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The Impact of Foreign Shocks on the Polish Economy¹

Abstract: This study concerns the impact of foreign shocks on the Polish economy. We consider output shocks from China, the euro area, and the United States. We estimate structural vector autoregressive (SVAR) models with the level of foreign economic activity as an endogenous variable and foreign output shock as an exogenous variable. We identify foreign output shocks outside the model. Our results indicate that a euro-area output shock has the strongest effect on the Polish economy. Meanwhile, the spillover effects from China are similar for Poland and the euro area.

Keywords: spillover effects, SVAR model, Polish economy

JEL codes: C32, E32, F10, O50

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Wpływ szoków zagranicznych na polską gospodarkę

Streszczenie: W artykule zanalizowano wpływ szoków zagranicznych na polską gospodarkę – szoków popytowych pochodzących z Chin, strefy euro i Stanów Zjednoczonych. Estymowano strukturalny model wektorowej autoregresji (SVAR) z miarą aktywności gospodarczej za granicą jako zmienną endogeniczną i zagranicznym szokiem popytowym jako zmienną egzogeniczną. Szoki zagraniczne identyfikowane są na zewnątrz modelu. Otrzymane wyniki wskazują, że szok popytowy ze strefy euro najsilniej oddziałuje na polską

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gospodarkę. Natomiast szok popytowy z Chin podobnie oddziałuje na gospodarkę polską i gospodarkę strefy euro.

Słowa kluczowe: efekty spillover, model SVAR, polska gospodarka

Kody klasyfikacji JEL: C32, E32, F10, O50

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Introduction

The size and significance of global interconnections and spillovers have been increasing. What happens elsewhere in the world matters for the domestic economy. The volume of world trade, for instance, has increased tenfold since 1980 (see Figure 6 in the Appendix). When analysing the domestic economy, we should take into account the economic situation abroad.

In this study, we estimate a structural vector autoregressive (SVAR) model for the Polish economy. An interesting research problem is determining how external shocks can be included in such a model. We include foreign demand shocks as an exogenous variable in the SVAR model. The aim of the study is to find out the impact of foreign shocks on the basic macroeconomic characteristics of the domestic economy, such as the level of domestic demand, the level of exports and imports, the level of prices, the interest rate, and the exchange rate. Moreover, we check whether including the level of foreign economic activity changes the identified effects of monetary policy.

In the study, we consider for example the effects of China demand shocks. The spillover effects from the Chinese economy are frequently estimated using GVAR (global vector autoregressive models) models (cf. Sznajderska 2019, and Sznajderska and Kapuściński 2020). Here we present a simpler SVAR model for Poland and separately, for comparison, for the euro area. It is an alternative way to measure spillover effects between countries. We provide a detailed critique of GVAR models in the methodology section.

China's enormous role in the global economy is beyond dispute. In 1979, China began a series of reforms combined with opening up its economy. By 2018 the country's share in global GDP had increased to 18.75%, from 2.3% in 1980. In July 2001, China joined the World Trade Organisation (WTO), leading to the dynamic development of trade from and to China. The Chinese economy began to grow rapidly, and many trade barriers were removed. This allowed for an increase in the level of sales of consumer and investment goods to China. China is one of the world's most important economies. Since 2005 the contribution of China to the global GDP growth rate is about 1 pp, which is one-third of global GDP growth [Dieppe et al., 2018]. China is also a major importer and producer of many commodities. It recently embarked on a shift from an export- and investment-driven economy to a consumption-driven economy. The transformation of the economy has led to slower but more stable

economic growth. It is interesting to study the impact of the Chinese economy on other economies, in particular in terms of how it has changed over time.

The structure of the paper is the following. In the first section, we describe trade and financial linkages between Poland and China and between the euro area and China. In the second section, we describe selected studies on spillover effects from China to the euro area and to Poland. In the third section we describe the methodology of the research. First, we provide a critique of GVAR models; second, we discuss the identification of foreign demand shocks; and third, we discuss the way spillover effects are estimated in SVAR models. The fourth section describes the data. The fifth section presents the results of the estimated SVAR models. We describe dynamic multipliers that show the reaction of endogenous variables to foreign exogenous shocks. The last section concludes.

China's linkages with the euro area and Poland

Both trade and financial linkages between the euro area and China are stronger than those between Poland and China. Moreover, it seems that the impact of the Chinese economy on the euro-area economy should increase in the coming years due to growing financial linkages and a trade war between China and the United States. Bolt, Mavromatis and Wijnbergen [2019] use a general equilibrium model (ECB EAGLE) to assess the impact of the trade war between China and the United States on the euro area. In the wake of the introduction of tariffs, economic growth and investment decelerated significantly in both China and the United States. Meanwhile, exports from the euro area to the United States have increased, as have imports from China to the euro area, accompanied by faster economic growth and a higher level of investment in the euro area. As a consequence of an appreciating effective exchange rate in the euro area, the level of consumption has increased. Meanwhile, the euro area has seen increased employment levels, unlike China and the United States.

Trade openness in Poland is lower than in the euro area [Chmielewski et al., 2018]. In 2016, international trade in Poland was equivalent to 68.2% of GDP, whereas in the euro area it was 100.7% of GDP.

China is an important trading partner for both the euro area and Poland. Below we compare the volumes of exports and imports between Poland and the euro area and those between Poland and China. China accounts for 4% of total euro-area exports and for 1% of Poland's exports in volume terms (see Figure 7 in the Appendix). It has a 7% share in total euro-area imports, and an 8% share in Poland's imports.

If we take into account data on value added in trade, including indirect exports (notably intermediate goods, which are exported to another trading partner but are ultimately consumed in China), China's role in trade is even greater. The country accounts for 8.5% of total euro-area exports and for 2% of Poland's exports (OECD TiVA data).

