Economics Bulletin

Volume 43, Issue 4

On the transmission of us uncertainty shocks to the European labor market

Michel C. de Souza
Federal University of Jequitinhonha and Mucuri Valleys

Abstract

We investigate the effects of a United States uncertainty shock on the European Union labor market by proposing a two-country Dynamic Stochastic General Equilibrium (DSGE) model with search and matching frictions and comparing the impulse response functions with data from twelve economies in a Bayesian Global Vector Autoregression (BGVAR) framework. Our results indicate that the Euro response is similar to a negative aggregate demand shock in the first eighteen months. However, afterward, the labor market frictions and trade intensity drive a stagflation process.

I want to thank the Editor of the Economics Bulletin and the Anonymous Referees, who made fundamental suggestions to improve the paper. Furthermore, I declare that I do not have any conflicts of interest, and all opinions in this text are my responsibility.
Citation: Michel C. de Souza, (2023) "On the transmission of us uncertainty shocks to the European labor market", *Economics Bulletin*, Volume 43, Issue 4, pages 1666-1679
Contact: Michel C. de Souza - michel.souza@ufvjm.edu.br.
Submitted: May 27, 2022. **Published:** December 30, 2023.

1 Introduction

With the development of the financial market and network technology, allowing agents almost instantaneous access to news worldwide, economies have become more integrated. Consequently, the dynamics of domestic uncertainty (mainly for the top players) may lead to fast global recessions, as empirically analyzed by Feldkircher and Huber (2016), Trung (2019), and Bhattarai et al. (2020). These papers focus on the classical short-run relationship between uncertainty and economic cycles (see Bernanke (1983),Romer (1990),Dixit and Pindyck (1994)). Furthermore, their results indicate that uncertainty shocks from the United States (US) negatively affect the output of its biggest trade partners.

However, at this point, regarding the transmission channels of the shock, most papers adopt the classical assumptions without considering search frictions in the labor market, as presented by Andolfatto (1953). Among the advances that included search frictions, we highlight a recent study by Leduc and Liu (2016). The authors use a model calibrated for the US economy and compare the results with a BVAR. There are at least two essential transmission channels to operate in modern labor markets for an uncertainty shock. The first, the more traditional one, occurs via aggregate demand, in which unemployment rises and the average price of goods falls. Then secondly, the drop in aggregate demand reduces the value of new matches for firms, boosting unemployment via the option-value channel and highlighting the importance of search friction when economic uncertainty is high. Finally, the authors conclude that an uncertainty shock acts like an aggregate demand shock for both approaches, calibrate and database models.

Considering the search and matching approach and the spillover effects of uncertainty shocks, our main question is: Are US Uncertainty Shocks transmitted as Aggregate demand shocks to the European Union (EU)? The main objective of this paper is to understand how labor markets are linked and how expansive the effects of an US uncertainty shock can be. Briefly, we provide a new look at how uncertainty affects unemployment through a two-country version of a Dynamic Stochastic General Equilibrium (DSGE) model by Leduc and Liu (2016) (based on Galí and Monacelli (2005)) and validate the patterns using a Bayesian Global Vector Autoregression model (BGVAR), by Pesaran et al. (2004)), Dees et al. (2007), and Cuaresma et al. (2016). In summary, the central contribution of this paper is the inclusion of the international bloc associated with the spillover effects of uncertainty through labor search frictions, which makes possible an analysis of how a US uncertainty shock affects the EU economy in a broader format.

Our results show that the DSGE and BGVAR models generate impulse response functions consistent with the evidence of Leduc and Liu (2016),s rising unemployment and falling inflation/interest rates lasting up to sixteen quarters (analogous to aggregate demand shocks). Furthermore, the calibrated model indicates that the effect of uncertainty on unemployment changes with openness and lasts about sixteen quarters after the shock. On the other hand, unemployment increases less for the EU (foreign) economy, and there is more dispersion conditioned on the degree of trade openness. This pattern resembles some of the evidence presented by NetSunajev and Glass (2017) using a BMSVAR model. Additionally, we present new evidence that the shock can induce stagflation cycles (high unemployment and prices) for EU economies in the medium term.

In what follows: Section 2 describes the model of Leduc and Liu (2016) and the inclusion of an international bloc. Section 3 explains the data/method details and Sections 4 and 5 discusses the results and present the mains conclusions. present the conclusions.

2 Theory Background

The Dynamic Stochastic General Equilibrium (DSGE) model proposed in this paper is an extension of the framework of Leduc and Liu (2016), using the model of Galí and Monacelli (2005). We focus on the labor market and an international bloc. Furthermore, we also use Christoffel et al. (2009) to calibrate and simulate the benchmark model. Here, we will briefly discuss the most basic idea of the core model of Leduc and Liu (2016) and include all the algebraic details in Appendix 1.

There is a continuum of identical individuals living for an infinite horizon. The representative household maximizes the utility function subject to a budget constraint composed of consumption, investments (government bonds and private companies), and wage earnings. The labor market operates through a search technology between agents who place advertisements, read newspapers and magazines, search for vacancies online, go to employment agencies, and use networks to improve their chances of matching an available vacancy.Furthermore, employed and unemployed workers have associated value functions, which summarize and determine the optimal wage through a Nash bargaining problem.

