms tend to increase their prices on impact, thus generating higher inflation.

The next sensitivity exercises concern the parameters of the Taylor rule. In the baseline model we have assumed no persistence in the interest rate. We now check what happens when there is some persistence. We therefore modify Equation (47) as follows:

$$\frac{1+R}{1+\bar{R}} = \left(\frac{1+\mathbf{R}_{-1}}{1+\bar{R}} \right)^{\phi_R} \left(\left(\frac{1+\pi}{1+\bar{\pi}} \right)^{\phi_\pi} \left(\frac{y}{\mathbf{y}_{-1}} \right)^{\phi_y} \right)^{1-\rho_R}, \tag{72}$$

where ϕ_R is the parameter controlling the degree of persistence. The second row of Figure 13 shows consumption and inflation responses when we vary the persistence ϕ_R of the interest rate in the Taylor rule. While interest rate persistence barely affects the consumption response, inflation drops by less the higher the persistence is.

The third and fourth rows of Figure 13 show consumption and inflation responses to an uncertainty shock for different levels of monetary policy responsiveness. In particular, the more responsive monetary

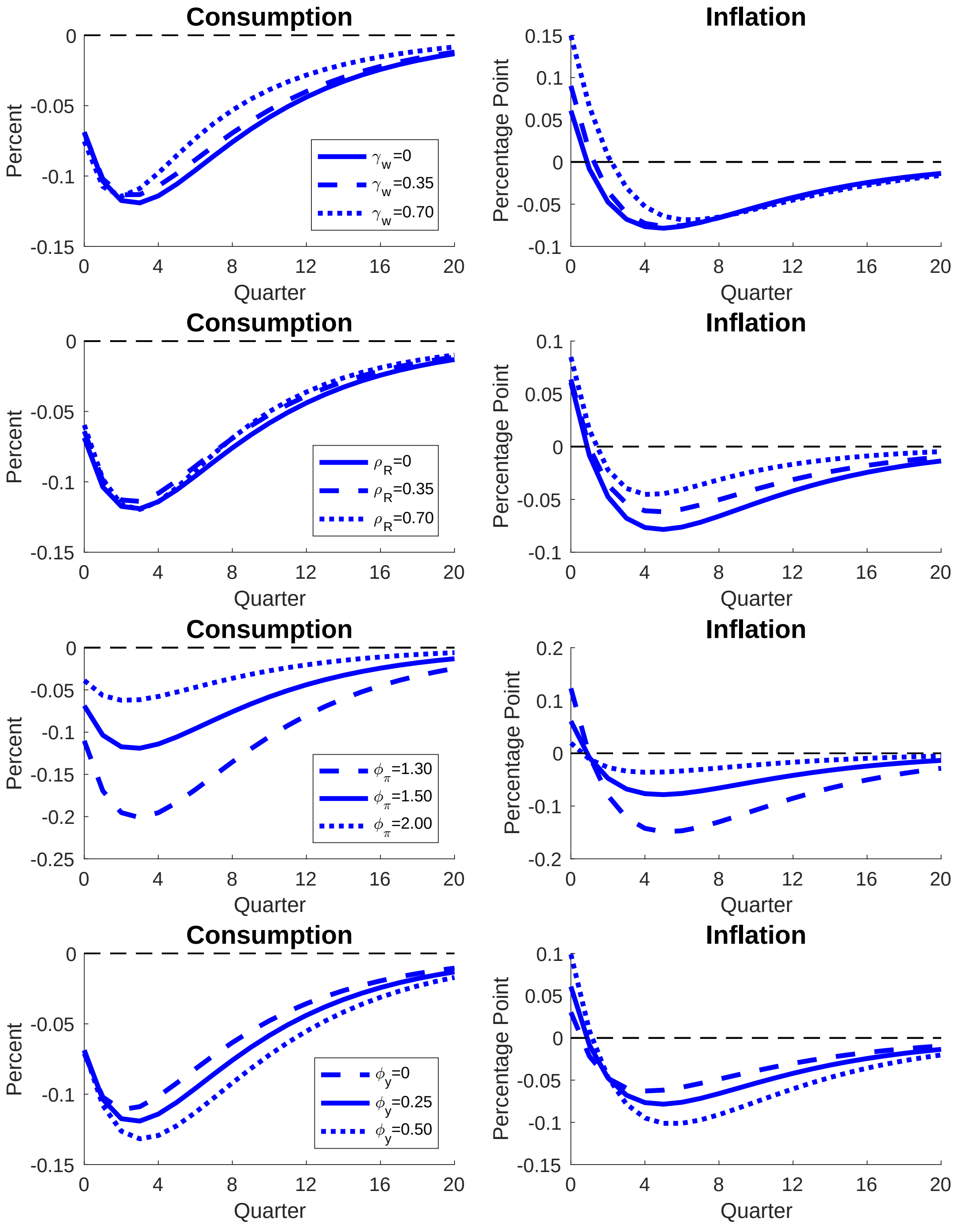

Figure 13: Sensitivity Analyses 2

Note: Impulse responses of consumption are in percent deviation from their stochastic steady state, while impulse responses of inflation are in annualized percentage point deviations from their stochastic steady state.

policy is to inflation (the higher ϕ_π), the smoother the real interest rate. A smoother real interest rate path reduces the inter-temporal substitution of imperfectly insured households, thus dampening the drop in consumption induced by an uncertainty shock. Indeed, the more responsive monetary policy is to inflation, the less inflation responds to an uncertainty shock. To the contrary, when monetary policy is more responsive to output growth, we get more volatility in consumption and inflation response.