Direct exports from the euro area to China in 2014 were estimated at around 1.2% of the euro area's GDP, while indirect exports were estimated at around 0.4% of euro-area GDP [Dieppe et al., 2018]. Indirect exports are exports of production inputs to other countries, such as South Korea, Taiwan, the United Kingdom, the United States, Japan and Switzerland. Production inputs are used to produce goods that are ultimately consumed in China.

Although Poland has limited trade and financial linkages with China, the impact of the Chinese economy on the Polish economy may be significant due to various indirect linkages. For example, an economic slowdown in China may weaken economic growth in the euro area, and consequently affect growth in Poland.²

China is a key player on international commodity markets. Mwase et al. [2016] show that the more an economy depends on commodity markets, the more strongly its stock exchange reacts to changes on the Chinese bourse. The reaction of the Polish stock exchange seems to be moderate.

China's financial linkages with the rest of the world are much weaker than its trade linkages. This is largely because the authorities control capital flows from and to China. Despite restrictions imposed by the state, China's financial linkages with the rest of the world are not negligible [Mwase et al., 2016]. Dieppe et al. [2018] calculate that China and Hong Kong together accounted for around 8% of global gross asset and liability positions in 2015. The authors also point out that China and Hong Kong account for a very small share of the euro area's overall financial integration with global financial markets. At the end of 2016, China and Hong Kong accounted for 2.7% of the euro area's extra-euro area banking claims and for around 1% of total euro-area banking claims when intra-euro area claims are included.

Spillover effects from China to the euro area and Poland

In this section, we describe the literature on spillover effects from China to the euro area and Poland.

Dieppe et al. [2018] use five different advanced econometric models to estimate the impact of a slowdown in the Chinese economy on other economies. One simulation shows the spillover effects from a 3% cumulative decline in Chinese GDP over three years. On average, the euro area response is low and amounts to a maximum of 0.3% of GDP over three years, according to structural models. The results from the GVAR model indicate a response that is twice as strong. Dieppe et al. report that this is due to the fact that structural models assume that China's monetary policy does not change and the exchange rate is set against the dollar. On the other hand, in the GVAR

² Poland has strong trade and financial linkages with the euro area. Germany is Poland's main trading partner. In 2018, it accounted for 27.5% of Poland's total exports and for 22.6% of its imports.

model, both the interest rate and the exchange rate are endogenous variables. As a result of the economic slowdown in the GVAR model, the exchange rate depreciates and advanced economies lose price competitiveness in relation to China. This causes a stronger output loss in these economies.

Dieppe et al. [2018] emphasise that the impact of an economic slowdown in China on the rest of the world depends on the assumptions made in the model. For example, the authors analyse various sources of economic slowdown, such as falling domestic demand in China and tighter financial conditions in China, leading to an increased global risk premium. The second source of shock leads to much greater spillovers effects. The authors also analyse a model with a greater oil price response (i.e., a stronger fall in oil prices). In the model, the reaction of oil importing countries is weaker (pillow effect), while the reaction of oil producing countries is stronger.

The authors also check what would happen if the financial exposure of the euro area changed in China's favour. They increase the share of euro-area assets in China fivefold while reducing the share of these assets for the rest of the world. In such a scenario, the fall in real GDP in the euro area is twice as strong. Considering all possible scenarios, and thus additional simulations, it turns out that GDP in the euro area could fall by a maximum of 1.1% in response to a cumulative 3.3% drop in China's GDP over a three-year period.

Sznajderska [2019] and Sznajderska and Kapuściński [2020] apply the GVAR model to estimate the impact of a slowdown in the Chinese economy on other economies. The GVAR model allows for changes in domestic GDP, the price level, the stock market index, the exchange rate and the interest rate after a Chinese GDP shock. The results show that an unexpected 1% decrease in Chinese GDP leads to a 0.12% decrease in the euro area's GDP after five quarters and to a statistically insignificant reaction by Polish GDP. The result for the euro area is similar to that obtained by Dieppe et al. [2018] for the structural models.

Blaggrave and Vesperoni [2016 and 2018] come up with similar results. They estimate a panel VAR model with Chinese GDP shocks as exogenous variables. These are identified outside the model. The authors analyse output shocks from secondary and tertiary sectors separately. The former have a stronger impact on China's trading partners than the latter.

According to their results, a 1% increase in Chinese domestic demand leads to a 0.4% increase in exports in Germany and less than a 0.1% increase in exports in Poland. The authors show that a Chinese GDP shock has stronger effects for advanced economies (the euro area) than for Central and Eastern Europe, including Poland.

Furceri, Jalles and Zdzienicka [2016] analyse time-varying spillover effects from China. They examine 148 economies from 1990 to 2014. The results show that a negative 1% output shock in China leads to a decline in economic growth in other economies by around 0.06% one year after the shock. If we limit the sample to recent years, the effect is greater and amounts to approximately

0.25%. The spillover effects are larger for countries neighbouring China, for economies with low incomes, and for emerging economies. The authors also point out that larger spillover effects appear for commodity exporters and industrial input exporters. These effects are greater during periods of greater uncertainty. Similarly, Mwase et al. [2016] report the greatest impact of spillover effects on Asian countries, especially commodity exporters and emerging economies with weaker fundamentals.

Methodology

The critique of GVAR models

In this study, we estimate an SVAR model with foreign shocks identified outside the model. We do so to measure the spillover effects between countries. We do not use the GVAR model, which is a standard tool here [Bussière et al., 2012, Dieppe et al., 2018, and Sznajderska and Kapuściński, 2020]. Below we present the arguments against using GVAR models.

The GVAR model usually contains more than 60 economies. Also, for each economy, it includes at least four variables. This means that we need to estimate at least $60 * 4 = 240$ equations. Such a large number makes it difficult to control for the quality of all these data and also for a proper specification of each equation.