There are three types of firms in the economy i) firms that produce homogeneous intermediate goods labeled as labor goods and need to find one worker to produce and sell in a competitive market. ii) Retail companies take the intermediate goods as input for producing differentiated goods based on a technology of constant returns to scale, restricted to monopolistic competition. Finally, iii) the aggregation sector combines differentiated products into a homogeneous consumer basket sold to consumers and the government as a final good. It is essential to point out that this sector determines the final price in the home economy (P_t) based on domestic/home ($P_{H,t}$) and foreign ($P_{F,t}$) products, the degree of trade is α, and the elasticity of substitution between products is η. These factors are some of the main channels that differentiate our model from the work of Leduc and Liu (2016).

$$P_t = [(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta}]^{\frac{1}{1-\eta}} \tag{1}$$

Furthermore, based on Galí and Monacelli (2005), the domestic economy is linked to the trading partner by the Uncovered Interest Rate Parity (UIP):

$$\frac{R_{H,t}}{R_{F,t}} = \frac{\varepsilon_{t+1}}{\varepsilon_t} \tag{2}$$

where ε_t is the nominal exchange rate, and $R_{F,t}$ is the foreign interest rate. Under the assumption of complete securities markets, the risk-sharing condition is the ratio between marginal utilities of consumption (U_k). Here, (*) represents the variable at the world level (or an approximation for the economies that are not directly modeled):

$$\frac{\varepsilon_t P_t^*}{P_t} = \frac{U_{c*}}{U_c} \tag{3}$$

It is essential to understand that for UIP works, we need similar volatility and stability in both financial markets. (See Backus and Smith (1993) and Obstfeld and Rogoff (2000)). Without this, the risk-sharing hypotheses may fail.

3 Empirical Model and Data

Pesaran et al. (2004) proposed the GVAR as an empirical framework for modeling the world economy and cross-country dependence. One of this model's most significant practical uses is its possible application to regional problems, since the impulse response functions are available by unit.

While in the standard Vector Autoregressive (VAR) model, we have a set of series for a given geographic unit (cities, regions, countries, among others), in the Global model, series from all units are present in the estimation. Another critical point is that in addition to simultaneous estimation, all VAR models are linked by the trade matrix between the geographic units, expanding impulse-response analysis capacity.

The model consists of a set of country-by-country $VARX^*(p, p^*)$, which includes the p-lag order of domestic variables (x_{it}) and the p^*-lag order of foreign ones (x^*_{it}):

$$x_{it} = a_{i0} + \sum_{s=1}^{p} \Phi_{is} x_{it-s} + \sum_{r=1}^{p^*} \Lambda_{ir} x^*_{it-r} + \varepsilon_{it} \tag{4}$$

Where $x^*_{it} = \sum_{j=0}^{N} \omega_{ij} x_{jt}$, with ω_{ij} denoting the trade-weight matrix between countries. Each element ω_{ij} corresponds to a bilateral trade flow between i and j, divided by i's total trade. Then, we stack the country-specific models to obtain a global representation given by $Gx_t = a_0 + \sum_{q=1}^{Q} H_q x_{t-q} + \epsilon_t$, where G is the matrix of contemporaneous relations between countries, a_0 is a constant, and H_q is a global coefficient matrix. The variable ϵ_t represents a universal vector error, with a $\Sigma_{\epsilon i}$ variance–covariance matrix. Rewritten the model, if $\Pi_i^{'} = (1, x_{it-1}^{'}, ..., x_{it-p}^{'}, x_{it}^{*'}, ..., x_{it-p^*}^{*'})^{'}$ and $Z_{it-1} = (a_{i0}, \Phi_{i1}, ..., \Phi_{ip}, \Lambda_{i0}, ..., \Lambda_{ip*})^{`}$, we have:

$$x_{it} = \Pi_i^{'} Z_{it-1} + \varepsilon_{it} \tag{5}$$

Bayesian inference is helpful for global macroeconomic models (see Litterman (1986)) since there is a large number of parameters to be estimated (which grows geometrically with the order of the model), and the available time series are limited. Cuaresma et al. (2016) propose a Bayesian inference approach using a set of hierarchical priors (see George et al. (2008)). We use the Stochastic Search Variable Selection (SSVS) prior, represented by a mix of normal distributions on each model coefficient and for $\Psi_i = vec(\Pi_i)$ in a hierarchical prior setup. One advantage of using the SSVS prior is its ability to assess the importance of specific variables by examining the posterior inclusion probabilities:

$$\Psi_{ij} | \delta_{ij} \sim (1 - \delta_{ij}) \mathcal{N}(0, \tau_{0,j}^2) + \delta_{ij} \mathcal{N}(0, \tau_{1,j}^2) \tag{6}$$