6 Conclusion

This paper has shown how households' heterogeneity is important to explain the propagation of uncertainty shocks to the macroeconomy. First, by estimating a VAR of macro variables and the macro uncertainty index of Jurado et al. (2015), it has provided empirical evidence that an increase in macro uncertainty generates a drop in output, consumption, inflation, and the job finding rate rate, and triggers a rise in the unemployment and the separation rate. Second, it has shown how heterogeneous households' consumption response is important in explaining the macro dynamics of the aggregate responses. To do so, it has estimated a VAR by using disaggregated CEX data instead of aggregate consumption data. It has shown that households respond heterogeneously across their income distribution: households belonging to the bottom 60% of the income distribution are more responsive to uncertainty shocks than those belonging to the top 40%. To rationalize these empirical findings, it has built a model with imperfectly insured unemployment risk, SaM frictions, and Calvo-type price rigidities. In response to a positive uncertainty shock, the interaction between the precautionary saving behavior of partially insured households, the labor market SaM frictions, and the precautionary pricing behavior of firms is able to generate: i) a drop in inflation, and ii) responses of output, consumption, and the policy rate, which are quantitatively as well as qualitatively in line with the empirical evidence. The goal of our model has been to study the propagation of uncertainty shocks in a model with unemployment risk and imperfect insurance. This has been possible thanks to the tractability of our framework. Our setup has allowed us to introduce a minimal heterogeneity across households, while at the same time retaining the main precautionary saving motive implied by heterogeneity. As our heterogeneity is kept to the minimum, it does not make our model particularly suitable to study distributional issues.

Lastly, our model abstracts from capital and investment. Introducing capital would provide households with an illiquid asset through which to precautionarily save when uncertainty increases. The option to accumulate capital would dampen the decrease in aggregate demand following a rise in uncertainty. This would somewhat weaken the feedback loop triggered by the precautionary saving behavior of uninsured households, which would nevertheless still be present. To get a response in aggregate demand similar to the model without capital, we would need to give households the possibility to also save through a liquid bond. Further, this addition would allow us to match a more realistic distribution of marginal propensities to consume. We leave the inclusion of capital and a liquid bond as well as a more thorough analysis of their implications to future studies.

Acknowledgements

We are grateful to Evi Pappa, Axelle Ferriere, and Leonardo Melosi for their guidance and support. We are also indebted to Guido Ascari, Dario Bonciani, Margherita Borella, Tobias Broer, Fabio Canova, Efrem Castelnuovo, Daeha Cho, Sangyup Choi, Jeanne Commault, Wei Cui, Juan Dolado, Miguel Faria-e-Castro, Elsa Fornero, Matteo Gatti, Nils Gornemann, ShinHyuck Kang, Kwang Hwan Kim, Mira Kim, Mathias Klein, Francesca Loria, Helmut Lütkepohl, Eunseong Ma, Ryan Michaels, Kurt Mitman, Benjamin Moll, Gergő Motyovszki, Makoto Nakajima, Dieter Nautz, Guangyu Pei, Osvaldo Pericon, Johannes Pfeifer, Carlo Pizzinelli, Céline Poilly, Bruce Preston, Morten O. Ravn, Alfonso Rosolia, Simon Xuguang Sheng, Myungkyu Shim, Mathias Trabandt, Karl Walentin, Thomas Winberry, Lars Winkelmann, and Donghoon Yoo for many insightful discussions. We thank numerous seminar participants for useful comments. All errors are our own.

References

Adjemian, Stéphane, Houtan Bastani, Michel Juillard, Fréderic Karamé, Junior Maih, Ferhat Mihoubi, George Perendia, Johannes Pfeifer, Marco Ratto, and Sébastien Villemot, "Dynare: Reference Manual Version 4," Dynare Working Papers 1, CEPREMAP 2011.

Anderson, Emily, Atsushi Inoue, and Barbara Rossi, "Heterogeneous Consumers and Fiscal Policy Shocks," *Journal of Money, Credit and Banking*, 2016, *48* (8), 1877–1888.

Andreasen, Martin M., Jesús Fernández-Villaverde, and Juan Rubio-Ramírez, "The Pruned State-Space System for Non-Linear DSGE Models: Theory and Empirical Applications," *Review of Economic Studies*, 2018, *85* (1), 1–49.

Angelini, Giovanni and Luca Fanelli, "Exogenous Uncertainty and the Identification of Structural Vector Autoregressions with External Instruments," *Journal of Applied Econometrics*, 2019, *Forthcoming.*

_ , Emanuele Bacchiocchi, Giovanni Caggiano, and Luca Fanelli, "Uncertainty across Volatility Regimes," *Journal of Applied Econometrics*, 2019, *34* (3), 437–455.

Basu, Susanto and Brent Bundick, "Uncertainty Shocks in a Model of Effective Demand," *Econometrica*, 2017, *85* (3), 937–958.

Bayer, Christian, Ralph Lüetticke, Lien Pham-Dao, and Volker Tjaden, "Precautionary Savings, Illiquid Assets, and the Aggregate Consequences of Shocks to Household Income Risk," *Econometrica*, 2019, *87* (1), 255–290.

Bilbiie, Florin, "Monetary Policy and Heterogeneity: An Analytical Framework," 2019. Working Papar.

Bloom, Nicholas, "The Impact of Uncertainty Shocks," *Econometrica*, 2009, *77* (3), 623–685.

Bonciani, Dario and Björn van Roye, "Uncertainty Shocks, Banking Frictions and Economic Activity," *Journal of Economic Dynamics and Control*, 2016, *73*, 200–219.

Born, Benjamin and Johannes Pfeifer, "Policy Risk and the Business Cycle," *Journal of Monetary Economics*, 2014, *68*, 68–85.

Caggiano, Giovanni, Efrem Castelnuovo, and Nicolas Groshenny, "Uncertainty Shocks and Unemployment Dynamics in U.S. Recessions," *Journal of Monetary Economics*, 2014, *67*, 78–92.

Calvo, Guillermo, "Staggered Prices in a Utility Maximizing Framework," *Journal of Monetary Economics*, 1983, *12*, 383–398.

Carriero, Andrea, Todd E. Clark, and Massimiliano Marcellino, “Endogenous Uncertainty,” 2018. Federal Reserve Bank of Cleveland Working Paper 18-05.

_ , _ , and _ , “Measuring Uncertainty and Its Impact on the Economy,” *Review of Economics and Statistics*, 2018, *100* (5), 799–815.

