Tampere University

HELI SIMOLA

Essays on Former Transition Economies and International Spillovers

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ABSTRACT

The topic of international spillovers and shock transmission has become even more important than before during the past couple of decades as international economic integration has widened and deepened significantly. Correspondingly, it has become increasingly important to take international disturbances into account when analyzing and forecasting the developments of any individual economy and in designing appropriate economic policies. Therefore, we empirically examine the significance and transmission of international shocks in the four essays of this work. We also try to evaluate the trends in shock transmission during the past couple of decades. Our work focuses on certain former transition economies (i.e., countries that have shifted from a planned economy to a market economy during the past decades). In the first two essays, our focus is on countries of the Commonwealth of Independent States (CIS), and in the two last essays we look at China.

In the first essay, we examine the pass-through of exchange rates and commodity prices to consumer prices in several CIS countries in the period 1999-2014. We provide up-to-date estimates for the pass-through effects in the CIS economies by using a methodology that is novel for these countries and which controls for a wider range of factors than in the previous literature and allows us to take into account the effects of idiosyncratic and common factors in CIS consumer price trends. We use a panel framework with a mean group estimator that controls for cross-sectional dependence. Our results indicate that exchange rate pass-through is still relatively high and rapid in the CIS countries. In addition, global factors are important for consumer price trends in the CIS countries. We also find evidence of an asymmetrical effect in the case of exchange rate pass-through, indicating that exceptionally large exchange rate shocks transmit more strongly and rapidly to consumer prices than small changes.

The second essay examines the spillover effects from foreign output shocks and oil price shocks on output in CIS countries with a global vector auto regressive (GVAR) model. We provide up-to-date estimates and a more detailed analysis on the impacts of foreign output shocks on the output of CIS economies than in earlier research. We compare the spillovers by region of origin, analyze the role of direct and indirect trade and financial channels, and examine the evolution of these effects

during the past couple of decades. We find that CIS economies are highly sensitive to both regional and global shocks, although there is wide variation across individual countries. Our results also indicate that the sensitivity of the CIS economies to global and regional shocks has changed notably during the past couple of decades. Finally, our results illustrate the importance of effects arising from indirect trade and financial channels.

The third essay features an analysis of Chinese production chains and, in particular, the role of the services in them. Our analysis complements the previous literature on global value chains by providing more detailed information on the significance of Chinese services and provides additional insights into Chinese economic development in qualitative terms. We apply the standard input-output techniques to the recently compiled World Input-Output Data (WIOD) covering the years 2000-2014 and decompose the global value-added production in value chains, showing the origin of the value added by country and sector. We analyze the characteristics and the development of Chinese value chains in comparison to other countries' chains. We also apply a constant market share analysis (CMS) to the global value-added production and exports. Our results suggest that the role of Chinese services has become more important in global value chains, especially in domestic ones but, increasingly, in foreign production chains too. The CMS analysis further suggests that services have also become a more important factor in recent years, supporting Chinese competitiveness both in domestic and foreign markets. Therefore, our results provide, on their part, support for the perception that Chinese production is gradually shifting towards higher value-added production stages.

In the fourth essay, we examine the international transmission and impact of various China-specific shocks. We consider shocks to Chinese final demand at the aggregate level, bilateral import tariffs between the U.S. and China, and sector-specific shocks to Chinese final demand and supply. We utilize the input-output framework applied to the latest WIOD table for 2014 for the analysis. We aim at assessing the international transmission and importance of the China-specific shocks and also compare the estimates achieved from the simple input-output framework to the results from more complex models in earlier literature. Our results suggest that aggregate-level China-specific shocks may also have important effects for several other countries, but the transmission of the shocks through the global production network is relatively limited since Chinese production is not very import-intensive. Our estimates calculated with the input-output framework are quite close to the results presented in the previous literature, but mainly located at the lower end. Concerning sector-specific shocks, we find that in general the international impact of Chinese sector-specific final demand and supply shocks is relatively modest at the aggregate level, but there are certain exceptions.

TIIVISTELMÄ

Kansainvälisten taloudellisten shokkien merkitys on viime vuosikymmeninä kasvanut huomattavasti, kun kansainvälinen taloudellinen integraatio on laajentunut ja syventynyt. Samalla kansainvälisten tapahtumien huomiointi on tullut entistä tärkeämmäksi arvioitaessa ja ennustettaessa minkä tahansa talouden kehitystä sekä suunniteltaessa sopivaa talouspolitiikkaa. Siksi tämän työn muodostamissa neljässä artikkelissa tutkitaan empiirisesti kansainvälisten shokkien välittymistä ja vaikutuksia sekä niissä viime vuosikymmeninä tapahtuneita muutoksia. Artikkeleissa keskitytään eräisiin siirtymätalouksiin, eli maihin, jotka ovat siirtyneet suunnitelmataloudesta markkinatalouteen. Ensimmäiset kaksi artikkelia koskevat Itsenäisten Valtioiden Yhteisön (IVY) maita ja jälkimmäiset kaksi artikkelia keskittyvät Kiinaan.

Ensimmäisessä artikkelissa tarkastellaan valuuttakurssien ja raaka-aineiden hintojen muutosten välittymistä kuluttajahintoihin useissa IVY-maissa vuosina 1999-2014. Tutkimuksessa käytetään ensimmäistä kertaa näiden maiden tapauksessa menetelmää, jonka avulla voidaan paremmin erotella maakohtaiset ja yhteiset tekijät sekä huomioida laajempi määrä kontrollimuuttujia kuin aiemmassa kirjallisuudessa. Tulokset osoittavat, että valuuttakurssimuutosten läpimenoaste kuluttajahintoihin on IVY-maissa edelleen suhteellisen voimakasta ja nopeaa. Myös globaaleilla tekijöillä on tärkeä merkitys IVY-maiden kuluttajahintainflaation kehityksessä. Tutkimuksessa löydetään myös viitteitä siitä, että valuuttakurssimuutosten välittyminen voi olla epäsymmetristä.

Toisessa artikkelissa tutkitaan globaalin VAR-mallin avulla, kuinka muutokset ulkomaisessa tuotannossa ja öljyn hinnoissa vaikuttavat IVY-maiden kokonaistuotannon kasvuun. Artikkelissa vertaillaan eri maista peräisin olevien shokkien vaikutusta IVY-maiden talouskasvuun sekä arvioidaan eri vaikutuskanavien merkitystä shokkien välittymisessä. Lisäksi tutkimuksessa tarkastellaan, miten vaikutukset ovat muuttuneet parin viimeisen vuosikymmenen aikana IVY-maiden integroiduttua tiiviimmäksi osaksi kansainvälistä taloutta. Tutkimuksen tulosten mukaan IVY-maiden taloudet ovat hyvin herkkiä sekä alueellisille että globaaleille shokeille, mutta maiden välillä on paljon vaihtelua. Shokkien välittyminen ja eri vaikutuskanavien merkitys ovat muuttuneet selvästi vuosien mittaan. Tutkimuksen

tulokset osoittavat myös, että epäsuorien kauppa- ja rahoitusmarkkinasuhteiden kautta tulevat vaikutukset voivat olla merkittäviä.

Kolmannessa artikkelissa analysoidaan kiinalaisia tuotantoketjuja ja erityisesti palvelujen merkitystä niissä. Analyysin pohjana käytetään perinteistä panos-tuotos –kehikkoa, jota sovelletaan hiljattain julkaistuun globaalin tuotantoverkoston rakenteita vuosina 2000-2014 kuvaavaan World Input-Output Data (WIOD) –tietokantaan. Artikkelissa tutkitaan kiinalaisten arvoketjujen rakennetta ja kehitystä sekä verrataan sitä muihin maihin. Lisäksi Kiinan arvonlisäperusteisen tuotannon ja viennin kehitystä tarkastellaan vakiomarkkinaosuusanalyysin avulla. Tulosten perusteella Kiinassa tuotettujen palveluiden merkitys on kasvanut selvästi kansainvälisissä arvoketjuissa. Palvelusektorit ovat nousseet tärkeämpään asemaan myös Kiinan kilpailukykyä tukevana tekijänä. Tulokset tukevat käsitystä siitä, että Kiinan tuotanto siirtyy vähitellen kohti korkeamman arvonlisän tuotantovaiheita.