Because the GVAR model is so big, it is not possible to estimate the standard structural impulse response functions. We cannot apply the standard Cholesky decomposition. Usually the generalised impulse response functions (GIRFs) are calculated. GIRFs do not depend on the ordering of the variables. GIRFs show how changes in one variable (for instance China's GDP) affect other variables in the GVAR over time regardless of the source of the change. We do not know whether such a shock stems from a shift in the demand or supply of output in China or other countries.

Moreover, it is difficult to obtain a stable GVAR model, meaning convergent persistent profiles, eigenvalues lying in the unit circle, and non-explosive GIRFs. Researchers usually quietly change (most commonly decrease) the number of cointegrating relations for specific countries to obtain a stable model. Researchers also try to increase the lag order of domestic and/or foreign variables. Moreover, they change the specification of the model, meaning that they include or leave out certain foreign variables for a particular country, only to get a stable model. However, such an approach is highly questionable. Researchers sometimes make these changes to get a stable model and not because of econometric theory or because of their economic knowledge.

It is also difficult to obtain a sound GVAR model specification that delivers sensible impulse responses and other output in line with what one would expect from economic theory. Not to repeat the common procedures from the previous paragraph, we cite Ronald Coase: "If you torture the data long enough, it will confess to anything."

Identification of China GDP shock

Identifying the foreign demand shock is an important research problem. In this study, we are mostly interested in analysing the impact of China's demand shock on the Polish economy. For comparison, we additionally consider demand shocks from the euro area and the United States. Below we present the methodology for identifying the China demand shock. An analogous procedure was followed for identifying shocks originating in the euro area and in the United States.

There are different methods that may be used to identify a foreign demand shock. In the IMF research papers by Furceri, Jalles and Zdzienicka [2016] and Blagrove and Vesperoni [2018], the China output shock is approximated as the deviation from a regression of the GDP growth rate in China [on] the global GDP growth rate excluding China. The first method is based on the following regression model:

$$\Delta y_t = \alpha + \beta \Delta Y_t^{global} + \varepsilon_t \quad (1)$$

where Δy_t is seasonally adjusted quarterly growth of GDP in China, ΔY_t^{global} is global growth at market exchange rates, excluding China. We calculate global growth as a weighted average of the real GDP growth of economies included in the study with weights equal to the share of the nominal GDP of these economies in global GDP.

Blagrove and Vesperoni [2018] estimate a structural VAR model with global GDP growth as the first variable and Chinese GDP growth as the second variable for a robustness check. Shocks from such a specification and those obtained from equation (1) are highly correlated (correlation coefficient equal to 0.9).

The next two methods are based on SVAR models for China. The two methods differ depending on the way the level of foreign economic activity is included in the model. In the second method, the level of foreign economic activity is included as the first variable. Then the restrictions are added so that the domestic variables do not affect the level of foreign output. In the third method, we add the level of foreign economic activity as an exogenous variable. If the level of Chinese GDP is the first variable in the Cholesky decomposition than the structural shock is equal to the vector of errors from the first equation. In this method, the following SVAR model is estimated:

$$\mathbf{Y}_t = \mathbf{c} + \sum_{p=1}^P \mathbf{A}_p \mathbf{Y}_{t-p} + \mathbf{B} \boldsymbol{\varphi}_t + \boldsymbol{\mu}_t$$

where \mathbf{Y}_t is the vector of domestic variables, $\boldsymbol{\varphi}_t$ is the level of foreign economic activity, $\boldsymbol{\mu}_t$ is the vector of errors. The structural shocks are linear combination of $\boldsymbol{\mu}_t$. In this study we use the following vector of domestic variables:

$$\mathbf{Y}_t = \{GDP_t, price_t, rate_t, REER_t\},$$

GDP is the level of real GDP, *price* is the level of prices, *rate* is the level of short-term interest rate, *REER* is the real effective exchange rate. We use the weighted average of the real GDP levels in other economies as the level of foreign economic activity, where the weights are equal to the value-in-trade of these economies with China (or the euro area or the United States for the models that identify the shocks for those economies).

We estimated the China GDP shock using the three above methods. We decided to use the shock obtained from the third method. The shocks identified using the second and third methods were highly correlated, with the correlation coefficient equal to 0.9.

Estimation of China spillover effects

We estimated an SVAR model for Poland with the foreign shock as an exogenous variable to approximate the impact of foreign shocks on domestic variables. We estimated a similar SVAR model for the euro area for comparison purposes. Next the respective response functions were calculated as so-called dynamic multipliers. Dynamic multipliers show the reaction over time of endogenous variables to a one-unit increase in the exogenous variable.

The following VAR model was estimated:

$$\mathbf{Y}_t = \mathbf{m} + \sum_{p=1}^P \mathbf{L}_p \mathbf{Y}_{t-p} + \mathbf{K} \boldsymbol{\vartheta}_t + \boldsymbol{\epsilon}_t \quad (2)$$

where

$$\mathbf{Y}_t = \{foreign_t, domestic\ demand_t, export_t, import_t, price_t, rate_t, REER_t\},$$

Thus, the following endogenous variables are included in the model: the level of foreign GDP (*foreign_t*), the level of domestic demand (*domestic demand_t*), the level of exports (*export_t*), the level of imports (*import_t*), the price level (*price_t*), the level of interest rate (*rate_t*), the level of real effective exchange rate (*REER_t*). $\boldsymbol{\vartheta}_t$ is the foreign output shock identified outside the model (see the previous section).