Castelnuovo, Efrem, “Domestic and Global Uncertainty: A Survey and Some New Results,” 2019. CAMA Working Paper 75/2019.

Cesa-Bianchi, Ambrogio and Emilio Fernandez-Corugedo, “Uncertainty, Financial Frictions and Nominal Rigidities: A Quantitative Investigation,” *Journal of Money, Credit and Banking*, 2018, *50* (4), 603–636.

Challe, Edouard, “Uninsured Unemployment Risk and Optimal Monetary Policy in a Zero-Liquidity Economy,” *American Economic Journal: Macroeconomics*, 2020, *Forthcoming.*

_ , Julien Matheron, Xavier Ragot, and Juan F. Rubio-Ramirez, “Precautionary Saving and Aggregate Demand,” *Quantitative Economics*, 2017, *8* (2), 435–478.

Cho, Daeha, “Unemployment Risk, MPC Heterogeneity, and Business Cycles,” 2019. Working Paper.

de Groot, Oliver, Alexander W. Richter, and Nathanial A. Throckmorton, “Uncertainty Shocks in a Model of Effective Demand: Comment,” *Econometrica*, 2018, *86* (4), 1513–1526.

Den Haan, Wouter J., Garey Ramey, and Joel Watson, “Job Destruction and Propagation of Shocks,” *American Economic Review*, 2000, *90* (3), 482–498.

_ , Pontus Rendahl, and Markus Riegler, “Unemployment (Fears) and Deflationary Spirals,” *Journal of the European Economic Association*, 2018, *16* (5), 1281–1349.

Dolado, Juan J., Gergő Motyovszki, and Evi Pappa, “Monetary Policy and Inequality under Labor Market Frictions and Capital-Skill Complementarity,” *American Economic Journal: Macroeconomics*, 2020, *Forthcoming.*

Fasani, Stefano and Lorenza Rossi, “Are Uncertainty Shocks Aggregate Demand Shocks?,” *Economics Letters*, 2018, *167*, 142–146.

Fernández-Villaverde, Jesús, Pablo Guerrón-Quintana, Juan Rubio-Ramírez, and Martín Uribe, “Risk Matters: The Real Effects of Volatility Shocks,” *American Economic Review*, 2011, *101* (6), 2530–2561.

_ , _ , Keith Kuester, and Juan Rubio-Ramírez, "Fiscal Volatility Shocks and Economic Activity," *American Economic Review*, 2015, *105* (11), 3352–3384.

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

Gornemann, Nils, Keith Kuester, and Makoto Nakajima, "Doves for the Rich, Hawks for the Poor? Distributional Consequences of Monetary Policy," 2016. Working Paper.

Heathcote, Jonathan and Fabrizio Perri, "Wealth and Volatility," *Review of Economic Studies*, 2018, *85* (4), 2173–2213.

_ , _ , and Giovanni L. Violante, "Unequal we stand: An empirical analysis of economic inequality in the United States," *Review of Economic Dynamics*, 2010, *13* (1), 15–51.

Jurado, Kyle, Sydney C. Ludvigson, and Serena Ng, "Measuring Uncertainty," *American Economic Review*, 2015, *105* (3), 1177–1216.

Kaplan, Greg, Benjamin Moll, and Giovanni L. Violante, "Monetary Policy According to HANK," *American Economic Review*, 2018, *108* (3), 697–743.

Katayama, Munechika and Kwang Hwan Kim, "Uncertainty Shocks and the Relative Price of Investment Goods," *Review of Economic Dynamics*, 2018, *30*, 163–178.

Lagerborg, Andresa, Evi Pappa, and Morten O. Ravn, "Sentimental Business Cycles," 2019. Working Paper.

Leduc, Sylvain and Zheng Liu, "Uncertainty Shocks are Aggregate Demand Shocks," *Journal of Monetary Economics*, 2016, *82*, 20–35.

Ma, Eunseong, "The Heterogeneous Responses of Consumption between Poor and Rich to Government Spending Shocks," *Journal of Money, Credit and Banking*, 2019, *51* (7), 1999–2028.

McKay, Alisdair and Ricardo Reis, "The Role of Automatic Stabilizers in the U.S. Business Cycle," *Econometrica*, 2016, *84* (1), 141–194.

_ and _ , "Optimal Automatic Stabilizers," 2017. Working Paper.

Mortensen, Dale T. and Christopher A. Pissarides, "Job Creation and Job Destruction in the Theory of Unemployment," *Review of Economic Studies*, 1994, *61* (3), 397–415.

Mumtaz, Haroon and Konstantinos Theodoridis, "The International Transmission of Volatility Shocks: An Empirical Analysis," *Journal of the European Economic Association*, 2015, *13* (3), 512–533.

Oh, Joonseok, "The Propagation of Uncertainty Shocks: Rotemberg versus Calvo," *International Economic Review*, 2020, *61* (3), 1097–1113.

Petrongolo, Barbara and Christopher A. Pissarides, "Looking into the Black Box: A Survey of the Matching Function," *Journal of Economic Literature*, 2001, *39* (2), 390–431.

Piffer, Michele and Maximilian Podstawski, "Identifying Uncertainty Shocks Using the Price of Gold," *Economic Journal*, 2018, *128* (616), 3266–3284.

Pizzinelli, Carlo, Konstantinos Theodoridis, and Francesco Zanetti, "State Dependence in Labor Market Fluctuations: Evidence, Theory, and Policy Implications," 2018. Working Paper.

Ravn, Morten O. and Vincent Sterk, "Job Uncertainty and Deep Recessions," *Journal of Monetary Economics*, 2017, *90*, 125–141.

_ **and** _ , "Macroeconomic Fluctuations with HANK & SAM: an Analytical Approach," *Journal of the European Economic Association*, 2020, *Forthcoming.*

Riegler, Markus, "The Impact of Uncertainty Shocks on the Job-Finding Rate and Separation Rate," 2019. Working Papar.

Rotemberg, Julio J., "Sticky Prices in the United States," *Journal of Political Economy*, 1982, *90* (6), 1187–1211.