Neljännessä artikkelissa keskitytään Kiinasta peräisin olevien shokkien kansainväliseen välittymiseen ja vaikutuksiin muihin maihin. Tutkimuksessa tarkastellaan Kiinan loppukysyntään kohdistuvia muutoksia, Kiinan ja Yhdysvaltain välisiä tuontitulleja sekä Kiinan sektorikohtaisia kysyntä- ja tarjontashokkeja. Tarkastelun pohjana on jälleen panos-tuotos –kehikko, jota sovelletaan WIOD-tietokantaan. Tulokset osoittavat, että Kiinan talouteen – jopa yksittäisille toimialoille - kohdistuvilla shokeilla voi olla merkittäviä vaikutuksia myös muihin maihin. Shokkien välittyminen kansainvälisen tuotantoverkoston kautta on kuitenkin rajallista, koska Kiinan talous on suhteellisen vähän riippuvainen tuonnista.

CONTENTS

1 INTRODUCTION

The topic of international spillovers and shock transmission has been examined for several decades, but it has gained increasing interest in the 2000s as international economic integration has widened and deepened significantly. International trade has grown rapidly, especially as production chains have become increasingly international. Although the international fragmentation of production chains is by no means a new phenomenon, it has reached unprecedented volumes and complexity during the past decades as countries have removed barriers to international trade and financial flows, and technological advances have enabled the wider international dispersion of production chains (Baldwin & Lopez-Gonzalez 2015). International interdependency has grown significantly also in financial markets as was vividly illustrated during the global financial crisis of 2008-2009. Therefore, it has become increasingly important to also take into account international disturbances when analyzing and forecasting the developments in any individual economy and in designing appropriate economic policies.

In the four essays that form this work, we examine the significance and transmission of international shocks. We also try to evaluate the trends in shock transmission during the past couple of decades. Our work focuses on certain former transition economies (i.e., countries that have shifted from a planned economy to a market economy). They provide an interesting and heterogeneous sample of countries that have—as part of their wider framework of notable structural changes—opened up and increased their international economic integration notably during recent decades. On the one hand, we have a set of countries of the Commonwealth of Independent States (CIS)1 that are small open economies and relatively dependent on international trade, in particular, but also on international financial markets. At the other extreme, we have China that has become one of the

[1] CIS refers to the countries that were formerly members of the Soviet Union (excluding the Baltic countries). The cooperation framework currently includes 11 countries (with varying statuses of integration): Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyz Republic, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

largest economies in the world, supported by its active integration into international value chains.

In the first two essays, we examine the sensitivity of several CIS countries to various international shocks, analyze the transmission channels of the shocks, and evaluate the changes that have occurred during the past couple of decades. Most CIS countries are relatively small, open economies, which makes them prone to international fluctuations. Moreover, many of them are still continuing with structural economic changes and formulating their economic policy frameworks. Vulnerability to international shocks can be important from the point of view of, for example, the exchange rate regime. We find that CIS economies are highly sensitive to both regional and global shocks. Foreign shocks are important for the development of both output and inflation, although there is wide variation across individual countries. Our results also indicate that the sensitivity of the CIS economies to global and regional shocks has changed during the past couple of decades. In addition, our findings suggest that indirect transmission channels should also be taken into account when assessing the effects of international shocks on the CIS economies.

In the second pair of essays. we change the viewpoint and examine the importance of China in the global production network and as an origin of international shocks. After spectacular growth over several decades, China has become one of the largest economies in the world and become an essential part of global value chains. Our findings provide support for the perception that China's role has grown rapidly in international production chains and that China is gradually shifting from the low value-added sectors and production stages to higher value-added production. Taking into account China's increased role in global production networks, it is not surprising that our results also suggest that China-specific shocks—even certain sector-specific shocks—can have important spillover effects for other countries. On the other hand, China's role in international production chains is still limited, and in Chinese production chains, import intensity has actually declined, which reduces the international transmission of Chinese shocks through the global production network. However, important additional effects might also occur, stemming from commodity price movements and financial markets that cannot be taken into account in our analysis framework.

In this introductory chapter, we first review some theoretical issues and earlier empirical results as a background and wider context for our essays. Then, we briefly discuss certain aspects related to the choice of empirical approach for the examination of our issues of interest. At the end of the introduction, we provide summaries of the essays, while the essays themselves are presented in the following chapters. Chapter 2 features the analysis of pass-through and common factors in the price development of certain CIS countries. In chapter 3, the transmission and impact of foreign shocks on the output of certain CIS countries are examined. In chapter 4, we move on to China, examining its role in global value chains and its evolution during the past decades, and we analyze the structure of Chinese value chains. Finally, chapter 5 examines the international transmission and spillovers of various China-specific shocks.

1.1 Earlier literature

There is a vast theoretical and empirical literature on the transmission of international shocks and their importance for economic fluctuations, both studied as a separate topic and also as a part of the business cycle synchronization literature. External shocks are usually found to be an important factor affecting business cycle fluctuations in most countries, in particular, in small open economies. External shocks can be common global or regional disturbances affecting all or several markets at the same time, like oil price shocks, or country-specific shocks that spill over to other countries due to the presence of interdependencies in goods or assets markets. In this section, we present a brief review of the previous literature related to the topic on both the theoretical and empirical sides in order to place our essays within a wider perspective in the field. In the part on theoretical literature, we concentrate on discussing the models depicting the transmission of country-specific shocks, but in the section on empirical literature, we also review findings related to the importance of global and regional shocks.

1.1.1 Theoretical background

There are numerous theoretical models that aim at depicting the transmission of shocks from one country to another. Based on these models, spillover effects of country-specific shocks are not unambiguous but depend on the specification details like the nature of the shocks, the assumed market structure, and certain model parameters like trade elasticity. The basic spillover channels are trade in goods and financial markets, and there are several models that include only one of the channels or both. With different assumptions about, for example, financial market completeness and the elasticity of substitution between domestic and foreign goods, the transmission effects of an idiosyncratic shock may vary substantially. Moreover, the short-term and long-term effects can differ. In order to illustrate the variety of theoretical implications, we discuss briefly some spillover effects and transmission channels present in different models. We focus here on shocks to the real economy instead of monetary policy shocks and, therefore, mostly discuss real business cycle (RBC) models.

We take as a starting point a basic identical two-country and one-good international RBC model (Backus et al. 1992), featuring complete financial markets. In this model, a positive technology shock in country 1 leads to an increase in both output and demand in country 1. Demand grows more than domestic output, also causing imports from country 2 to grow. In addition, capital flows from country 2 to country 1 as the return on investment is now higher in country 1. This resource shifting channel dominates the trade channel, and, therefore, investment and output decline in country 2. In the Backus et al. (1992) model, the effect is, however, reversed in the longer term because technology is assumed to gradually spill over from country 1 to country 2, improving productivity in country 2 as well.

The potential of different consequences from a demand and supply shock are illustrated, for example, by Backus et al. (1994), with a standard international RBC model with two countries and two goods, with each country producing a different good, and the final consumption consisting of a composite of domestic and foreign goods. Imperfect substitutability between the domestic and foreign goods is a key factor for the transmission mechanism, with the elasticity of substitution affecting notably the magnitudes of the effects. A positive demand shock in country 1 leads to a rise in domestic output and prices, causing real appreciation of the domestic currency. Higher demand and improved terms of trade cause the imports into country 1 from country 2 to grow, and, correspondingly, exports and output increase in country 2. Prices in country 2 also go up if the increase in country 1's prices passes through the exchange rate. On the other hand, a positive technology shock in country 1 leads to an increase in domestic output and a decline in domestic prices. The domestic currency depreciates, and the terms of trade of country 1 deteriorate, causing a decline in its imports and a rise in its exports, whereas imports in country 2 grow correspondingly. Exchange rate pass-through also pushes the price level down in country 2. The higher the elasticity of substitution between the domestic and foreign goods, the higher are the trade effects.