The level of foreign GDP (*foreign_t*) was calculated as weighted average of the real GDP levels in other economies (*GDP_i* for *i*th economy). The weights were equal to the value-in-trade with Poland (or the euro area in model for the euro area). Importantly, we use time-varying weights (ω_{ti}). The level of foreign GDP does not include the *k*th economy for which the foreign shock is examined (which is China or the euro area or the United States). The procedure is similar to that used in Blagrove and Vesperi (2018):

$$foreign_t = \sum_{i=1}^{41} \omega_{ti} GDP_i - \omega_{tk} GDP_k$$

We impose restrictions on the coefficients in the model so that the domestic variables do not influence the level of foreign activity. This means, for exam-

ple, that the domestic variables in Poland, such as the level of GDP, the level of prices and so on, have no effect on the level of Chinese GDP).

The following zero restrictions are put on \mathbf{L}_p matrix:

$$\mathbf{L}_p = \begin{bmatrix} & 0 & 0 & 0 & 0 & 0 & 0 \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \end{bmatrix} \quad \text{for each } p.$$

We use the Cholesky decomposition to identify the impulse response functions for monetary policy shocks. The reactions to a one-unit foreign demand shock are calculated as dynamic multipliers.

Data

We use quarterly data from Q1 1996 to Q2 2019. It is not possible to extend the sample before Q1 1996 due to limited data availability for Poland.

In the basic SVAR model, we use the following variables: the level of domestic demand (i.e. consumption plus investment), the level of exports, the level of imports, the level of prices, the level of the short-term interest rate, the level of the real effective exchange rate (REER), and the level of foreign economic activity. In the case of the models used to identify the foreign GDP shock, we also use the levels of real and nominal GDP for the economies included in the study (see Table 1).

The levels of GDP and GDP components are seasonally adjusted and logarithmised. The source of these data is Eurostat.

The price index is chosen as the variable that is mainly monitored by the central bank. These are the CPI index for Poland, the HICP index for the euro area, and the PCE index for the United States.

The interest rate is the short-term interest rate. We considered both the one-month and three-month money market rates for Poland. In the case of the latter, the price puzzle appeared in the model. We therefore decided to use the one-month money market rate for Poland. The source of this rate is IMF IFS. In the case of the United States and the euro area, we use shadow rates that include nonstandard monetary policy measures (such as quantitative easing) and allow for negative rates. We decided to use the shadow rates calculated by L. Krippner. Krippner [2017] shows that his calculations are better than those obtained on the basis of Wu and Xia [2016].

The REER and the weights in trade are from the BIS statistics. The REER is in logarithms. We used also the weights in trade calculated using trade in value added values from the TiVA OECD database. These weights were cal-

culated as the sum of “Forward participation in GVCs: Domestic value added in foreign exports as a share of gross exports, by foreign exporting country” and “Backward participation in GVCs: Foreign value added share of gross exports, by value added origin country.” We used time-varying weights if only the data were available. In the case of BIS statistics, the data change every three years, and in the case of the TiVA OECD statistics the data change each year starting from 2005.

Table 1. Countries included in the study as foreign economies

1	Algeria	15	Hong Kong SAR	29	Poland
2	Argentina	16	Hungary	30	Romania
3	Australia	17	Iceland	31	Russia
4	Brazil	18	India	32	Saudi Arabia
5	Bulgaria	19	Indonesia	33	Singapore
6	Canada	20	Israel	34	South Africa
7	Chile	21	Japan	35	Sweden
8	China	22	South Korea	36	Switzerland
9	Chinese Taipei	23	Malaysia	37	Thailand
10	Colombia	24	Mexico	38	Turkey
11	Croatia	25	New Zealand	39	United Arab Emirates
12	Czech Republic	26	Norway	40	United Kingdom
13	Denmark	27	Peru	41	United States
14	Euro area	28	Philippines		

Source: author's own elaboration.

Next we describe how the level of foreign economic activity was calculated. We created a dataset for 59 economies (40 + 18 economies of the euro area), of which the euro area was included as one economy (see Table 1). We gathered data on the level of nominal GDP, the level of real GDP, and the exchange rate to the US dollar. The source of these data is IMF IFS. If data were not available there, we used IMF WEO, OECD databases and national sources. We decided to use the level of real GDP for China from the Macrobond database, because these data were more consistent with the data from the Chinese Statistical Office than those from IMF IFS. We used seasonally adjusted and logarithmised data on all the GDP measures.

The global real GDP growth rate was calculated as the weighted average of real GDP growth rates in 41 analysed economies. The weights were equal to the share of nominal GDP in dollars in a particular economy in the level of global nominal GDP in dollars.

The foreign real GDP growth rate for Poland (or any other economy) was calculated as the weighted average of real GDP growth rates in 40 other economies. The weights were equal to the share of trade with Poland in total trade, which was calculated using data from BIS or TiVA OECD statistics.

Table 2 shows the data sources and the names of all the variables used in the description of our results.

Table 2. Data sources

Name of time series		Description	Source
c_i_poland		domestic demand: consumption + investment	Eurostat
c_i_euro_area			Eurostat
exports_poland		exports	Eurostat
exports_euro_area			Eurostat
imports_poland		imports	Eurostat
imports_euro_area			Eurostat
cpi_poland		consumer price index	BIS
cpi_euro_area			BIS
hicp_poland		harmonised index of consumer prices	Eurostat
hicp_euro_area			Eurostat
pce_us		personal consumption expenditures	FRED
interest_rate_poland		short-term interest rate	IMF IFS
interest_rate_euro_area			Eurostat
shadow_rate_euro_area, shadow_rate_us		shadow rate	Leo Krippner (Reserve Bank of New Zealand)
reer_poland		real effective exchange rate	BIS
reer_euro_area, reer_us			BIS
rgdp_global for 41 economies (euro area as one)	rgdp	real GDP	IMF IFS, IMF WEO, Macrobond for China
	ngdp	nominal GDP	IMF IFS, IMF WEO
	exchange_rate	nominal exchange rate	IMF IFS, Eurostat
weights in trade			BIS effective exchange rates
			TIVA OECD

Source: author's own elaboration.