Shimer, Robert, "The Cyclical Behavior of Equilibrium Unemployment and Vacancies," *American Economic Review*, 2005, *95* (1), 25–49.

_ , "Reassessing the Ins and Outs of Unemployment," *Review of Economic Dynamics*, 2012, *15* (2), 127–148.

Wu, Jing Cynthia and Fan Dora Xia, "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound," *Journal of Money, Credit and Banking*, 2016, *48*, 253–291.

Earlier Working Papers:

For a complete list of Working Papers published by Sveriges Riksbank, see www.riksbank.se

Estimation of an Adaptive Stock Market Model with Heterogeneous Agents *by Henrik Amilon*	2005:177
Some Further Evidence on Interest-Rate Smoothing: The Role of Measurement Errors in the Output Gap *by Mikael Apel and Per Jansson*	2005:178
Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through by Malin Adolfson, Stefan Laséen, Jesper Lindé and Mattias Villani	2005:179
Are Constant Interest Rate Forecasts Modest Interventions? Evidence from an Estimated Open Economy DSGE Model of the Euro Area *by Malin Adolfson, Stefan Laséen, Jesper Lindé and Mattias Villani*	2005:180
Inference in Vector Autoregressive Models with an Informative Prior on the Steady State *by Mattias Villani*	2005:181
Bank Mergers, Competition and Liquidity *by Elena Carletti, Philipp Hartmann and Giancarlo Spagnolo*	2005:182
Testing Near-Rationality using Detailed Survey Data *by Michael F. Bryan and Stefan Palmqvist*	2005:183
Exploring Interactions between Real Activity and the Financial Stance *by Tor Jacobson, Jesper Lindé and Kasper Roszbach*	2005:184
Two-Sided Network Effects, Bank Interchange Fees, and the Allocation of Fixed Costs *by Mats A. Bergman*	2005:185
Trade Deficits in the Baltic States: How Long Will the Party Last? *by Rudolfs Bems and Kristian Jönsson*	2005:186
Real Exchange Rate and Consumption Fluctuations follwing Trade Liberalization *by Kristian Jönsson*	2005:187
Modern Forecasting Models in Action: Improving Macroeconomic Analyses at Central Banks *by Malin Adolfson, Michael K. Andersson, Jesper Lindé, Mattias Villani and Anders Vredin*	2005:188
Bayesian Inference of General Linear Restrictions on the Cointegration Space *by Mattias Villani*	2005:189
Forecasting Performance of an Open Economy Dynamic Stochastic General Equilibrium Model *by Malin Adolfson, Stefan Laséen, Jesper Lindé and Mattias Villani*	2005:190
Forecast Combination and Model Averaging using Predictive Measures *by Jana Eklund and Sune Karlsson*	2005:191
Swedish Intervention and the Krona Float, 1993-2002 *by Owen F. Humpage and Javiera Ragnartz*	2006:192
A Simultaneous Model of the Swedish Krona, the US Dollar and the Euro *by Hans Lindblad and Peter Sellin*	2006:193
Testing Theories of Job Creation: Does Supply Create Its Own Demand? *by Mikael Carlsson, Stefan Eriksson and Nils Gottfries*	2006:194
Down or Out: Assessing The Welfare Costs of Household Investment Mistakes *by Laurent E. Calvet, John Y. Campbell and Paolo Sodini*	2006:195
Efficient Bayesian Inference for Multiple Change-Point and Mixture Innovation Models *by Paolo Giordani and Robert Kohn*	2006:196
Derivation and Estimation of a New Keynesian Phillips Curve in a Small Open Economy *by Karolina Holmberg*	2006:197
Technology Shocks and the Labour-Input Response: Evidence from Firm-Level Data *by Mikael Carlsson and Jon Smedsaas*	2006:198
Monetary Policy and Staggered Wage Bargaining when Prices are Sticky *by Mikael Carlsson and Andreas Westermark*	2006:199
The Swedish External Position and the Krona *by Philip R. Lane*	2006:200

Price Setting Transactions and the Role of Denominating Currency in FX Markets *by Richard Friberg and Fredrik Wilander*	2007:201
The geography of asset holdings: Evidence from Sweden *by Nicolas Coeurdacier and Philippe Martin*	2007:202
Evaluating An Estimated New Keynesian Small Open Economy Model *by Malin Adolfson, Stefan Laséen, Jesper Lindé and Mattias Villani*	2007:203
The Use of Cash and the Size of the Shadow Economy in Sweden *by Gabriela Guibourg and Björn Segendorf*	2007:204
Bank supervision Russian style: Evidence of conflicts between micro- and macro-prudential concerns *by Sophie Claeys and Koen Schoors*	2007:205
Optimal Monetary Policy under Downward Nominal Wage Rigidity *by Mikael Carlsson and Andreas Westermark*	2007:206
Financial Structure, Managerial Compensation and Monitoring *by Vittoria Cerasi and Sonja Daltung*	2007:207
Financial Frictions, Investment and Tobin's q *by Guido Lorenzoni and Karl Walentin*	2007:208
Sticky Information vs Sticky Prices: A Horse Race in a DSGE Framework *by Mathias Trabandt*	2007:209
Acquisition versus greenfield: The impact of the mode of foreign bank entry on information and bank lending rates *by Sophie Claeys and Christa Hainz*	2007:210
Nonparametric Regression Density Estimation Using Smoothly Varying Normal Mixtures *by Mattias Villani, Robert Kohn and Paolo Giordani*	2007:211
The Costs of Paying – Private and Social Costs of Cash and Card *by Mats Bergman, Gabriella Guibourg and Björn Segendorf*	2007:212
Using a New Open Economy Macroeconomics model to make real nominal exchange rate forecasts *by Peter Sellin*	2007:213
Introducing Financial Frictions and Unemployment into a Small Open Economy Model *by Lawrence J. Christiano, Mathias Trabandt and Karl Walentin*	2007:214
Earnings Inequality and the Equity Premium *by Karl Walentin*	2007:215
Bayesian forecast combination for VAR models *by Michael K. Andersson and Sune Karlsson*	2007:216
Do Central Banks React to House Prices? *by Daria Finocchiaro and Virginia Queijo von Heideken*	2007:217
The Riksbank's Forecasting Performance *by Michael K. Andersson, Gustav Karlsson and Josef Svensson*	2007:218
Macroeconomic Impact on Expected Default Freqency *by Per Åsberg and Hovick Shahnazarian*	2008:219
Monetary Policy Regimes and the Volatility of Long-Term Interest Rates *by Virginia Queijo von Heideken*	2008:220
Governing the Governors: A Clinical Study of Central Banks *by Lars Frisell, Kasper Roszbach and Giancarlo Spagnolo*	2008:221
The Monetary Policy Decision-Making Process and the Term Structure of Interest Rates *by Hans Dillén*	2008:222
How Important are Financial Frictions in the U S and the Euro Area *by Virginia Queijo von Heideken*	2008:223
Block Kalman filtering for large-scale DSGE models *by Ingvar Strid and Karl Walentin*	2008:224
Optimal Monetary Policy in an Operational Medium-Sized DSGE Model *by Malin Adolfson, Stefan Laséen, Jesper Lindé and Lars E. O. Svensson*	2008:225
Firm Default and Aggregate Fluctuations *by Tor Jacobson, Rikard Kindell, Jesper Lindé and Kasper Roszbach*	2008:226
Re-Evaluating Swedish Membership in EMU: Evidence from an Estimated Model *by Ulf Söderström*	2008:227