The international fragmentation of the production process may increase the propagation of shocks by adding another transmission channel (as discussed e.g., in Kose & Yi 2001; Burstein et al. 2008; Arkolakis & Ramanarayanan 2010). A key extension in their models is a two-stage production process, where final products require both domestic and foreign inputs. A positive technology shock to country 1's intermediate good production leads to an increase in country 1's output and an increase in its import demand for the intermediate goods produced in country 2. The higher import demand is, however, partly offset by the now relatively higher price of country 2's intermediates. The shock also causes a decline in the price of the intermediate produced in country 1, which lowers the production costs of the final product in country 2. Moreover, the impacts of trade barriers, like transport costs, are larger in the presence of production fragmentation. Johnson (2014) develops this aspect further, differentiating between gross and value-added trade in a three-country setup and illustrating a third-country effect. A shock hitting country 1 can affect country 3 even if they are not directly trading with each other if country 3 provides intermediates for the goods produced in country 2 and exported to country 1 or if country 3 imports goods from country 2 that use intermediates imported from country 1.

Financial markets can also notably affect the transmission of shocks as illustrated, for example, in Corsetti et al. (2008). They build a two-country, two-good endowment economy model, which implies that with complete markets, a positive productivity shock in country 1 unambiguously leads to a fall in the price of the goods produced by country 1 and, therefore, the depreciation of its terms of trade. But with incomplete financial markets, the same shock can lead to either a fall or a rise in the price of country 1's goods, depending on other parameters of the model, in particular, the elasticity of substitution between domestic and foreign goods. The price of domestic goods may increase despite the positive endowment shock if strong wealth effects drive aggregate demand for country 1's goods above the supply. Consequently, the terms of trade of country 1 can either worsen or improve, also implying different developments for the exports and imports of country 2.

Devereux and Yetman (2010) extend a basic international RBC model of the financial market side to include both equity and debt markets, and they examine the effects of financial integration and leverage constraints on shock transmission. They show that under integrated equity markets, segregated bond markets, and without binding leverage constraints, a negative technology shock in country 1 only lowers investment in country 1, and investment in country 2 is not affected. In contrast, when the leverage constraint is binding, investment also falls in country 2 because investors in country 1 have to repatriate their investments to meet the constraint. The transmission of the shock is further strengthened when the equity markets are fully integrated, and the effect of the shock can even eventually be larger in country

2 than in country 1, that originally hit by the shock. Moreover, with common bond markets, segregated equity markets, and binding leverage constraints, a negative productivity shock in country 1 leads to an increase in investment in country 2.

In the New Keynesian framework allowing nominal rigidities, additional factors affecting the transmission of international shocks arise from monetary policy considerations. As discussed, for example, by Erceg and Linde (2013) and Blagrave et al. (2018), the international transmission of foreign demand shocks can vary substantially depending on the monetary policy response by the country, with larger effects in the context of accommodative monetary policy and, in particular, in the vicinity of the zero lower bound. Corsetti et al. (2017) and Devereux and Yu (2019) illustrate differing implications of a floating exchange rate policy and an exchange rate peg in a two-country New Keynesian open economy setting. Devereux and Yu (2019) also show that a price-setting regime may have important implications for shock transmission. Under producer currency pricing, the transmission of shocks is much stronger than under local currency pricing, since the exchange rate changes pass through to foreign prices much more slowly.

The New Keynesian framework with price stickiness is the typical framework in models examining more closely the impacts of foreign variables on domestic inflation. Trade is again an obvious transmission channel, with imported inputs affecting producer prices and imported final goods adding to the effect on consumer prices. Guerrieri et al. (2010) indeed develop a model in which domestic inflation also depends on the ratio between domestic and imported goods. In addition, it is argued that foreign shocks can influence domestic inflation indirectly by increasing competition and causing downward pressures on domestic prices, making inflation dependent on foreign factors too (Benigno & Faia 2016; Razin & Binyamini 2007). The role of exchange rate changes in determining inflation is highlighted in the model of Gali and Monacelli (2005), which incorporates expectations on terms of trade to the Phillips curve. Moreover, exchange rate pass-through may affect the transmission of international shocks. Typically, the models assume complete exchange rate pass-through, but as shown, for example, by Devereux and Engel (2002), incomplete pass-through can hamper the transmission of shocks through the trade channel. Therefore, it is important for monetary policy design to have estimates of the size and speed of the pass-through.

This theoretical discussion shows that international spillovers of country-specific shocks can be expected to be important in determining business cycle fluctuations, especially in small open economies. The sign or the magnitude of the effects are not, however, unambiguously determined by theoretical models, but they remain an empirical question. Therefore, we discuss some of the most relevant empirical literature in the next section.

1.1.2 Empirical results

There is abundant empirical research related to the role and transmission of international shocks across countries. Among the most popular related topics is business cycle synchronization, which usually refers to correlation between the growth of output or some other key economic variables between countries or regions. This literature offers plenty of evidence on the key impact of global factors on business cycle fluctuations in several countries (Kose et al. 2003; Crucini et al. 2011; Cesa-Bianchi et al. 2019) as well as on the importance of regional shocks (Monfort et al. 2004; Stock & Watson 2005; Mumtaz et al. 2011), although the significance of different factors varies across countries. Moreover, several studies find support for the increasing importance of international factors in business cycle fluctuations during the past decades (Kose et al. 2008; Bordo & Helbling 2010; Mumtaz et al. 2011).

There is also a vast literature concerning the channels and determinants of international shock transmission. The trade channel is usually found to be important, with higher trade integration leading to tighter business cycle synchronization between countries (Frankel & Rose 1998; Imbs 2004; Baxter & Kouparitsas 2005; Dees & Zorell 2012; Duval et al. 2016). This result might seem to be at odds with traditional trade theory, implying that tighter trade relations would lead to higher specialization between countries and to the divergence rather than the comovement of business cycles, at least following an industry-specific shock. This finding has been viewed to reflect the importance of intra-industry trade, and there is also empirical evidence supporting this view (Shin & Wang 2003; Calderon et al. 2007; Duval et al. 2016).

The positive association between trade integration and business cycle comovement can also be related to the international fragmentation of production. The international fragmentation of production makes parts of a production chain complements, thus leading to the comovement of their production. The importance of vertical linkages for business cycle synchronization is supported, for example, by di Giovanni and Levchenko (2010) and Ng (2010). Taken together with the evidence that similarity in the sectoral composition of production increases business cycle synchronization (Imbs 2004; Inklaar et al. 2008; Ductor & Leiva-Leon 2016), these results suggest that industry-specific shock transmission might also be an important factor for international fluctuations like it is at the national level, as shown, for example, by Acemoglu et al. (2012, 2016) and discussed in more detail below.

The financial market channel also plays a role, but results on the effects of financial integration are mixed. Some studies find that higher financial integration leads, directly or indirectly, to more synchronized business cycles (Imbs 2004; Dees & Zorell 2012; Fidrmuc et al. 2012), while in others it is associated with diverging development (Cerqueira & Martins 2009; Kalemli-Ozcan et al. 2013; Ductor & Leiva-Leon 2016). There is some evidence pointing to the idea that this could be related to differing effects, depending on the common or country-specific nature of shocks (Gong & Kim 2018; Cesa-Bianchi et al. 2019), the frequency of the examined data (Cerqueira & Martins 2009; Fidrmuc et al. 2012), or if the financial market integration concerns debt or equity markets (Davis 2014).

Most of this research has focused on industrialized countries, but, recently, more attention has also been given to emerging economies, especially in the context of the debate on global convergence versus decoupling business cycles between developed and emerging economies. The evidence is, however, again somewhat mixed. Some studies have found support for growing comovement between developed and emerging economies as well as for the increasing transmission of shocks not only from developed to emerging economies but also vice versa (Kim et al. 2011; Pula & Peltonen 2011; Ductor & Leiva-Leon 2016). On the other hand, there is also evidence on the increasing importance of regional or other group-specific factors, implying decoupling at the global level or between developed and emerging economies (Dong & Wei 2012; Kose et al. 2012; Levy Yeyati & Williams 2012).