Results

This section presents the results of estimating our baseline model (var_PL_china) and the three additional models. These are three models for Poland and one for the euro area. We take the following notation:

- var_PL_china – is the SVAR model for Poland with the level of foreign economic activity excluding China as an endogenous variable and with the China demand shock as an exogenous variable;
- var_PL_ea – is the SVAR model for Poland with the level of foreign economic activity excluding the euro area as an endogenous variable and with the euro area demand shock as an exogenous variable;

- var_PL_us – is the SVAR model for Poland with the level of foreign economic activity excluding the United States as an endogenous variable and with the United States demand shock as an exogenous variable;
- var_EA_china – is the SVAR model for the euro area with the level of foreign economic activity excluding the euro area as an endogenous variable and with the China demand shock as an exogenous variable;

In accordance with the Hannan-Quinn information criterion, we use two lags in all four models.

In our baseline SVAR model (var_PL_china), we test the impact of two impulses. First, we analyse the impulse response functions of domestic variables in the case of a foreign output shock. Second, we analyse the impulse response functions for a monetary policy shock, namely the response to a domestic short-term interest rate shock. This analysis enables us to assess whether the monetary transmission mechanism in Poland works in accordance with economic theory and the results of other studies. The baseline model is stable, meaning that all the eigenvalues lie inside the unit circle.

Below we present the respective impulse response functions and dynamic multipliers with 68% confidence bands. Figure 1 shows the response of domestic variables to an interest rate shock for var_PL_china model. In the beginning (at point zero), the shock is equal to one standard deviation of the error vector from the interest rate equation, i.e. about 0.6 (see Figure 1E).

An unexpected interest rate increase, interpreted as a tightening of monetary policy in Poland, leads to an immediate appreciation of the domestic currency.³ The higher interest rate is linked with greater profitability of financial assets and attracts foreign investors. As a consequence of the appreciation of the domestic currency, we may observe a short-term increase in imports, and thus also an increase in exports.

After the interest rate shock, the level of domestic demand decreases, with the strongest decrease equal to 0.166% in the 6th quarter (see Figure 1A). Also, the CPI decreases, with the strongest decrease (0.172%) in the 9th quarter after the shock (see Figure 1B). The levels of imports and exports decrease as well, with the strongest reaction for imports in the 8th quarter (0.233%) and the strongest reaction for exports in the 9th quarter (see Figure 1C and 1D).

The reaction of the level of foreign economic activity to an interest rate shock in Poland is equal to zero and statistically insignificant (see Figure 1G).

The obtained impulse response functions for a monetary policy impulse in Poland are in accordance with economic theory on monetary transmission mechanisms and in accordance with the results of other studies (see Chmielewski *et al.* 2018, Leszczyńska-Paczesna 2020, Kolasa 2009). Similar results were obtained for var_PL_ea and var_PL_us models, and thus we do not discuss them separately.

³ In our study, an increase in REER means an appreciation of the domestic currency.

In the next step, we analyse so-called dynamic multipliers to see the impact of foreign shocks on the Polish economy. Figure 2 is based on the results of estimating the `var_PL_china` model and shows the response of domestic variables to China output shocks. An unexpected output shock in China causes an increase in the level of foreign output in Poland (see Figure 2G). The exchange rate (REER) appreciates, which seems to be linked with an improvement in the global economic situation. The economic improvement is connected with lower risk aversion. Colacito, Riddiough and Sarno (2019) argue that the relative strength of the business cycle affects currency returns.

As a result of a China output shock, the levels of imports and exports in Poland increase, as do the levels of domestic demand and prices (see Figure 2). The reaction of domestic demand is the strongest in the 17th quarter (about 0.6%) and the reaction of prices is the strongest in the 33rd quarter (about 0.3%). The prices increase as a result of increased domestic demand.

Next, for comparison purposes, we present the results of estimating the `var_PL_ea`, `var_PL_us` and `var_EA_china` models. Figure 3 presents the results of estimating the `var_PL_ea` model. The direction of reactions of the variables is the same as in the previous model (`var_PL_china`). Importantly, one may observe a much stronger reaction of domestic variables – such as the level of domestic output, the level of CPI, the level of exports and imports, and the exchange rate – to a euro-area output shock than to a China output shock. The reaction of domestic demand is the strongest in the 13th quarter (about 1.8%), while the reaction of prices is the strongest in the 25th quarter (about 1.03%). Also, the reaction of foreign output in Poland to a euro-area output shock is much stronger than in the case of a China output shock. In both models, the reaction of the interest rate to a foreign demand shock is statistically insignificant.

Next we estimate the SVAR model for Poland with a foreign output shock from the United States. Figure 4 shows the dynamic multipliers for the `VAR_PL_us` model. Also, the direction of changes in the variables after the foreign demand shock is similar to those in the previous two models. We observe an increase in the level of domestic demand, the price index, and exports and imports. The exchange rate appreciates and the level of foreign demand increases. The strength of the reaction of the Polish economy is slightly stronger than in the `var_PL_china` model and weaker than in the `var_PL_ea` model. The reaction of domestic demand is the strongest in the 19th quarter (about 0.9%), and the reaction of prices is the strongest in the 39th quarter (about 0.4%).

In order to compare the reactions of the Polish economy and the euro area to a foreign demand shock, we estimated an analogous SVAR model for the euro area. The results of estimating the `var_EA_china` model show that an increase in the shadow interest rate in the euro area leads to a decrease in domestic demand, a statistically insignificant reaction of imports and exports, and an initial increase and a subsequent decrease of HICP. Thus, there appears a price puzzle.