The Effect of Cash Flow on Investment: An Empirical Test of the Balance Sheet Channel *by Ola Melander*	2009:228
Expectation Driven Business Cycles with Limited Enforcement *by Karl Walentin*	2009:229
Effects of Organizational Change on Firm Productivity *by Christina Håkanson*	2009:230
Evaluating Microfoundations for Aggregate Price Rigidities: Evidence from Matched Firm-Level Data on Product Prices and Unit Labor Cost *by Mikael Carlsson and Oskar Nordström Skans*	2009:231
Monetary Policy Trade-Offs in an Estimated Open-Economy DSGE Model *by Malin Adolfson, Stefan Laséen, Jesper Lindé and Lars E. O. Svensson*	2009:232
Flexible Modeling of Conditional Distributions Using Smooth Mixtures of Asymmetric Student T Densities *by Feng Li, Mattias Villani and Robert Kohn*	2009:233
Forecasting Macroeconomic Time Series with Locally Adaptive Signal Extraction *by Paolo Giordani and Mattias Villani*	2009:234
Evaluating Monetary Policy *by Lars E. O. Svensson*	2009:235
Risk Premiums and Macroeconomic Dynamics in a Heterogeneous Agent Model *by Ferre De Graeve, Maarten Dossche, Marina Emiris, Henri Sneessens and Raf Wouters*	2010:236
Picking the Brains of MPC Members *by Mikael Apel, Carl Andreas Claussen and Petra Lennartsdotter*	2010:237
Involuntary Unemployment and the Business Cycle *by Lawrence J. Christiano, Mathias Trabandt and Karl Walentin*	2010:238
Housing collateral and the monetary transmission mechanism *by Karl Walentin and Peter Sellin*	2010:239
The Discursive Dilemma in Monetary Policy *by Carl Andreas Claussen and Øistein Røisland*	2010:240
Monetary Regime Change and Business Cycles *by Vasco Cúrdia and Daria Finocchiaro*	2010:241
Bayesian Inference in Structural Second-Price common Value Auctions *by Bertil Wegmann and Mattias Villani*	2010:242
Equilibrium asset prices and the wealth distribution with inattentive consumers *by Daria Finocchiaro*	2010:243
Identifying VARs through Heterogeneity: An Application to Bank Runs *by Ferre De Graeve and Alexei Karas*	2010:244
Modeling Conditional Densities Using Finite Smooth Mixtures *by Feng Li, Mattias Villani and Robert Kohn*	2010:245
The Output Gap, the Labor Wedge, and the Dynamic Behavior of Hours *by Luca Sala, Ulf Söderström and Antonella Trigari*	2010:246
Density-Conditional Forecasts in Dynamic Multivariate Models *by Michael K. Andersson, Stefan Palmqvist and Daniel F. Waggoner*	2010:247
Anticipated Alternative Policy-Rate Paths in Policy Simulations *by Stefan Laséen and Lars E. O. Svensson*	2010:248
MOSES: Model of Swedish Economic Studies *by Gunnar Bårdsen, Ard den Reijer, Patrik Jonasson and Ragnar Nymoen*	2011:249
The Effects of Endogenuos Firm Exit on Business Cycle Dynamics and Optimal Fiscal Policy *by Lauri Vilmi*	2011:250
Parameter Identification in a Estimated New Keynesian Open Economy Model *by Malin Adolfson and Jesper Lindé*	2011:251
Up for count? Central bank words and financial stress *by Marianna Blix Grimaldi*	2011:252
Wage Adjustment and Productivity Shocks *by Mikael Carlsson, Julián Messina and Oskar Nordström Skans*	2011:253