Where δ_{ij} is a binary indicator variable for the coefficient j in the country i (δ_{ij} and follows a Bernoulli distribution with ($\underline{\text{q}}_{ij}$) probability. It equals 1 if the corresponding variable is in the model, with variance $\tau_{1,j}^2$ and 0 if the respective prior is excluded from the ith country, with $\tau_{0,j}^2$ close to zero, pushing the coefficient towards zero. The prior mean (when using SSVS) is around some value of $\underline{\Psi}_{ij}$. Collecting the parameters into a diagonal matrix $D_i = diag(d_{i1}, d_{i2}, ...d_{i\nu_i})$, the prior on Ψ_i reduces to the following hierarchical prior setup:

$$\Psi_i|D_i \sim \mathcal{N}(0, \underline{\mathrm{R}}_i) \tag{7}$$

$$\Sigma_{\epsilon i} \sim \mathcal{IW}(\underline{\mathrm{S}}_i, \underline{\nu}_i) \tag{8}$$

$\underline{\mathrm{R}}_i = D_i D_i$ and the $\Sigma_{\epsilon i}$ prior is a standard inverse Wishart with $\underline{\nu}_i$ degrees of freedom, and $\underline{\mathrm{S}}_i$ is the scale matrix.

Our BGVAR model covers monthly data for 12 countries (Canada,China,France, Germany, Greece, Ireland, Italy, the Netherlands, Spain, Mexico, the United Kingdom, and the United States) from January 2000 to January 2020. The weight matrix comes from the OECD Bilateral Trade database, built using annual trade flows from 2000 to 2020.

The endogenous variables are unemployment, the consumer price index, the interest rate (from OECD, FRED, and CEIC databases [1]), and an economic policy uncertainty index (from Baker et al. (2016)). Furthermore, in the structural analysis, we calculate the median General Impulse Response Functions (GIRF) considering 68% confidence intervals and 100,000 draws.

However, Chudik and Pesaran (2016) indicate, taking into consideration that the DSGE models must be solved using a VAR companion representation, that for full compatibility/integration of the GVAR and DSGE approaches, the construction of open economy DSGE models containing N countries capable of encompass all long-term and short-term movements would be required. According to Dées et al. (2014), even in this case, there would be several problems with measuring steady states, lag orders, and specifying models for different countries. Our study modestly proposes a partial compatibility from a theoretical model with two-by-two countries (the US and each trading partner) to a global empirical model containing twelve economies. In this case, we try to minimize the damage by working with the same order of lags for both economies and using structural steady-state equations to impose restrictions on the contemporaneous effects matrix of the BGVAR model. Our research interests policymakers and foreign traders since it can help the understanding of the local dynamics of unemployment and international uncertainty transmission channels.

4 Results

From Christoffel et al. (2009) and Leduc and Liu (2016), we calibrate and simulate the benchmark model to explore the effects of a US uncertainty shock on EU variables (unemployment, inflation, and the interest rate). Out of the 12 countries treated by Christoffel et al. (2009), we use France, Germany, Greece, Ireland, Italy, the Netherlands, Spain, and the UK, which already account for approximately 75% of the EU production. Austria, Belgium, Finland, and Luxemburg were excluded due to limitations in the analyzed series.

First, for the DSGE model, we change the trade parameter α. Here, the coefficient directly affects the proportion of external prices changing the aggregate price index and indirectly determines the demand dynamics through the Phillips curve. Furthermore, we also present two sensitivity cases for α (for 45% and 5% of US trade)[2]. Second, for the

[1] For China's unemployment, we use quarterly data and interpolate monthly values.

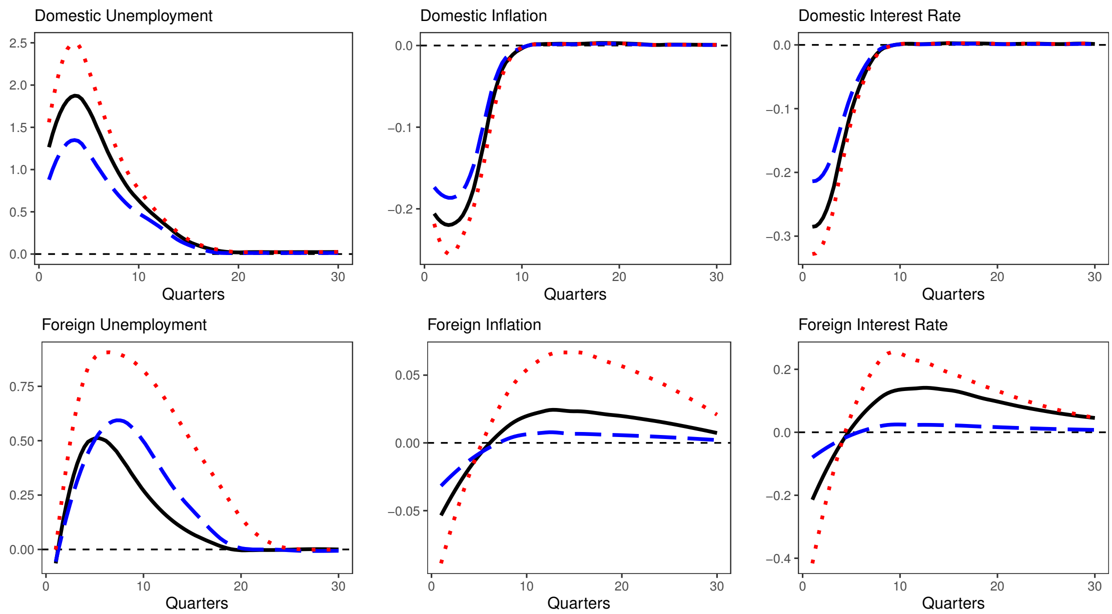
[2] We use the same strategy as Leduc and Liu (2016) and calibrate the theoretical model using quarterly data, and the empirical application uses monthly data