On the other hand, the reactions to a China demand shock are similar as in the model for Poland (var_PL_china). Figure 5 shows that after a China demand shock the level of domestic demand in the euro area increases, and so do the levels of imports and exports. The level of prices increases, the exchange rate appreciates, and the level of foreign demand rises. Also, in this model we observe an increase in the interest rate. The strength of these reactions is similar to that in the model for Poland. The reactions of imports and exports seem to be even greater for the Polish economy, but if we take into account the confidence bands we may conclude that the reactions are identical. This result is different than in Blagrove and Vesperoni [2016] or Sznajderska [2019] and Sznajderska and Kapuściński [2020], where the authors report a stronger impact of a China demand shock on the euro area than on the Polish economy.

Conclusions

In this study, we measure spillover effects for the Polish economy using SVAR models with a foreign demand shock identified outside the model. This method is alternative to GVAR models measuring spillover effects between countries. In the manuscript, we provide a detailed critique of the GVAR methodology.

We estimate three models for Poland, the first with a foreign output shock from China, the second with a foreign output shock from the euro area, and the third with a foreign output shock from the United States. We also estimate a model for the euro area with a foreign output shock from China.

We use the following endogenous variables in our models: the level of foreign economic activity, the level of domestic demand, the level of exports, the level of imports, the level of prices, the level of the interest rate, and the level of the exchange rate. We use the foreign output shock as an exogenous variable. The effect of a foreign demand shock on the domestic variables is measured using dynamic multipliers.

The model for the Polish economy with the level of foreign economic activity and the output shock from China is stable and the obtained reactions are in accordance with economic theory and the results of other research [Chmielewski et al., 2018].

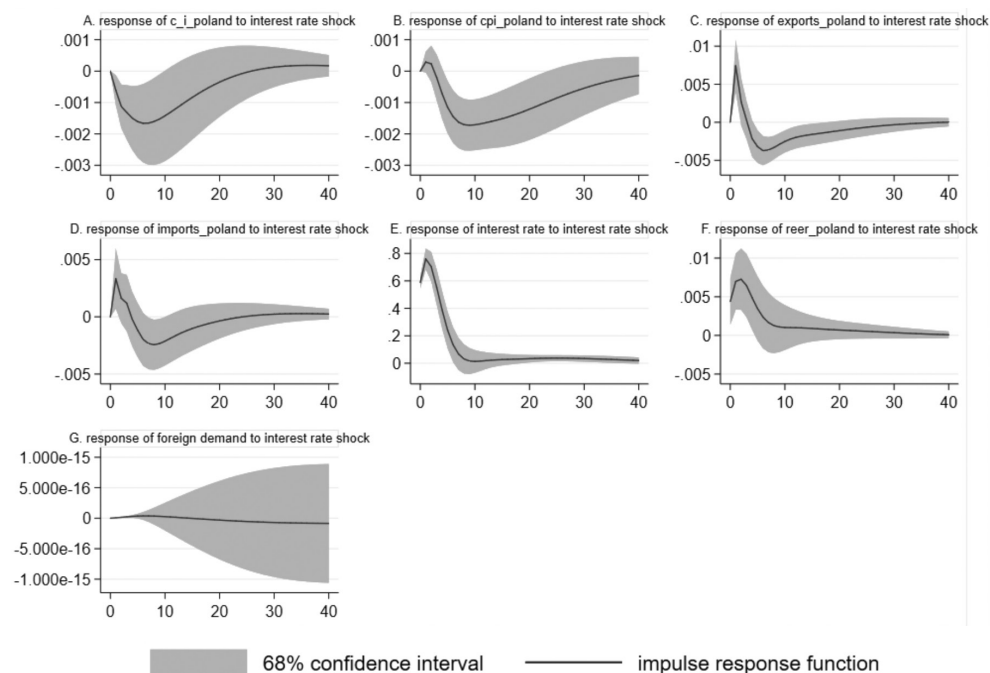
An unexpected increase in the level of GDP in China causes an increase in foreign output for Poland. The exchange rate (REER) appreciates, which seems to be due to a better global economic situation and lower risk aversion. After the positive China impulse, the levels of exports and imports increase, as do the levels of domestic demand and prices.

After an unexpected increase in the level of GDP in the euro area as well as in the United States, the direction of change in the variables in the SVAR model is the same. But the strength of the reaction is different. The Polish economy reacts most strongly to an economic impulse from the euro area. This is not surprising because there are strong trade and financial linkages

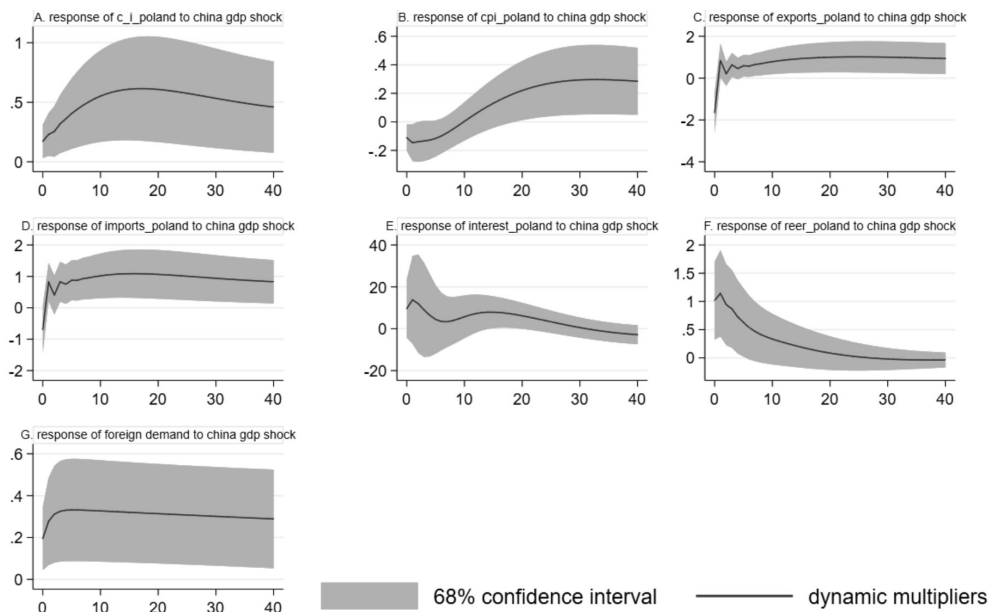
between the Polish economy and the euro-area economy. The strength of reaction of the Polish economy to an impulse from the United States is a little stronger than for an impulse from China and weaker than in the case of an impulse from the euro area.