Stylized (Arte) Facts on Sectoral Inflation *by Ferre De Graeve and Karl Walentin*	2011:254
Hedging Labor Income Risk *by Sebastien Betermier, Thomas Jansson, Christine A. Parlour and Johan Walden*	2011:255
Taking the Twists into Account: Predicting Firm Bankruptcy Risk with Splines of Financial Ratios *by Paolo Giordani, Tor Jacobson, Erik von Schedvin and Mattias Villani*	2011:256
Collateralization, Bank Loan Rates and Monitoring: Evidence from a Natural Experiment *by Geraldo Cerqueiro, Steven Ongena and Kasper Roszbach*	2012:257
On the Non-Exclusivity of Loan Contracts: An Empirical Investigation *by Hans Degryse, Vasso Ioannidou and Erik von Schedvin*	2012:258
Labor-Market Frictions and Optimal Inflation *by Mikael Carlsson and Andreas Westermark*	2012:259
Output Gaps and Robust Monetary Policy Rules *by Roberto M. Billi*	2012:260
The Information Content of Central Bank Minutes *by Mikael Apel and Marianna Blix Grimaldi*	2012:261
The Cost of Consumer Payments in Sweden *by Björn Segendorf and Thomas Jansson*	2012:262
Trade Credit and the Propagation of Corporate Failure: An Empirical Analysis *by Tor Jacobson and Erik von Schedvin*	2012:263
Structural and Cyclical Forces in the Labor Market During the Great Recession: Cross-Country Evidence *by Luca Sala, Ulf Söderström and AntonellaTrigari*	2012:264
Pension Wealth and Household Savings in Europe: Evidence from SHARELIFE *by Rob Alessie, Viola Angelini and Peter van Santen*	2013:265
Long-Term Relationship Bargaining *by Andreas Westermark*	2013:266
Using Financial Markets To Estimate the Macro Effects of Monetary Policy: An Impact-Identified FAVAR* *by Stefan Pitschner*	2013:267
DYNAMIC MIXTURE-OF-EXPERTS MODELS FOR LONGITUDINAL AND DISCRETE-TIME SURVIVAL DATA *by Matias Quiroz and Mattias Villani*	2013:268
Conditional euro area sovereign default risk *by André Lucas, Bernd Schwaab and Xin Zhang*	2013:269
Nominal GDP Targeting and the Zero Lower Bound: Should We Abandon Inflation Targeting?* *by Roberto M. Billi*	2013:270
Un-truncating VARs* *by Ferre De Graeve and Andreas Westermark*	2013:271
Housing Choices and Labor Income Risk *by Thomas Jansson*	2013:272
Identifying Fiscal Inflation* *by Ferre De Graeve and Virginia Queijo von Heideken*	2013:273
On the Redistributive Effects of Inflation: an International Perspective* *by Paola Boel*	2013:274
Business Cycle Implications of Mortgage Spreads* *by Karl Walentin*	2013:275
Approximate dynamic programming with post-decision states as a solution method for dynamic economic models *by Isaiah Hull*	2013:276
A detrimental feedback loop: deleveraging and adverse selection *by Christoph Bertsch*	2013:277
Distortionary Fiscal Policy and Monetary Policy Goals *by Klaus Adam and Roberto M. Billi*	2013:278
Predicting the Spread of Financial Innovations: An Epidemiological Approach *by Isaiah Hull*	2013:279
Firm-Level Evidence of Shifts in the Supply of Credit *by Karolina Holmberg*	2013:280

Lines of Credit and Investment: Firm-Level Evidence of Real Effects of the Financial Crisis *by Karolina Holmberg*	2013:281
A wake-up call: information contagion and strategic uncertainty *by Toni Ahnert and Christoph Bertsch*	2013:282
Debt Dynamics and Monetary Policy: A Note *by Stefan Laséen and Ingvar Strid*	2013:283
Optimal taxation with home production *by Conny Olovsson*	2014:284
Incompatible European Partners? Cultural Predispositions and Household Financial Behavior *by Michael Haliassos, Thomas Jansson and Yigitcan Karabulut*	2014:285
How Subprime Borrowers and Mortgage Brokers Shared the Piecial Behavior *by Antje Berndt, Burton Hollifield and Patrik Sandås*	2014:286
The Macro-Financial Implications of House Price-Indexed Mortgage Contracts *by Isaiah Hull*	2014:287
Does Trading Anonymously Enhance Liquidity? *by Patrick J. Dennis and Patrik Sandås*	2014:288
Systematic bailout guarantees and tacit coordination *by Christoph Bertsch, Claudio Calcagno and Mark Le Quement*	2014:289
Selection Effects in Producer-Price Setting *by Mikael Carlsson*	2014:290
Dynamic Demand Adjustment and Exchange Rate Volatility *by Vesna Corbo*	2014:291
Forward Guidance and Long Term Interest Rates: Inspecting the Mechanism *by Ferre De Graeve, Pelin Ilbas & Raf Wouters*	2014:292
Firm-Level Shocks and Labor Adjustments *by Mikael Carlsson, Julián Messina and Oskar Nordström Skans*	2014:293
A wake-up call theory of contagion *by Toni Ahnert and Christoph Bertsch*	2015:294
Risks in macroeconomic fundamentals and excess bond returns predictability *by Rafael B. De Rezende*	2015:295
The Importance of Reallocation for Productivity Growth: Evidence from European and US Banking *by Jaap W.B. Bos and Peter C. van Santen*	2015:296
SPEEDING UP MCMC BY EFFICIENT DATA SUBSAMPLING *by Matias Quiroz, Mattias Villani and Robert Kohn*	2015:297
Amortization Requirements and Household Indebtedness: An Application to Swedish-Style Mortgages *by Isaiah Hull*	2015:298
Fuel for Economic Growth? *by Johan Gars and Conny Olovsson*	2015:299
Searching for Information *by Jungsuk Han and Francesco Sangiorgi*	2015:300
What Broke First? Characterizing Sources of Structural Change Prior to the Great Recession *by Isaiah Hull*	2015:301
Price Level Targeting and Risk Management *by Roberto Billi*	2015:302
Central bank policy paths and market forward rates: A simple model *by Ferre De Graeve and Jens Iversen*	2015:303
Jump-Starting the Euro Area Recovery: Would a Rise in Core Fiscal Spending Help the Periphery? *by Olivier Blanchard, Christopher J. Erceg and Jesper Lindé*	2015:304
Bringing Financial Stability into Monetary Policy* *by Eric M. Leeper and James M. Nason*	2015:305
SCALABLE MCMC FOR LARGE DATA PROBLEMS USING DATA SUBSAMPLING AND THE DIFFERENCE ESTIMATOR *by MATIAS QUIROZ, MATTIAS VILLANI AND ROBERT KOHN*	2015:306