There are also several studies that aim to measure quantitatively the importance of international shock transmission and the different transmission channels for economic fluctuations, but the results are ambiguous. Some research emphasizes the significance of the trade channel (Bems et al. 2010; Bagliano & Morana 2012), whereas other studies find the financial channel much more important (Bayoumi & Swiston 2007; Poirson & Weber 2011; Feldkircher & Huber 2016). Regarding the transmission channels, results are similar for both developed and emerging markets, but the importance of different channels varies. Overall trade integration leads to higher synchronization between developed countries (Calderon et al. 2007), whereas tighter vertical trade linkages increase comovement, in particular, between developed and emerging economy pairs (Di Giovanni & Levchenko 2010), and trade linkages are especially important for shock transmission in emerging Europe (Gong & Kim 2018).

In most studies, U.S. shocks are found to have a significant and a relatively important effect on fluctuations in other countries. A 1% shock to U.S. output leads in the medium term, on average, to a 0.2-0.5% change in the output of euro area countries, a 0-0.4% change in Japanese output, and a 0.4-0.5% change in the output of other industrialized countries (Bayoumi & Swiston 2007; Dees & Saint-Guilhem 2009; Bems et al. 2010; Bagliano & Morana 2012). In emerging Europe, the corresponding effect is found to be 0.5-0.7% (Bagliano & Morana 2012; Feldkircher 2015), whereas the estimated average impacts for emerging economies of Latin America and Asia vary substantially from 0.1% (Dees & Saint-Guilhem 2011; Feldkircher & Huber 2016) up to around 1% (Bagliano & Morana 2012; Erten 2012; Fadejeva et al. 2017). Shocks originating in the euro area or Japan are usually found to have much smaller impacts than U.S. shocks (Bayoumi & Swiston 2007; Poirson & Weber 2011; Erten 2012) with the exception of the effect of euro area shocks on emerging European countries (Feldkircher 2015; Fadejeva et al. 2017). In advanced economies, shocks originating in the U.S., euro area, or Japan are estimated to explain 2-15% of the variation in medium-term GDP growth (Bayoumi & Swiston 2007).

Recently, the role of Chinese shocks has induced particular interest as China has become one the largest economies in the world. There is evidence that the importance of China as a source of international shocks has indeed increased notably in recent decades (Arora & Vamvadikis 2011; Cesa-Bianchi et al. 2012). In quantitative terms, according to most estimates, a 1% shock on Chinese GDP is estimated to have an impact of 0.1-0.3% on output in the U.S., euro area, and Japan in the medium term (Cesa-Bianchi et al. 2012; Feldkircher & Korhonen 2012; Dreger & Zhang 2014). Corresponding effects for Latin American countries are found to be on average 0.2-0.3%, with 0-0.1% for emerging Asia and 0.2% for emerging Europe (Cesa-Bianchi et al. 2012; Feldkircher & Korhonen 2012; Furceri et al. 2017).

Besides real economy variables, there is also evidence on the importance of international shocks on price development in most countries (Galesi & Lombardi 2009; Mumtaz et al. 2011; Neely & Rapach 2011). Several studies find relatively high inflation synchronization across countries (Monacelli & Sala 2009; Ciccarelli & Mojon 2010; Mumtaz & Surico 2012). In addition, some research provides support for the importance of foreign factors in the Phillips curve (Borio & Filardo 2007; Mihailov et al. 2011; Bianchi & Civelli 2015), although there are also opposing findings (Ihrig et al. 2008). Among the international factors that affect inflation synchronization, the participation in international value chains (Auer & Mehrotra 2014; Auer et al. 2017, 2019), international labor costs (Eickmeier & Pijnenburg

2012), and exchange rate movements (Honohan et al. 2003) were found to be significant.

Finally, as noted above, exchange rate pass-through can affect the propagation of international shocks both in terms of output and inflation. Although in most theoretical models the exchange rate pass-through is assumed to be instantaneous and complete, empirical evidence shows that this is rarely the case, especially concerning consumer prices. For developed countries, the long-term pass-through to consumer prices is typically estimated to be around 10-30% (Bailliu & Fujii 2004; Gagnon & Ihrig 2004; Choudhri & Hakura 2006), although there is vast variation across countries. Most studies find the pass-through to be slightly higher in emerging than in developing economies, with typical estimates varying between 30-50% in the long term, although, again, there is great variation across countries (Choudhri & Hakura 2006; Aron et al. 2014; Caselli & Roitman 2019). For the emerging economies in Europe and Central Asia, the exchange rate pass-through has been found to be particularly high, at even around 60% (Beirne & Bijsterboch 2009; Beckman & Fidrmuc 2013).

So, as our brief review of the related empirical literature shows, there is abundant evidence that suggests that international shocks are important for fluctuations in both real variables and price developments in most countries. The contribution of international factors is often also significant in quantitative terms. The increased openness and integration of the global economy seem to further strengthen the transmission of international shocks, and, thus, the role of international factors in the economic fluctuations of most countries has increased. Therefore, it is interesting to complement this literature with new estimates, and we thus concentrate on the empirical side of the question. In the next section, we briefly discuss some key aspects related to the choice of the empirical approach for our various areas of interest.

1.2 Methodological issues

In this section, we discuss some issues related to the choice of empirical approach and place the methodologies used in our essays in the context of earlier research. Various approaches have been used previously in the literature to address the questions we are interested in. We briefly discuss their advantages and disadvantages as well as presenting the main features of the empirical approaches used in the essays. In general, we focus on more data-oriented approaches in order to avoid an abundance of a priori restrictions, since theoretical models cannot offer unambiguous guidance on them as discussed above.

1.2.1 Aggregate level examination

There are several methodological approaches that have been used in the literature for examining the international transmission and spillover effects of various shocks on output, prices, and other variables at the aggregate level of total economies. Multi-equation or system models are often a more intuitive framework for analyzing issues related to the topic and have gained popularity in recent years, but for several questions single-equation models also have their advantages.

In the essays included in this work, we utilize both types of models as discussed in this section. We have opted for a more data-oriented approach at the cost of structural considerations, and, thus, dynamic stochastic general equilibrium (DSGE) models are not used in this work. Although they have plenty of advantages, the downside is that DSGE models also require posing several ex ante restrictions, which are not always in line with the statistical properties of the data. Canova and Ciccarelli (2013) even argue that, due to the restrictions, much of the responses produced by these models are often largely determined by the assumptions of the model. Multi-country DSGE models are also quite tedious to build and calibrate, which is beyond the scope of the current essays. Such models have been developed, for example, by the IMF, and also used in the analysis of international shock transmission (Freedman et al. 2010).

A key challenge related to this type of analysis (as in many macroeconometric applications) is the curse of dimensionality. Here, the curse of dimensionality refers to the common feature in most macroeconomic panels in that the number of cross-sectional units N is large relative to the number of time periods T available for estimation. This problem is even accentuated in the case of emerging economies (including CIS countries and China), which are often characterized by the scarcity and poor quality of data, in many cases also featuring significant structural changes during the relatively short time periods for which data are available. Moreover, an essential point of interest in these kinds of studies is often the examination of complex and interdependent transmission channels of global, international, or country-specific shocks in other countries, taking into account the potential heterogeneity in the responses of the individual countries. This further strengthens the curse of dimensionality and requires the empirical setup to allow for cross-sectional dependence and heterogeneous coefficients.

Due to these features that have to be taken into account, a choice also has to be made about the restrictions or data shrinkage process to be applied in the estimation. There are several alternatives: explicit restrictions derived from economic theory, Bayesian approaches, other restrictions on the influence channels (e.g., spatial models), and factor models. Also at this point, we have chosen a more data-oriented approach using factor modeling and minimal restrictions based on the data, as discussed below.