Lastly, we estimate an analogous SVAR model for the euro area for comparison purposes. It turns out that the strength of reaction of Poland and the euro area to a foreign output shock from China is similar. One could expect a stronger reaction of the euro area because of its stronger trade and financial linkages with China [Sznajderska and Kapuściński, 2020 and Sznajderska, 2019]. The impulse from China, however, may have greater indirect effects on the Polish economy, for example through the euro area.

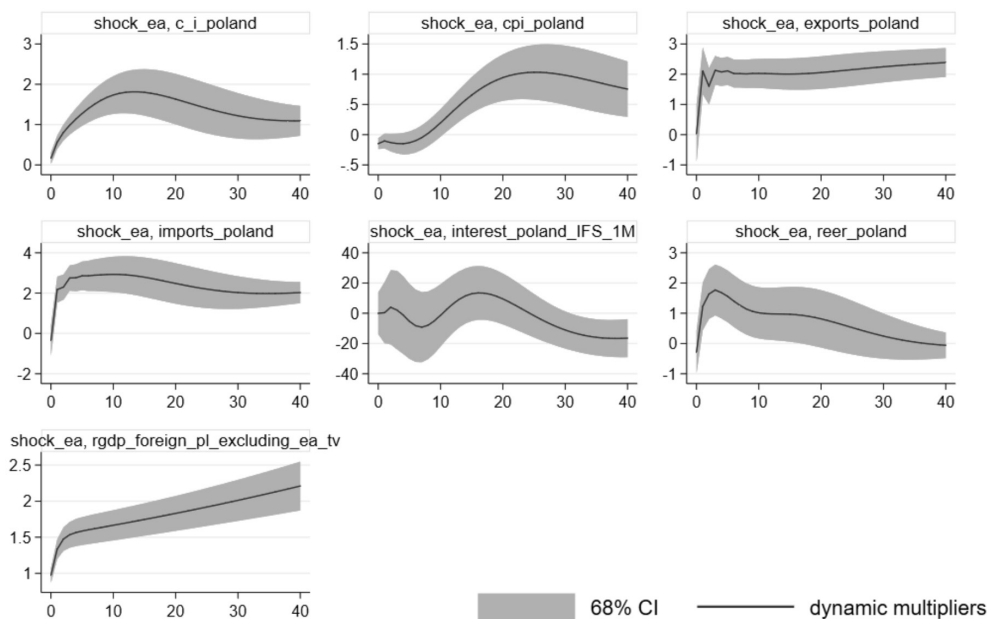
Figure 1. Impulse response functions to interest rate shock, var_PL_china model



Source: own calculations.

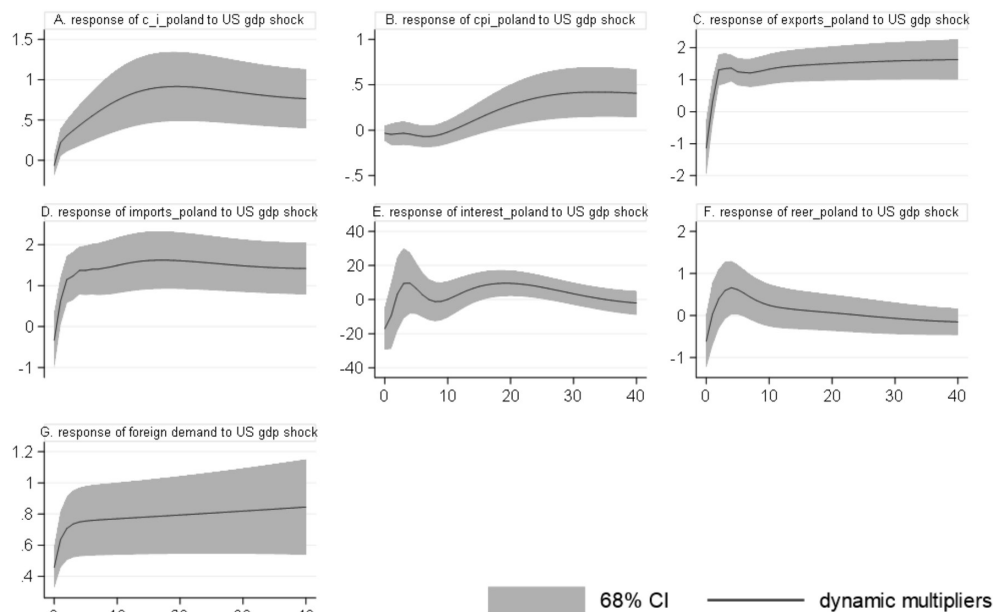
Figure 2. Dynamic multipliers to China demand shock (exogenous variable), var_PL_china model

Source: own calculations.