empirical representation, BGVAR, we change the weight matrix, ω, which represents the actual demand for goods in the international market, so that the change in the percentage of bilateral trade between two countries has repercussions (as an adjustment) across the entire weight matrix.

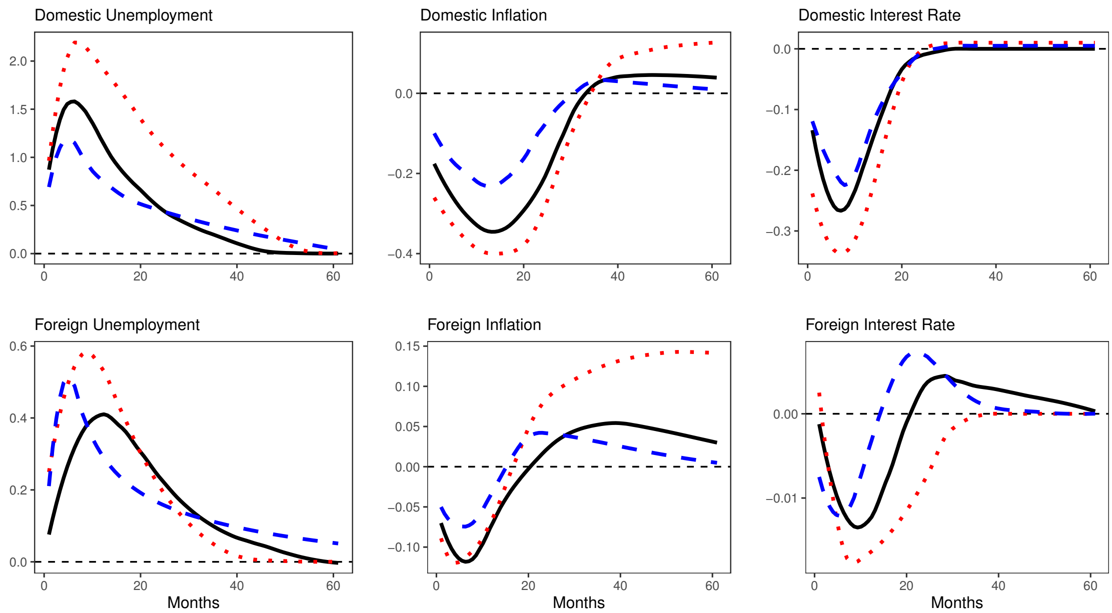
Our comparison strategy is to apply the change in the bilateral trade matrix from the chosen α. For example, if countries A and B have $\alpha = 45\%$, we apply $\omega_{12} = 45\%$ and redistribute the 55% of trade across the other countries, weighted by the previous distribution.

Figure 1 – Impulse Response Functions—DSGE and BGVAR

(a) **DSGE Model**



(b) **BGVAR Model**



Note: Generated by the author using Dynare-MatLab. The first six diagrams are from the DSGE model, and the second set is from the BGVAR model. The black lines represent the basic model, the red lines are the case of low trade intensity (5%), and the blue lines exemplify the case of high trade (45%).

For the US (domestic) economy, see Figure 1, both DSGE and BGVAR models generate impulse response functions consistent with the evidence in Leduc and Liu (2016): rising unemployment and falling inflation/interest rates lasting up to sixteen quarters (analogous to aggregate demand shocks). Furthermore, the calibrated model indicates that the effect of uncertainty on unemployment changes with openness but lasts about sixteen quarters after the shock. On the other hand, unemployment increases less for the EU (foreign) economy, and there is more dispersion conditioned on the degree of trade openness. This pattern resembles some of the evidence presented by NetSunajev and Glass (2017) using BMSVAR models, which makes the expected reaction stronger since the reaction is maintained even in structurally distinct models. For prices, the dynamics are different, adverse and moderate effects up to the eighth quarter and then a positive and persistent response. As the interest rate follows the same movement, the US uncertainty shock starts acting as an aggregate demand shock in EU. However, afterward, the effects change the sign, and, in the medium-term, the shock can induce stagflation cycles in EU economies: high unemployment, an increase in the price level, and higher interest rates. As the effect seems smaller in cases of higher openness, this reinforces the analysis of NetSunajev and Glass (2017) of trade advantages.