1.2.1.1 Single-equation approach

In the first essay of this work, we use a single-equation approach for examining the pass-through of certain global shocks and exchange rate movements to consumer prices in several CIS countries. The single-equation approach allows us to take into account a wider set of explanatory variables more flexibly despite the relatively short time series available. In addition, in the single-equation setup, it is quite straightforward to also examine non-linearities and structural breaks, which allows us to account for asymmetrical effects more easily than in the multi-equation framework (Aron et al. 2014).

On the other hand, in the single-equation setup, challenges often arise especially with the endogeneity of variables. Furthermore, in single-equation panel models, endogeneity can arise due to both serial correlation and correlation between the explanatory variables. A widely used solution is to apply general method of moments (GMM) estimation methods. When examining the international propagation of shocks, however, cross-sectional dependence is often present in the data, as noted above. Moreover, in many cases it is plausible to allow for heterogeneity in the coefficients among units of the panel (typically countries), but these features may invalidate the use of GMM estimators.

For datasets with a large number of cross-sectional units N relative to the time dimension T and cross-sectional dependence, the most common solutions for estimation strategy are spatial or factor models (Sarafidis & Wansbeek 2012). Spatial models represent a parameter shrinkage process so that restrictions are posed on the nature of the cross-sectional dependence (e.g., neighboring units showing higher cross-sectional dependence than more distant units). However, in many macroeconomic applications, it might be difficult to formulate the restrictions, or the dependencies might be more general.

In our case, we indeed find it difficult to determine plausible spatial parameter restrictions. An alternative approach is to opt for data shrinkage instead by applying a factor model. Factor models are based on the idea that the comovements present in a large dataset may be driven by a small number of latent variables. There are also several possibilities for applying the factor approach, but we have chosen to use an augmented mean group estimator introduced by Eberhardt and Teal (2010). This estimator is suitable for dynamic, cross-sectional dependent panels with heterogeneous coefficients and allows for cointegration. In addition, common factors are not considered as just a nuisance to be accounted for but are treated as observed common factors and taken into account explicitly as separate explanatory variables. In order to address the possible endogeneity between variables, we provide a robustness check, applying the dynamic CCE (MG)-GMM estimator of Neal (2015) for the estimations, and receive largely similar results.

1.2.1.2 Multi-equation models

In the multi-equation framework, various vector auto regression (VAR) models are a popular approach for examining the transmission and spillover effects of international shocks. In VAR models, all variables are typically treated as endogenous and interdependent, although it is possible to also include exogenous variables. The dependent variable is regressed on its own lagged values as well as contemporaneous and lagged values of certain other variables, which alleviates the endogeneity problem. The VAR models provide a very general representation and allow the capturing of complex data relationships as they attempt to capture the relationships present in the data with a minimal set of ex ante restrictions (Canova & Ciccarelli 2013).

On the other hand, the high level of generality also causes drawbacks to the VAR models. They have been criticized for a lack of theoretical foundations and for problems with structural interpretation. But, as Canova and Ciccarelli (2013) argue, it is possible to generate VAR models from standard intertemporal optimization problems under constraints, and vast literature already exists on structural identification in the VAR framework (Canova & Ciccarelli 2013; Chudik & Pesaran 2016). The high level of generality also limits the number of variables that can be included in the model, which potentially causes an omitted variable bias.

The curse of dimensionality is an essential problem in VAR models, but there are several alternative approaches presented in the literature to address the issue. Structural VARs can be used when focusing only on a small set of countries or aggregated regions so that the degrees of freedom are preserved by reducing the number of regressors (Bayuomi & Swiston 2007). With large-scale VARs, a common factor approach is again an option for data shrinkage. Cross-country comovements of several variables are collapsed into common factors, and vectors of domestic variables are then augmented with these estimated factors to form small-scale models (Cimadomo & Benassy-Quere 2012). Another approach is the Bayesian VAR, which uses priors about the cross-country correlation patterns that are subsequently updated with the data (Banbura et al. 2010). Finally, global VAR models address the dimensionality problem by decomposing the large unconditional model into smaller conditional models that are linked through cross-sectional averages (Chudik & Pesaran 2016).

In the second essay, we turn to the multi-equation approach and opt for the global VAR (GVAR) approach to examine the impact of various country-specific output shocks and oil price shocks on several CIS economies. Although requiring a priori assumptions on the interlinkages between countries, GVAR models offer an intuitively appealing framework in the context of international shock transmission. GVAR models have gained popularity in various macroeconometric applications after the seminal contribution by Pesaran et al. in 2004 as they impose an intuitive structure on cross-country interlinkages, but no restrictions are imposed on the dynamics of the individual sub-models (Chudik & Pesaran 2016).

The GVAR model is composed of several small-scale country-specific models that are first estimated conditional on the rest of the world. The country-specific models include domestic variables and weakly exogenous foreign variables that are weighted cross-sectional averages as well as global variables. Following the previous literature, we utilize trade and financial shares as weights. Moreover, we use time-varying weights in order to take into account the significant changes in the international relations of the countries under examination and to evaluate if the transmission of shocks has changed correspondingly. As a global variable we have oil price, which is common in the literature, and we model it as a dominant unit variable, as in Chudik and Pesaran (2013), to allow for endogenous relationships between domestic and global variables within the VAR models. Then, the country-specific models are stacked and estimated simultaneously as one large global VAR model. The resulting GVAR model can be used for scenario analysis and forecasting in a similar way to the traditional simple VAR models, and we calculate generalized response functions to assess the effects of various output and oil price shocks.

1.2.2 Sector level examination

Besides economy-wide shocks, sector-specific disturbances might also have an impact on aggregate fluctuations of economic variables. Traditionally, this possibility has been downplayed following Lucas's argument on idiosyncratic subsector shocks averaging out at the aggregate level. Recently, several studies have, however, pointed that this is not necessarily always the case (Gabaix 2011; Acemoglu et al. 2012, 2016). Sector- or even firm-specific shocks might have important spillover effects that are also reflected at the aggregate level nationally or even internationally. A key factor facilitating international spillovers is the increase in the international fragmentation of production chains.

Most models discussed in the previous section are usually applied at the aggregate level without examining subsector developments more closely. The key challenges related to them, like endogeneity and the curse of dimensionality, often become even more pervasive when there is yet another dimension in the data. In addition, DSGE models become much more complex to solve and trace analytically if the aggregate level is divided into numerous subsectors. Computable general equilibrium (CGE) models are often used for sector-level analysis, but they tend to require relatively elaborate assumptions on the adjustment of variables. This is the case, in particular, in the context of complex international production chains, although it is essential to take into account the input linkages and interdependencies between different sectors.

A simple and intuitive approach for examining the international sector-level interdependencies and their effects on cross-country shock propagation is the input-output framework introduced by Leontief (1936). It has been left in the background in economic research in the past decades due to its relatively specific nature and the increased econometric sophistication of other methodologies. Recently, however, as new datasets on international production linkages have been built that can be readily used for input-output analysis, there has also been renewed interest in utilizing and developing the input-output analysis. Therefore, we have also chosen, in the last two essays, to examine the role of China in international value chains and as an origin of international shocks by using the input-output approach applied to the recently published international input-output data. In this section, we briefly discuss input-output analysis and describe the main features of international input-output data.

1.2.2.1 Input-output framework

The input-output framework is essentially a demand-driven model of the economy. The exogenously determined final demand defines the corresponding levels of production in each sector to balance supply and demand consisting of the intermediate use of the sectors' products as inputs in all the sectors of the economy and final consumption. Following Miller and Blair (2009), this can be expressed in a matrix form at the aggregate level as the following:

$$x = Ax + f, \qquad (1)$$

where x is a vector of total output including the outputs of all individual sectors, A is the technical coefficient matrix that describes the amount of inputs needed from the industry itself and other industries for producing one unit of output, and f is a vector of final demand for all sectors. Equation (1) can be rearranged to express the relationship between output and final demand (provided that the matrix I-A is non-singular):

$$x = (I\text{-}A)\text{-}1\ f, \qquad (2)$$

where I is the identity matrix and the term (I-A)-1 is the Leontief inverse matrix. The Leontief inverse matrix describes how much output from each sector of the economy is required to fulfill one unit of final demand. Thus, the coefficients of the Leontief inverse matrix can be used in a straightforward manner to calculate the impacts of various shocks on different sectors and the total economy, also taking into account higher order effects caused by the interlinkages between sectors.