Figure 3. Dynamic multipliers to euro-area demand shock (exogenous variable), var_PL_ea model

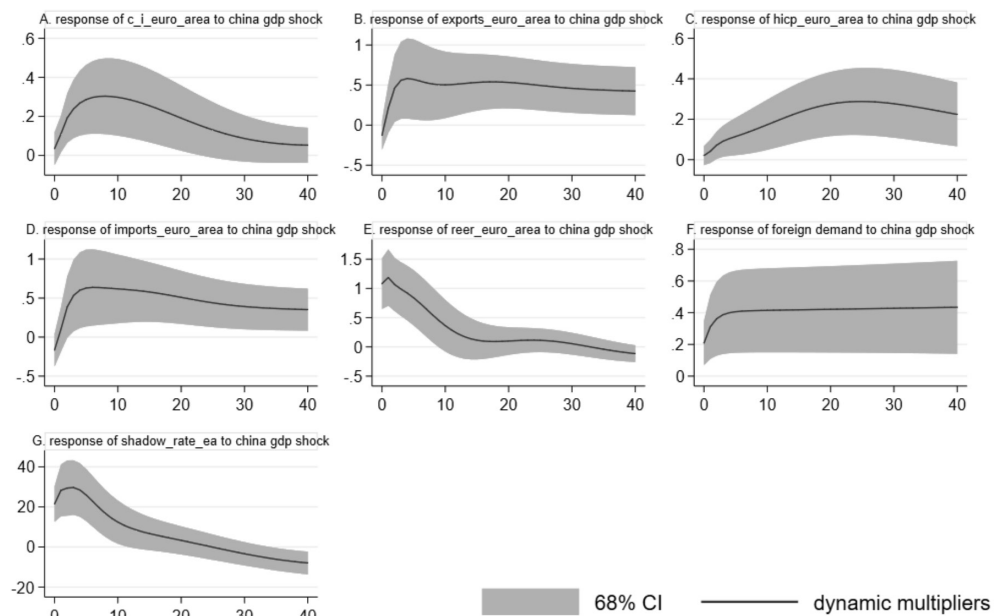
Source: own calculations.

Figure 4. Dynamic multipliers to United States demand shock (exogenous variable), var_PL_us model



Source: own calculations.

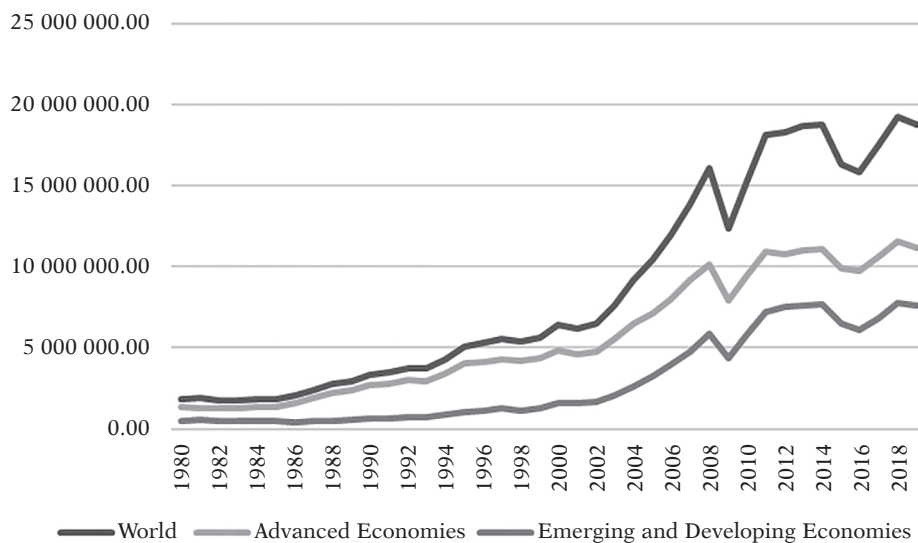
Figure 5. Dynamic multipliers to China demand shock (exogenous variable), var_EA_china model



Source: own calculations.

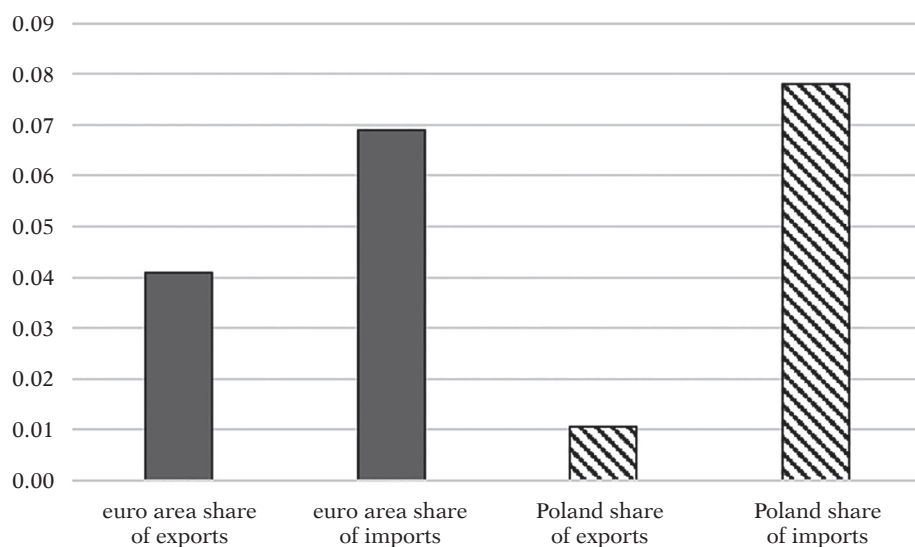
Appendix

Figure 6. The volume of world exports in millions of US dollars



Source: IMF DOTS.

Figure 7. The share of imports and exports from the euro area and Poland to China, May 2019.



Source: own calculations based on IMF DOTS.

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