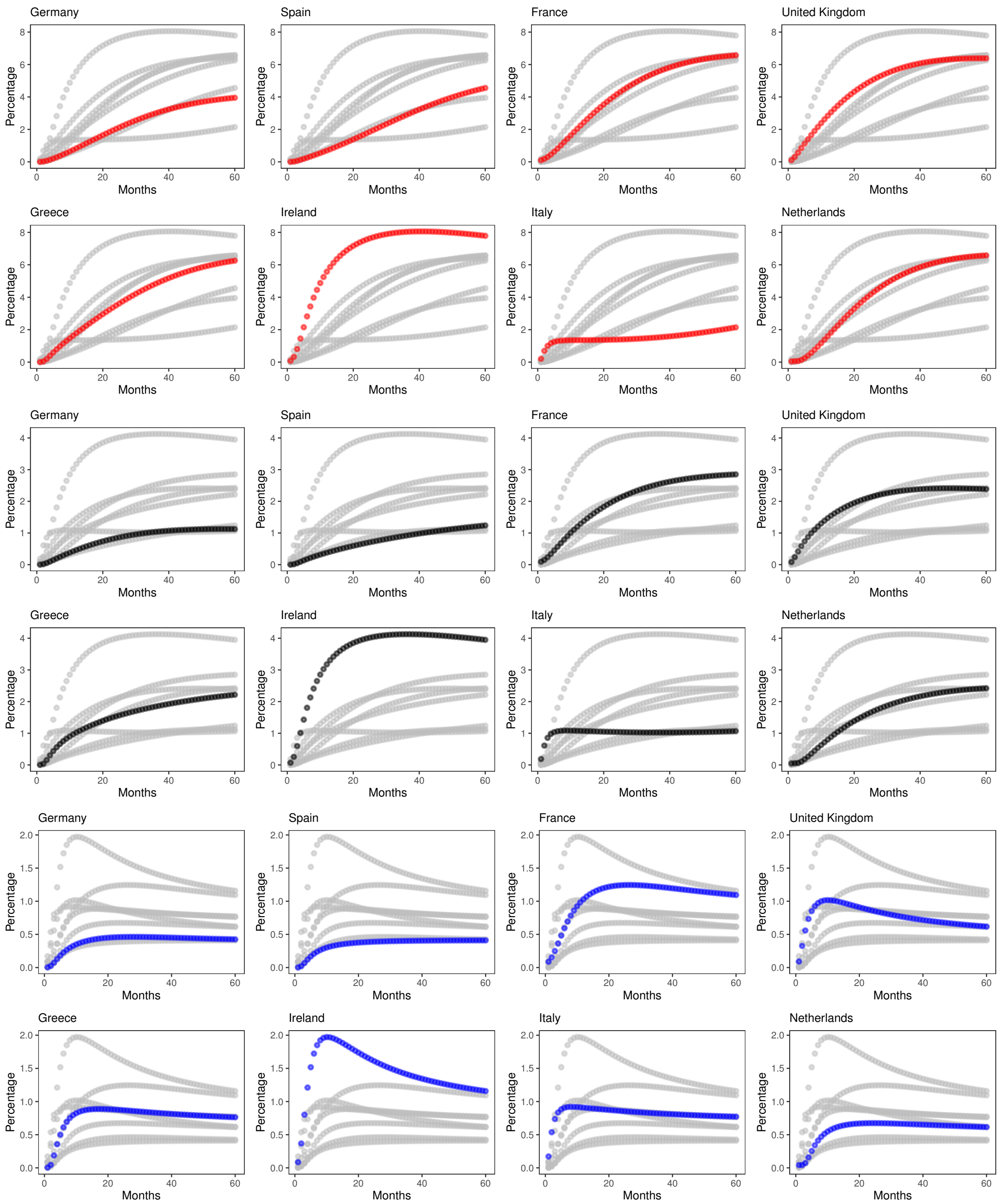
The case of stagflation is related to the friction in the commercial partner's labor market and expectations. When the domestic uncertainty shock reaches the foreign economy, it drives two phenomena, which occur in opposite directions i) price adjustment is anticipated, which pressures inflation, and ii) the investment/hiring decision is postponed, increasing unemployment due to uncertainty about the value of the worker to the hiring firm. Thus, to keep foreign capital productive and avoid the risk of default, the foreign government increases the interest rate, compensating the risk premium. Finally, the greater the degree of commercial interdependence, the greater the possible effects.

In what follows, as our interest is in EU countries' responses, in Figure 2, we present the eight EU nations in the sample[3]. The set of black FEVDS refers to the baseline model. The red FEVDS are associated with the lowest trade intensity and the blue FEVDS with the highest intensity. Furthermore, the light gray curves are shadow-shaped representations of all the other FEVDS exposed. The BGVAR's forecast error variance decomposition verifies the same patterns (see Figure 2). The percentage that a US uncertainty shock explains in the EU unemployment forecast error variance fluctuates from 0.5% to 2% for intense trade flows and 2% to 8% for low trade. This counterfactual exercise, which explores possible scenarios through the bilateral trade matrix, shows that spillover effects can drive stagflation cycles in the aggregate EU bloc and within the each individual economies.