The input-output framework provides a simple and transparent tool for analyzing interdependency between countries and, in particular, at the sector level. Simplicity is also the main drawback of the methodology as it is based on several rather restricting assumptions (Galbusera & Giannopoulos 2012). First, the input-output tables depict the structure of the economy at only one point in time, and, therefore, the basic input-output framework allows only static analysis. Second, the framework assumes the infinite elasticity of supply with respect to demand, disregarding capacity constraints. Finally, the technical coefficients are assumed to be fixed and constant returns to scale are assumed to prevail in production.

Due to the several disadvantages, the input-output methodology has only been in limited use for certain specific applications in economic research in the past decades. However, as international value chains have recently received increased interest leading to attempts to build accounts on global production structure, the input-output methodology has also received more attention. There have been several projects by international organizations and research institutes (Lenzen et al. 2013; Timmer et al. 2015) to create regional or global input-output tables in order to facilitate the analysis of international production chains and linkages between different countries and sectors. In addition, input-output analysis has recently been utilized in combination with other methodologies, for example, in the context of network analysis (Acemoglu et al. 2012, 2016).

The new datasets on global production structure have supported the emergence of a branch of literature concentrating on examining global value chains and international trade in value-added from this perspective. These studies often rely on techniques associated with the input-output framework as they are readily applicable to the data. One branch of applications includes the calculation and comparison of gross and value-added trade, which may differ significantly due to the international fragmentation of production chains (Johnson & Noguera 2012, 2017; Koopman et al. 2014). There are also several studies that analyze the structure and evolution of global value chains (Timmer et al. 2014; Los et al. 2015; Amador & Cabral 2016), which have been built upon by the third essay in this work. Finally, the datasets have also been utilized in analyzing international effects of certain shocks in a similar vein as we have done in the fourth essay of this work (Vandenbussche et al. 2017, 2019).

1.2.2.2 Global input-output data

Several global and regional input-output datasets exist, which all have their advantages and disadvantages (Timmer et al. 2015), but for the essays in this work, we have chosen to use the World Input-Output Data (WIOD). The main advantages of the WIOD compared to other similar projects are its annual series of relatively recent data and that it is, as much as possible, based on actual publicly available data instead of estimated inputs. On the other hand, this restricts the number of countries that are covered by the data when compared to certain other datasets.

The WIOD project was launched in 2009 and funded by the European Commission with the aim of facilitating the analysis of European competitiveness. The latest version of the WIOD global input-output tables covers 43 countries and a rest of the world bloc over the years 2000-2014. The tables are further divided into 53 sectors according to the International Standard Industrial Classification revision 4 (ISIC Rev. 4), in accordance with the national account statistics standard SNA 2008. The tables were constructed by combining and harmonizing national accounts data from different countries with detailed customs and balances of payments statistics and augmented with estimated inputs for gaps, as discussed in Timmer et al. (2015). All entries are in current U.S. dollars. The resulting global input-output tables present the distribution of global supply and its use by countries and industries, as the example in Table 1 illustrates.

Table 1. An illustrative example of a global input-output table

			Intermediate use							Final use			Total use
			Country 1			…	Country N			Country 1	…	Country N	
			Ind. 1	…	Ind. K		Ind. 1	…	Ind. K				
	Country 1	Ind. 1											
		…											
		Ind. K											
Supply	…												
	Country N	Ind. 1											
		…											
		Ind. K											
Value added													
Gross output													

Source: Modified by the author from Timmer et al. (2015).

As we can see from Table 1, the columns of the first part of the table depict all the inputs needed to produce the total output, divided into intermediates by the country and sector (including both domestic and imported intermediates) of origin and finally into the value-added created in the sector. The intermediates include both goods and services. The second part of the table shows the structure of the end use by the country and sector of origin, and it is further divided into private and public consumption and investment. The table gives a closed account of world production as it is augmented with a residual rest of the world bloc that proxies for the countries that are not included individually.

There are several assumptions that are needed in constructing input-output tables, although they are often rather restricting. We note a few of the key assumptions regarding the WIOD as they should be kept in mind when analyzing the data and interpreting the results. The so-called import proportionality assumption is applied in WIOD only within the end use categories, improving from the standard procedure of not even differentiating between the end use categories. In practice, this means that the total import share as well as the shares by country of origin are assumed to be the same across industries inside the end use categories. Another important assumption that is commonly applied in input-output tables and also in the WIOD is the homogeneity of technology within industries, implying that all firms of sector *j* in country *i* are similar, and, therefore, the table depicts the average production structure in sector *j* of country *i*. These assumptions are not always plausible and have to be kept in mind when examining the data, but the data still give appealing possibilities for analyzing numerous interesting topics related to global production structure.

1.3 Summaries of the essays

1.3.1 The pass-through to consumer prices in CIS economies: the role of exchange rates, commodities and other common factors

In the first essay, we examine the transmission of international shocks to consumer prices. We consider more country-specific shocks in the form of exchange rate pass-through but also examine the roles of commodity prices and other global factors. We concentrate on seven economies that were formerly part of the Soviet Union and later associated with the CIS. Due to their geographic proximity, strong mutual economic links, and similar institutional legacies, common factors and spillover effects can be expected to have a significant impact on consumer prices in the CIS countries. As some CIS countries are relatively dependent on oil and other commodity export income, and others rely heavily on imported energy, they are all also highly vulnerable to changes in global commodity prices.

This essay provides up-to-date estimates for the pass-through effects in the CIS economies by using a methodology novel for these countries, which controls for a wider range of factors than in the previous literature and allows the disentangling of the effects of common factors and spillovers in CIS consumer price trends. We use a factor panel framework instead of the traditional VAR methodology applied in the earlier literature. This allows us to take into account a wider range of possible explanatory factors and examine asymmetries in the pass-through, despite the limited availability of data for these countries. In order to account for the effects of both idiosyncratic and common factors, we apply a mean group estimator in the panel estimation that is augmented in a way that takes into account the heterogeneity in the coefficients across individual countries and also corrects for the presence of cross-sectional dependence. The model is estimated on quarterly data covering the years 1999-2014. We also provide novel insights into asymmetry in the exchange rate pass-through in the CIS countries by using a cross-country setting in such an analysis for the first time.

Our results indicate that exchange rate pass-through is still relatively high and rapid in the CIS countries. When the nominal effective exchange rate index declines by 1%, the consumer price index increases by 0.12-0.13% over the next quarter. This effect is quite robust across several specifications and various time periods. The pass-through effect roughly doubles after two quarters and rises to about 0.5% after four quarters. Common factors also seem to affect consumer price trends in the CIS countries. We also find evidence of an asymmetrical effect in the case of exchange rate pass-through vis-à-vis the U.S. dollar, indicating that exceptionally large exchange rate shocks transmit more strongly and rapidly to consumer prices than small changes.

1.3.2 The transmission of international shocks to CIS economies: a global VAR approach

In the second essay, we examine spillover effects from foreign output shocks and oil price shocks on output in selected CIS countries. These countries are mainly small open economies, and many of them are relatively dependent on commodity exports or imports. During the past couple of decades, they have become increasingly integrated into the world economy, and, therefore, they provide an illuminating example of the importance of international shocks for domestic output.

The essay provides up-to-date estimates on the effects of foreign output shocks and oil price shocks on the output in CIS countries and analyzes the effects in more detail. We examine the magnitude of the effects by region of origin, the role of direct and indirect trade, and financial channels, as well as the temporal evolution of these effects, because the trade and financial linkages of the CIS economies have changed significantly during the past couple of decades under examination. We also provide a descriptive analysis of factors that are associated with the vulnerability of CIS countries to external shocks. Thus, the main contribution of the essay is in providing a more detailed analysis of the impacts of foreign output shocks on the output of CIS economies.