SPEEDING UP MCMC BY DELAYED ACCEPTANCE AND DATA SUBSAMPLING *by MATIAS QUIROZ*	2015:307
Modeling financial sector joint tail risk in the euro area *by André Lucas, Bernd Schwaab and Xin Zhang*	2015:308
Score Driven Exponentially Weighted Moving Averages and Value-at-Risk Forecasting *by André Lucas and Xin Zhang*	2015:309
On the Theoretical Efficacy of Quantitative Easing at the Zero Lower Bound *by Paola Boel and Christopher J. Waller*	2015:310
Optimal Inflation with Corporate Taxation and Financial Constraints *by Daria Finocchiaro, Giovanni Lombardo, Caterina Mendicino and Philippe Weil*	2015:311
Fire Sale Bank Recapitalizations *by Christoph Bertsch and Mike Mariathasan*	2015:312
Since you're so rich, you must be really smart: Talent and the Finance Wage Premium *by Michael Böhm, Daniel Metzger and Per Strömberg*	2015:313
Debt, equity and the equity price puzzle *by Daria Finocchiaro and Caterina Mendicino*	2015:314
Trade Credit: Contract-Level Evidence Contradicts Current Theories *by Tore Ellingsen, Tor Jacobson and Erik von Schedvin*	2016:315
Double Liability in a Branch Banking System: Historical Evidence from Canada *by Anna Grodecka and Antonis Kotidis*	2016:316
Subprime Borrowers, Securitization and the Transmission of Business Cycles *by Anna Grodecka*	2016:317
Real-Time Forecasting for Monetary Policy Analysis: The Case of Sveriges Riksbank *by Jens Iversen, Stefan Laséen, Henrik Lundvall and Ulf Söderström*	2016:318
Fed Liftoff and Subprime Loan Interest Rates: Evidence from the Peer-to-Peer Lending *by Christoph Bertsch, Isaiah Hull and Xin Zhang*	2016:319
Curbing Shocks to Corporate Liquidity: The Role of Trade Credit *by Niklas Amberg, Tor Jacobson, Erik von Schedvin and Robert Townsend*	2016:320
Firms' Strategic Choice of Loan Delinquencies *by Paola Morales-Acevedo*	2016:321
Fiscal Consolidation Under Imperfect Credibility *by Matthieu Lemoine and Jesper Lindé*	2016:322
Challenges for Central Banks' Macro Models *by Jesper Lindé, Frank Smets and Rafael Wouters*	2016:323
The interest rate effects of government bond purchases away from the lower bound *by Rafael B. De Rezende*	2016:324
COVENANT-LIGHT CONTRACTS AND CREDITOR COORDINATION *by Bo Becker and Victoria Ivashina*	2016:325
Endogenous Separations, Wage Rigidities and Employment Volatility *by Mikael Carlsson and Andreas Westermark*	2016:326
Renovatio Monetae: Gesell Taxes in Practice *by Roger Svensson and Andreas Westermark*	2016:327
Adjusting for Information Content when Comparing Forecast Performance *by Michael K. Andersson, Ted Aranki and André Reslow*	2016:328
Economic Scarcity and Consumers' Credit Choice *by Marieke Bos, Chloé Le Coq and Peter van Santen*	2016:329
Uncertain pension income and household saving *by Peter van Santen*	2016:330
Money, Credit and Banking and the Cost of Financial Activity *by Paola Boel and Gabriele Camera*	2016:331
Oil prices in a real-business-cycle model with precautionary demand for oil *by Conny Olovsson*	2016:332
Financial Literacy Externalities *by Michael Haliasso, Thomas Jansson and Yigitcan Karabulut*	2016:333

The timing of uncertainty shocks in a small open economy *by Hanna Armelius, Isaiah Hull and Hanna Stenbacka Köhler*	2016:334
Quantitative easing and the price-liquidity trade-off *by Marien Ferdinandusse, Maximilian Freier and Annukka Ristiniemi*	2017:335
What Broker Charges Reveal about Mortgage Credit Risk *by Antje Berndt, Burton Hollifield and Patrik Sandåsi*	2017:336
Asymmetric Macro-Financial Spillovers *by Kristina Bluwstein*	2017:337
Latency Arbitrage When Markets Become Faster *by Burton Hollifield, Patrik Sandås and Andrew Todd*	2017:338
How big is the toolbox of a central banker? Managing expectations with policy-rate forecasts: Evidence from Sweden *by Magnus Åhl*	2017:339
International business cycles: quantifying the effects of a world market for oil *by Johan Gars and Conny Olovsson l*	2017:340
Systemic Risk: A New Trade-Off for Monetary Policy? *by Stefan Laséen, Andrea Pescatori and Jarkko Turunen*	2017:341
Household Debt and Monetary Policy: Revealing the Cash-Flow Channel *by Martin Flodén, Matilda Kilström, Jósef Sigurdsson and Roine Vestman*	2017:342
House Prices, Home Equity, and Personal Debt Composition *by Jieying Li and Xin Zhang*	2017:343
Identification and Estimation issues in Exponential Smooth Transition Autoregressive Models *by Daniel Buncic*	2017:344
Domestic and External Sovereign Debt *by Paola Di Casola and Spyridon Sichlimiris*	2017:345
The Role of Trust in Online Lending *by Christoph Bertsch, Isaiah Hull, Yingjie Qi and Xin Zhang*	2017:346
On the effectiveness of loan-to-value regulation in a multiconstraint framework *by Anna Grodecka*	2017:347
Shock Propagation and Banking Structure *by Mariassunta Giannetti and Farzad Saidi*	2017:348
The Granular Origins of House Price Volatility *by Isaiah Hull, Conny Olovsson, Karl Walentin and Andreas Westermark*	2017:349
Should We Use Linearized Models To Calculate Fiscal Multipliers? *by Jesper Lindé and Mathias Trabandt*	2017:350
The impact of monetary policy on household borrowing – a high-frequency IV identification *by Maria Sandström*	2018:351
Conditional exchange rate pass-through: evidence from Sweden *by Vesna Corbo and Paola Di Casola*	2018:352
Learning on the Job and the Cost of Business Cycles *by Karl Walentin and Andreas Westermark*	2018:353
Trade Credit and Pricing: An Empirical Evaluation *by Niklas Amberg, Tor Jacobson and Erik von Schedvin*	2018:354
A shadow rate without a lower bound constraint *by Rafael B. De Rezende and Annukka Ristiniemi*	2018:355
Reduced "Border Effects", FTAs and International Trade *by Sebastian Franco and Erik Frohm*	2018:356
Spread the Word: International Spillovers from Central Bank Communication *by Hanna Armelius, Christoph Bertsch, Isaiah Hull and Xin Zhang*	2018:357
Predictors of Bank Distress: The 1907 Crisis in Sweden *by Anna Grodecka, Seán Kenny and Anders Ögren*	2018:358