Briefly, frictions in the labor market produce the traditional channel transmissions (demand and option-value, see Bernanke (1983) and Dixit and Pindyck (1994)), complementing the evidence of Leduc and Liu (2016), Feldkircher and Huber (2016), Trung (2019), and Bhattarai et al. (2020). Nevertheless, we find a new pattern: the spillover channel, which occurs through labor frictions and trade intensity. In uncertain scenarios, foreign players also postpone investments, increasing unemployment and pressing both prices and interest rates (after a year and a half) through trade and risk premium terms.

[3] FEVDS for other countries are available and can be requested.

Figure 2 – Forecast Error Variance Decomposition for EU Members (Unemployment)



Note: Generated by the author using Dynare-MatLab.

5 Conclusions

The main channel we have explored in this paper is that US uncertainty shocks can spill over to EU economies. Our DSGE and BGVAR models indicate that the transmission channel of a US uncertainty shock transmission channel to EU might occur through search frictions and trade pressure, leveraging a stagflation process. This differs from Feldkircher and Huber (2016), Trung (2019) and Bhattarai et al. (2020). Our analysis can be useful for policy-makers, as it stresses that even when labor market frictions differ, the uncertainty shocks are intensely transmitted to partners with lower trade intensities.

Appendix 1. The Model of Leduc and Liu (2016)

1 Households

The utility function (U) is given by

$$U = E \sum_{t=0}^{\infty} \beta^t [ln(C_t - hC_{t-1}) - \chi N_t] \tag{9}$$

where $E[.]$ denotes the expectations operator,β is the subjective discount factor, C_t is the aggregate consumption of households, h measures habit persistence, N_t is the fraction of household members employed in the model, and χ represent the disutility from working. In addition, households face a budget constraint.

$$C_t + \frac{B_t}{P_t R_t} + T_t = \frac{B_{t-1}}{P_t} + w_t N_t + \phi(1 - N_t) + d_t \tag{10}$$

B_t the risk-free bonds, R_t the nominal interest rate, w_t the real wage, ϕ the unemployment benefit paid by the government, d_t the profits from intermediary and retail goods firms owned by the household, and T_t is a lump-sum tax paid to the government.

In summary, income comes from salary, benefits paid to the unemployed population, private profits, and the gains from public bonds between two periods. On the other side of the equation, expenses sum the final consumption of households added to the amount of tax paid.

2 Labor Market

Following Andolfatto (1953), frictions in the labor market are represented by a function *matching*, in the Cobb-Douglas form. This function summarizes the negotiation technology between firms and individuals in the market:

$$m_t(v_t, u_t) = \mu u_t^{\zeta} v_t^{1-\zeta} \tag{11}$$

The number of new *matches* produced, m_t, depends on the number of workers looking for a new job,u_t, and the number of vacancies available in the labor market,v_t.Here, μ represent parameter of the global efficiency linked to labor market[4] and ζ the elasticity of *matching* in the function. The probability of filling a vacant position is $q_t^v = \frac{m_t}{v_t}$, and the likelihood of an individual finding employment is determined by $q_t^u = \frac{m_t}{u_t}$.

There are N_{t-1} workers, and at the end of each period, new *matches* of work occur, and a fraction of the pre-existing ones finish. There is a probability of job separation, ρ, which causes the employment in each period to be guided by a law of motion given by the stock of employees who remain in their jobs plus those generated by the new *matches*:

$$N_t = (1 - \rho)N_{t-1} + m_t \tag{12}$$

The unemployment rate can be considered as the portion of the population without a job after the hiring period ends at t; this rate is $U_t = u_t - m_t = 1 - N_t$.

[4] This parameter summarizes all the technology involved in the search and matching process in the job market, involving workers' networks, monitoring the primary communication vehicles, and even institutional differences in the job markets, which can drastically alter the match's ease.

3 Aggregation Sector

Given P_t as the price level of the domestic economy (affected by both domestic and foreign products) and α the degree of trade:

$$P_t = [(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta}]^{\frac{1}{1-\eta}} \tag{13}$$

where $P_{H,t}$, and $P_{F,t}$ are the prices of domestic and foreign intermediate goods. Defining the final consumer good, produced by a basket of retail goods, as Y_t and a specific retail good of type j such that $Y_t(j)$, $\forall\ j \in [0.1]$.

$$Y_t = \left(\int_0^1 Y_t(j)^{\frac{\eta-1}{\eta}} di\right)^{\frac{\eta}{\eta-1}} \tag{14}$$

where $\eta > 1$ is the elasticity of substitution between the differentiated products. The solution to the expenditure minimization problem implies that the demand for a retail good of type j is inversely related to the relative price $Y_t^d(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\eta} Y_t$. If $P_t(j)$ is the relative price of a retail good of type j, assuming perfect competition and zero profit in the aggregation sector, $P_t = \left(\int_0^1 P_t(i)^{\frac{1}{1-\eta}}\right)^{1-\eta}$.