We construct a global VAR model (GVAR) comprising 30 economies (the euro area is considered to be a single unit) that, when combined, account for 80% of the global GDP in purchasing power parity terms. We examine five individual CIS economies (Azerbaijan, Belarus, Kazakhstan, Georgia, and Ukraine), whereas Russia is excluded from the CIS region because it is so much larger than the others and because we want to examine the effect of Russian output shocks on the rest of the CIS region separately. Following previous literature, each individual country model includes four domestic variables: consumer inflation, real output, nominal short-term interest rate, and real exchange rate. As foreign-specific variables, which are weakly exogenous, we use foreign output weighted with goods trade shares and foreign interest rates weighted with shares of security holdings. Both fixed and time-varying weights are used. Finally, oil price is included as a global variable. The model is estimated on quarterly data covering the time period of 2001-2016.

In line with earlier literature, we find that CIS economies are highly sensitive to both regional and global shocks, although there is wide variation across individual countries. In general, CIS economies are the most sensitive to shocks originating in the U.S. economy. During the whole time period under consideration, a 1% shock to U.S. output results in a long-term output increase of a similar size in the CIS region. Our analysis suggests that those CIS countries that have lower global trade integration and higher financial integration tend to be more vulnerable to U.S. shocks.

Our results also indicate that the sensitivity of CIS economies to global and regional shocks has changed during the past couple of decades. The sensitivity of CIS economies has increased, especially with respect to euro area shocks, from about 0.1% with 2001-2004 weights to nearly 0.8% with 2013-2016 weights. On the contrary, the response of the CIS output to U.S. shocks has slightly decreased. Finally, our results illustrate the importance of the effects arising from indirect trade and financial channels. For example, the sensitivity of the CIS economies to Chinese shocks has increased, especially due to these indirect effects with direct trade and financial linkages growing much more moderately.

1.3.3 Chinese services gaining significance in global production chains

In the third essay, we examine the role of China in global production chains with a particular focus on services. China has been a key participant in the growing international fragmentation of production during the last decades. Traditionally, China has specialized in labor-intensive manufacturing sectors and production stages, but it has been striving to shift towards higher value-added production. Another recent trend in the development of international value chains has been the increasing contribution of services to the value-added created in the production. Therefore, we want to examine the evolving role of Chinese services in international production chains. Our analysis complements the previous literature on global value chains by providing more detailed information on the significance of Chinese services in particular, and it gives additional insights into Chinese economic development in qualitative terms.

Our analysis is conducted with the input-output methodology that can be applied in quite a straightforward way in the analysis of production chains, taking into account the interlinkages between countries and sectors. We apply the standard input-output techniques to the recently compiled WIOD tables covering the years 2000-2014 and decompose the global value-added production in 2,408 country- and sector-specific value chains. This decomposition shows the origin of value-added in each chain by country and sector. Then, we analyze the characteristics and the development of Chinese value chains in comparison to other country chains. Next, we extend the analysis to the development of total value-added production and China's exports to obtain a more comprehensive view of the development and role of Chinese services. To examine the role of services in Chinese production more closely, we apply a constant market share (CMS) analysis to global value-added production and exports, decomposing the market share developments of China into competitiveness and country- and sector-related structural effects.

Our results suggest that the role of Chinese services has become more important in global value chains. The development mainly reflects the substitution of foreign service inputs with domestic ones in Chinese production chains. The share of Chinese service inputs has also increased in foreign production chains. Despite the rapid increase in the use of Chinese services, the average share of Chinese business services in foreign production chains is still relatively low compared to certain countries, like Germany and the U.S., but already close to that of Japan. The largest value-added contributions of Chinese services in foreign production chains are found in the manufacturing of machinery and equipment and particularly in certain Eastern European countries. The CMS analysis further suggests that services have also, in recent years, become a more important factor, supporting Chinese competitiveness both in domestic and foreign markets. Therefore, our results provide, on their part, support for the perception that Chinese production is gradually shifting towards higher value-added production stages.

1.3.4 Evaluating international impacts of China-specific shocks in the input-output framework

In the last essay, we evaluate the international transmission and impact of various China-specific shocks. Chinese growth has slowed down in recent years, imbalances in the economy have grown, and additional risks have arisen from international trade disputes, in particular with the U.S. As China has become one of the largest economies in the world and an essential part of global value chains, disturbances in the Chinese economy might also have important repercussions for other economies. We consider shocks to Chinese final demand at the aggregate level, bilateral import tariffs between the U.S. and China, and sector-specific shocks to Chinese final demand and supply.

We utilize the input-output framework applied to the latest WIOD table for 2014 for the analysis. Several estimates exist in the previous literature, achieved with various methodologies, for the effects of aggregate demand shocks and U.S.-China tariffs. Therefore, in this part, we also want to find out how the results from a simple and uniform input-output framework relate to the estimates from more complex methodologies. At the sector level, the previous literature is much scarcer, and, therefore, we want to examine the transmission and impact of sector-specific shocks in China on other economies. Moreover, the analysis of the international effects of sector-specific shocks contributes to the branch of literature on aggregate impacts of idiosyncratic sub-aggregate-level shocks that has gained popularity recently.

Our results suggest that aggregate-level China-specific shocks may also have important effects for several other countries, but the transmission of shocks through the global production network is relatively limited since Chinese production is not very import-intensive. A negative shock to Chinese final demand corresponding to 1% of GDP translates into an effect of -0.12-0% on GDP and if combined with a demand structure shift from investment to consumption into an effect of -0.49-0.01% on GDP for other countries. For the bilateral tariffs between the U.S. and China, we find a negative impact of -1.02% on the GDP of China and a mere -0.12% on the GDP of the U.S. Our estimates, calculated with the input-output framework, are quite close to the results presented in the previous literature regarding only short-term effects and trade channels.

Concerning sector-specific shocks, we find that in general the international impact of Chinese sector-specific final demand and supply shocks is relatively modest at the aggregate level. There are, however, a few Chinese sectors that can induce larger effects. Our results suggest that a 10% negative shock to the Chinese final demand for electronics would result in an effect of -0.17% on the GDP of Korea and a corresponding shock to the Chinese output of basic metals with an effect of -0.16% for Australia. Moreover, the aggregate impact could be higher when also including additional effects from commodity prices and financial markets, which cannot be taken into account in our framework. Therefore, our results also provide support for the view that idiosyncratic shocks might also be important at the aggregate level in the international context.

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I

The Pass-Through to Consumer Prices in CIS Economies: The Role of Exchange Rates, Commodities and Other Common Factors

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2 ESSAY 1: THE PASS-THROUGH TO CONSUMER PRICES IN CIS ECONOMIES: THE ROLE OF EXCHANGE RATES, COMMODITIES AND OTHER COMMON FACTORS

Abstract

This empirical study considers the pass-through of key nominal exchange rates and commodity prices to consumer prices in the Commonwealth of Independent States (CIS), taking into account the effect of idiosyncratic and common factors influencing prices. In order to do that, given the relatively short window of available quarterly observations (1999–2014), we choose heterogeneous panel frameworks and control for cross-sectional dependence. The exchange rate pass-through is found to be relatively high and rapid for CIS countries in the case of the nominal effective exchange rate, but not significant for the bilateral rate with the US dollar. We also show that global factors in combination with financial gaps and commodity prices are important. In the case of large rate swings, the exchange rate pass-through of the bilateral rate with the US dollar becomes significant and similar to that of the nominal effective exchange rate.

Keywords: Commonwealth of independent states, Exchange rate pass-through, Commodity prices, Dynamic panel data, Inflation, Exchange rates, Cross-sectional dependence, Financial cycle

JEL classification: C38, E31, F31

2.1 Introduction

The Commonwealth of Independent States (CIS) countries, a group of twelve former Soviet republics2 provides an interesting and topical, but relatively little studied object for examining exchange rate pass-through (ERPT). We concentrate only on seven of them (Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyz Republic, Russia, and Ukraine) due to data limitations. During the early 2000s, the CIS countries enjoyed high economic growth combined with relatively high, but slowing inflation. For the most part they maintained inflexible exchange rate policies. Many CIS countries were hit hard by the global financial crisis and since then have experienced substantial fluctuations in their exchange rates followed by rising inflation. Given that some CIS countries recently shifted to inflation targeting in their monetary policy (Armenia in 2008, Georgia in 2010 and Russia in 2014), and several more are planning the shift, policymakers stand to benefit from an improved understanding of the magnitude and timing of effects on prices from exchange rate changes. The importance of ERPT in CIS inflation trends has been established in a few previous studies, but literature on the topic is still relatively scarce, especially concerning cross-country ERPT analyses. Although there are obvious limitations related to estimates based on historical data during a regime shift or otherwise exceptional event, establishing baseline estimate as solid as possible can in any case help to assess also the current situation.