Diversification Advantages During the Global Financial Crisis *by Mats Levander*	2018:359
Towards Technology-News-Driven Business Cycles *by Paola Di Casola and Spyridon Sichlimiris*	2018:360
The Housing Wealth Effect: Quasi-Experimental Evidence *by Dany Kessel, Björn Tyrefors and Roine*	2018:361
Identification Versus Misspecification in New Keynesian Monetary Policy Models *by Malin Adolfson, Stefan Laseén, Jesper Lindé and Marco Ratto*	2018:362
The Macroeconomic Effects of Trade Tariffs: Revisiting the Lerner Symmetry Result *by Jesper Lindé and Andrea Pescatori*	2019:363
Biased Forecasts to Affect Voting Decisions? The Brexit Case *by Davide Cipullo and André Reslow*	2019:364
The Interaction Between Fiscal and Monetary Policies: Evidence from Sweden *by Sebastian Ankargren and Hovick Shahnazarian*	2019:365
Designing a Simple Loss Function for Central Banks: Does a Dual Mandate Make Sense? *by Davide Debortoli, Jinill Kim and Jesper Lindé*	2019:366
Gains from Wage Flexibility and the Zero Lower Bound *by Roberto M. Billi and Jordi Galí*	2019:367
Fixed Wage Contracts and Monetary Non-Neutrality *by Maria Björklund, Mikael Carlsson and Oskar Nordström Skans*	2019:368
The Consequences of Uncertainty: Climate Sensitivity and Economic Sensitivity to the Climate *by John Hassler, Per Krusell and Conny Olovsson*	2019:369
Does Inflation Targeting Reduce the Dispersion of Price Setters’ Inflation Expectations? *by Charlotte Paulie*	2019:370
Subsampling Sequential Monte Carlo for Static Bayesian Models *by David Gunawan, Khue-Dung Dang, Matias Quiroz, Robert Kohn and Minh-Ngoc Tran*	2019:371
Hamiltonian Monte Carlo with Energy Conserving Subsampling *by Khue-Dung Dang, Matias Quiroz, Robert Kohn, Minh-Ngoc Tran and Mattias Villani*	2019:372
Institutional Investors and Corporate Investment *by Cristina Cella*	2019:373
The Impact of Local Taxes and Public Services on Property Values *by Anna Grodecka and Isaiah Hull*	2019:374
Directed technical change as a response to natural-resource scarcity *by John Hassler, Per Krusell and Conny Olovsson*	2019:375
A Tale of Two Countries: Cash Demand in Canada and Sweden *by Walter Engert, Ben Fung and Björn Segendorf*	2019:376
Tax and spending shocks in the open economy: are the deficits twins? *by Mathias Klein and Ludger Linnemann*	2019:377
Mind the gap! Stylized dynamic facts and structural models *by Fabio Canova and Filippo Ferroni*	2019:378
Financial Buffers, Unemployment Duration and Replacement Labor Income *by Mats Levander*	2019:379
Inefficient Use of Competitors' Forecasts? *by André Reslow*	2019:380
How Much Information Do Monetary Policy Committees Disclose? Evidence from the FOMC's Minutes and Transcripts *by Mikael Apel, Marianna Blix Grimaldi and Isaiah Hull*	2019:381
Risk endogeneity at the lender/investor-of-last-resort *by Diego Caballero, André Lucas, Bernd Schwaab and Xin Zhang*	2019:382
Heterogeneity in Households’ Expectations of Housing Prices – Evidence from Micro Data *by Erik Hjalmarsson and Pär Österholm*	2019:383
Big Broad Banks: How Does Cross-Selling A Affect Lending? *by Yingjie Qi*	2020:384
Unemployment Fluctuations and Nominal GDP Targeting *by Roberto Billi*	2020:385

FAQ: How do I extract the output gap? *by Fabio Canova*	2020:386
Drivers of consumer prices and exchange rates in small open economies *by Vesna Corbo and Paola Di Casola*	2020:387
TFP news, stock market booms and the business cycle: Revisiting the evidence with VEC models *by Paola Di Casola and Spyridon Sichlimiris*	2020:388
The costs of macroprudential deleveraging in a liquidity trap *by Jiaqian Chen, Daria Finocchiaro, Jesper Lindé and Karl Walentin*	2020:389
The Role of Money in Monetary Policy at the Lower Bound *by Roberto M. Billi, Ulf Söderström and Carl E. Walsh*	2020:390
MAJA: A two-region DSGE model for Sweden and its main trading partners *by Vesna Corbo and Ingvar Strid*	2020:391
The interaction between macroprudential and monetary policies: The cases of Norway and Sweden *by Jin Cao, Valeriya Dinger, Anna Grodecka-Messi, Ragnar Juelsrud and Xin Zhang*	2020:392
Withering Cash: Is Sweden ahead of the curve or just special? *by Hanna Armelius, Carl Andreas Claussen and André Reslow*	2020:393
Labor shortages and wage growth *by Erik Frohm*	2020:394

Sveriges Riksbank
Visiting address: Brunkebergs torg 11
Mail address: se-103 37 Stockholm

Website: www.riksbank.se
Telephone: +46 8 787 00 00, Fax: +46 8 21 05 31
E-mail: registratorn@riksbank.se