4 Retail Goods Producers

The production function, for retail goods $j \in [0,1]$, is given by $Y_t(j) = X_t(j)$. The intermediate $X_t(j)$ represents the input that produces $Y_t(j)$. They are price takers in the input market and monopolistic competitors in the output one. Furthermore, there is a quadratic price adjustment cost $\frac{\Omega_p}{2}\left(\frac{P_t(j)}{\pi P_{t-1}(j)} - 1\right)^2 Y_t$. The parameter $\Omega_p \geqslant 0$ denotes the adjustment cost (given in units of aggregate production), and π denotes inflation in its steady state. The retail producer maximization problem is

$$max_{P_t(j)} E_t \sum_{i=0}^{\infty} \beta^i \frac{\Lambda_{t+i}}{\Lambda_t} \left[\left(\frac{P_{t+i}(j)}{P_{t+i}} - q_{t+i}\right) Y_{t+i}^d(j) - \frac{\Omega_p}{2}\left(\frac{P_{t+i}(j)}{\pi P_{t+i-1}(j)} - 1\right)^2 Y_{t+i}\right] \tag{15}$$

where q_t is the relative price of intermediate goods and Λ_t denotes the marginal utility of consumption.

5 Intermediate Goods Firms

The firm produces if it succeeds in hiring workers. The production function of firms producing intermediate goods is $X_t = Z_t N_t$. The Z_t technology shock follows the process

$$lnZ_t = \rho_z lnZ_{t-1} + \sigma_{z,t} e_{z,t} \tag{16}$$

where $\sigma_{z,t}$ is the time-varying standard deviation of the innovation. Then, uncertainty (following Leduc and Liu (2016)) takes the form:

$$ln\sigma_{z,t} = (1-\rho_z)ln\sigma_z + \rho_{\sigma_z} + ln\sigma_{z,t-1} + \sigma_{\sigma_z} e_{\sigma_{z,t}} \tag{17}$$

6 Firm and Work Value

The value of the firm that matches J_t^F is theoretically given by the following Bellman equation $J_t^F = (q_t Z_t - w_t) + E_t \frac{\beta \Lambda_{t+1}}{\Lambda_t}[(1-\rho)J_{t+1}^F + \rho V_{t+1}]$. Here the value of an open vacancy is $V_t = -\kappa + q_t^v J_t^F + E_t \frac{\beta \Lambda_{t+1}}{\Lambda_t}(1-q_t^v)V_{t+1}$. Free entry of firms implies that $V_t = 0$, so $\frac{\kappa}{q_t^v} = J_t^F$. This relation describes optimal job creation. That is, the expected cost of creating a new vacancy J_t^F is the cost of opening the vacancy κ multiplied by the expected duration of the unfilled vacancy $\frac{1}{q_t^v}$.

It follows that $J_t^W = w_t - \frac{\chi}{\Lambda_t} + E_t \frac{\beta \Lambda_{t+1}}{\Lambda_t}[(1-\rho(1-q_{t+1}^u))J_{t+1}^W + \rho(1-q_{t+1}^u))J_{t+1}^U]$ is the marginal value of an employed worker and $J_t^U = \phi + E_t \frac{\beta \Lambda_{t+1}}{\Lambda_t}[q_{t+1}^u J_{t+1}^W + (1-q_{t+1}^u)J_{t+1}^U]$ the value of an unemployed worker.

7 Nash Bargaining and Wage Rigidity

The optimal wage follows the maximization problem (see Hall and Milgrom (2008) and Gertler and Trigari (2009)):

$$w_t^N = max\{(J_t^W - J_t^U)^b (J_t^F)^{1-b}\} \tag{18}$$

The bargaining solution implies that $b_t J_t^F = (1-b_t)(J_t^W - J_t^U)$, where the aggregate labor supply is a weighted average of the individual supplies according to their shares in the workforce. The total offer is given by $[\overline{w_t} - \tilde{w}_t]$, where $\overline{w_t}$ is the maximum salary when $J_t^F = 0$ and $\tilde{w}_t$ is the minimum wage when $(J_t^W - J_t^U) = 0$.

$$J_t^F \frac{b}{(1-b)} = \left(w_t^N - \phi - \frac{\chi}{\Lambda_t}\right) + E_t \frac{\beta \Lambda_{t+1}}{\Lambda_t}\left[(1-\rho)(1-q_{t+1}^u)J_{t+1}^F \frac{b}{(1-b)}\right] \tag{19}$$

The negotiated salary is a weighted average of the reserve salaries $w_t^N = b_t \overline{w_t} + (1 - b_t)\tilde{w}_t$. Substituting $J_t^F = \frac{\kappa}{q_t^v}$ and the respective reserve salaries, we get

$$w_t^N = (1-b_t)\left[\phi + \frac{\chi}{\Lambda_t}\right] + b_t\left[q_t Z_t + \beta(1-\rho)E_t \frac{\beta \Lambda_{t+1}}{\Lambda_t} J_{t+1}^F\right] \tag{20}$$

In general, the equilibrium real wage may differ from the Nash bargaining solution. Hall and Milgrom (2008) points out that the rigidity of real wages is important for generating empirical volatilities in vacancies and unemployment in the models. Following this reference, we have

$$w_t = w_{t-1}^{\gamma}(w_t^N)^{1-\gamma} \tag{21}$$

where $\gamma \in (0,1)$ represents the degree of wage rigidity, the current wage as a weighting between the wage of the Nash bargain, executed by the workers, and the wage of the previous period.

8 Government Policy

The monetary policy rule is

$$R_t = R_{t-1}^{\gamma_r}\left(E_t\left[\frac{\pi_{t+h}}{\overline{\pi}_{t+h}}\right]^{\phi_\pi} \overline{\pi} \quad \overline{R}\left(\frac{Y_t}{Y}\right)^{\phi_y}\right)^{1-\gamma_r} \tag{22}$$

Here ϕ_π determines the monetary authority's reaction to deviations from the inflation target, ϕ_y the reaction to fluctuations in the output gap, γ_r is the weight given to the inertial component of inflation, and $\overline{R}$ the steady-state real interest rate. Furthermore, the government budget constraint balances for each period, and the benefits paid to the unemployed must equal the taxes collected by the government.

$$\phi(1 - N_t) = T_t \tag{23}$$

References

Andolfatto, D. (1953). “Business cycles and labor-market search”. *The American EconomicReview*, 86(1):112–132.

Backus, D. K. and Smith, G. W. (1993). “Consumption and real exchange rates in dynamic economies with non-traded goods”. *Journal of International Economics*, pages 297–31.

Baker, S. R., Bloom, N., and Davis, S. J. (2016). “Measuring Economic Policy Uncertainty*”. *The Quarterly Journal of Economics*, 131(4):1593–1636.

Bernanke, B. S. (1983). “Irreversibility, uncertainty, and cyclical investment”. *The Quarterly Journal of Economics*, 98(1):85–106.

Bhattarai, S., Chatterjee, A., and Park, W. Y. (2020). “Global spillover effects of US uncertainty”. *Journal of Monetary Economics*, 114:71–89.

Christoffel, K., Kuester, K., and Linzert, T. (2009). “ The role of labor markets for euro area monetary policy”. *European Economic Review*, 53(8):908–936.

Chudik, A. and Pesaran, M. H. (2016). “ Theory and practice of GVAR modelling”. *Journal of Economic Surveys*, 30(1):165–197.

Cuaresma, J. C., Feldkircher, M., and Huber, F. (2016). “Forecasting with global vector autoregressive models: A Bayesian approach”. *Journal of Applied Econometrics*, 31(7):1371–1391.

Dees, S., Mauro, F. d., Pesaran, M. H., and Smith, L. V. (2007). “Exploring the international linkages of the euro area: A global VAR analysis”. *Journal of Applied Econometrics*, 22(1):1–38.

Dixit, A. and Pindyck, R. (1994). *Investment under Uncertainty*. Princeton University Press.

Dées, S., Pesaran, M., Smith, L., and Smith, R. (2014). “Constructing multi-country rational expectations models”. *Oxford Bulletin of Economics and Statistics*, pages 812–840.

Feldkircher, M. and Huber, F. (2016). “The international transmission of US shocks—Evidence from Bayesian global vector autoregressions”. *European Economic Review*, 81:167–188.

Galí, J. and Monacelli, T. (2005). “Monetary policy and exchange rate volatility in a small open economy”. *The Review of Economic Studies*, 72(3):707–734.

George, E. I., Sun, D., and Ni, S. (2008). “Bayesian stochastic search for VAR model restrictions”. *Journal of Econometrics*, 142(1):553–580.

Gertler, M. and Trigari, A. (2009). “Unemployment fluctuations with staggered Nash wage bargaining”. *Journal of Political Economy*, 117(1):38–86.

Hall, R. E. and Milgrom, P. R. (2008). “The limited influence of unemployment on the wage bargain”. *American Economic Review*, 98(4):1653–74.

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

Litterman, R. B. (1986). “ Forecasting with Bayesian vector autoregressions—Five years of experience”. *Journal of Business & Economic Statistics*, 4(1):25–38. DOI:10.1080/07350015.1986.10509491.

NetSunajev, A. and Glass, K. (2017). “Uncertainty and employment dynamics in the euro area and the US”. *Journal of Macroeconomics*, 51:48–62.

Obstfeld, M. and Rogoff, K. (2000). “The six major puzzles in international macroeconomics: Is there a common cause?” *NBER Macroeconomics Annual*, pages 339–390.

Pesaran, M. H., Schuermann, T., and Weiner, S. M. (2004). “Modeling regional interdependencies using a global error-correcting macroeconometric model”. *Journal of Business & Economic Statistics*, 22(2):129–162.

Trung, N. B. (2019). “The spillover effects of US economic policy uncertainty on the global economy: A global VAR approach”. *The North American Journal of Economics and Finance*, 48:90–110.