Therefore, our aim is to provide up-to-date estimates for exchange rate pass-through to the consumer price index (CPI) in CIS countries. To accomplish this, we apply a novel methodology and control for a wider range factors than those mentioned in the literature. In particular, we try to disentangle the impact of common global factors and spillovers in CIS consumer price trends.[3] To our best knowledge, this is the first such study of CIS countries. Due to their geographic proximity, strong economic links and similar institutional legacies, common factors and spillover effects can be expected to play a significant role in CIS ERPTs. As some CIS countries depend on oil and other commodity export income and others rely heavily on imported energy, they all are also highly vulnerable to changes in global commodity prices. As we want to account for the effects of both idiosyncratic

2 Ukraine and Turkmenistan have never been formal members. Georgia canceled its membership in 2008.

3 The common factors here are key and may be related to global crises or other factors which may influence all the countries and partners (i.e. strong cross-sectional dependence).

and common factors influencing the consumer prices in the CIS economies, the short time span of the available data limits the use of traditional VAR approach. Thus, we use a factor panel framework instead of the traditional VAR approach seen in earlier research.[4] For our panel estimation, we use a mean group (MG) estimator augmented in a way that takes into account the heterogeneity in the coefficients across individual countries and also corrects for the presence of cross-sectional dependence (serial correlation in the idiosyncratic errors). Recent developments in the CIS countries include episodes of strong devaluation, so we also examine for possible asymmetries related to ERPT. As there is currently no similar research in a cross-country setting for the CIS countries, our results provide novel insights into this issue. Moreover, they improve the relevance of our results for the current discussion of ERPT in CIS countries.

We find that exchange rate pass-through is still relatively high and rapid in the CIS countries. When the nominal effective exchange rate index declines by 1%, the consumer price index increases by 0.12–0.13 % over the next quarter. This effect is quite robust across a variety of specifications and time periods. The pass-through effect roughly doubles after two quarters, and rises to about 0.5 % after four quarters.[5] Common factors and the financial gap also seem to be important in consumer price trends of the CIS countries. Finally, we present evidence of an asymmetrical effect in case of exchange rate vis-à-vis the US dollar. The paper is organized as follows. Section 2 reviews earlier literature on the topic. Our theoretical framework is presented in Section 3. Our empirical methodology and data are described in Section 4. Section 5 provides our estimation results and discussion for the implications of the results. Section 6 concludes.

2.2 Literature review

Exchange rate pass-through is defined as the elasticity of local currency prices with respect to the exchange rate. It first affects import prices (Stage 1 ERPT), but then can be passed on to producer (Stage 2 ERPT) and consumer prices (ERPT overall). Normally ERPT should decline along this pricing chain. Assuming markets are perfectly competitive, prices fully flexible, and the law of one price holds, ERPT should be complete (i.e. the import price elasticity w.r.t. exchange rate should be

[4] A VAR setup is provided as a robustness check.

[5] In the rest of the paper we will report ERPTs to a 100% change in the exchange rate.

one) and immediate. Deviations from the benchmark situation can cause the pass-through to be incomplete (elasticity less than one) or at least gradual.

The most common theoretical framework applied in depicting the frictions related to ERPT comes from the pricing-to-market literature developed by e.g. Krugman (1987), Knetter (1989), and Feenstra et al. (1996). In this framework, exporting firms maximize profits by setting their export prices subject to the competitive conditions they face in foreign markets. With some monopoly power, firms can price discriminate across countries, letting their profit margins rather than foreign currency prices fluctuate in response to changes in exchange rates. Adjusting mark-ups gives firms the possibility to ensure a stable market share. Other frictions that can prevent complete and instantaneous pass-through include trade costs such as transport costs, tariffs, and other trade barriers (Obstfeld and Rogoff, 2000) and price stickiness (Devereux and Yetman, 2002; Burstein et al., 2003).

Empirical studies show ERPT is usually incomplete and gradual. Pass-through is highest for import prices and lowest for consumer prices, which include most non-tradables that are unaffected or are less affected by exchange rate changes. Cross-country variation in pass-through is high. Many studies point to higher ERPT in emerging economies than in advanced economies, although it could be that this only reflects differences in the level of inflation between countries (Aron et al., 2014). In any case, the vast body of empirical literature on ERPT mainly deals with industrialized countries. A survey of literature examining ERPT in emerging markets (Aron et al., 2014), finds quite heterogeneous ERPTs, especially at the country level, and that the comparability of results is hindered by differing methodologies and assumptions used in estimations. The authors suggest that the wide variety of ERPT estimates may be due to methodological deficiencies in earlier research as well as a lack of appropriate control variables. Cross-country studies of CIS countries on the subject are rare. The most relevant results to this study are presented in Table 2. Roughly speaking; we can say ERPT in emerging markets, for a 100% changes in the exchange rate, has been in the range of 5–20 % after one quarter, 20–30 % after four quarters, and 30–50 % over the longer term.

Despite the paucity of papers and varied results of earlier literature on CIS countries in particular, there are indications that the ERPT might be slightly higher for these countries than other emerging markets. The first cross-country comparison that included several CIS countries, Korhonen and Wachtel (2005), estimates VARs for consumer prices in several emerging markets for the period 1999–2004. Their results suggest that exchange rate pass-through is high and relatively rapid in most CIS countries, but there is large heterogeneity among countries. Exchange rate pass-through is also found to be higher in many CIS countries than in other emerging markets, but some of coefficients are of the wrong sign or implausibly high. As these problems seem to be associated mainly with oil exporting countries, the authors suggest discrepancies might be due to the interaction of oil prices, exchange rates, and inflation.

Table 2. Earlier estimates of ERPT to CPI in emerging economies (Q =quarters).

Study, sample, period, exchange rate measure and methodology	ERPT after one quarter	ERPT after two quarters	ERPT after four quarters	ERPT over long term
IMF (2015), 28 EM, 1980-2014, NEER, panel			22 %	25% (8Q)
Beckmann & Fidrmuc (2013), 7 CIS countries, 1999–2010, USD, VAR/panel (lt) *			26 %	57 %
Jimborean (2013), 10 CEE countries, 1996–2010, NEER, panel/single equation by country **	7 %			
Kohlscheen (2010), 8 emerging floaters, periods within 1994–2008, NEER, VAR	5 %	17 %	24 %	
Beirne & Biejsterboch (2009), 9 CEE countries, between 1995–2008, NEER, VAR		17 %	26 %	61 %
Mihaljek & Klau (2008), 14 EM, 1994–2006, NEER, single equation by country	12 %			
Ca'Zorzi et al. (2007), 12 EM, 1975–2004, NEER, VAR			24 %	45% (8Q)
Choudhri & Hakura (2006), 71 countries (52 EM/DM), 1979–2000, NEER, panel	14 %		24 %	27% (20Q)
Korhonen & Wachtel (2006), 27 EM, 1999–2004, USD, VAR ***			6 %	6% (8Q)
Bitans (2004), 13 EU NMS, 1998–2003, NEER, VAR	22 %	28 %	31 %	33% (8Q)
Goldfajn & Werlang (2000), 71 countries (24 EM), 1980–1998, NEER, panel		39 %	91 %	

* ERPT for four quarters refers to our calculated average.
** ERPT refers to our calculated average from individual country estimations.
*** ERPT refers to our median calculation.

Beirne and Bijsterboch (2009) and Jimborean (2011) examine ERPT in new EU member states of Central and Eastern Europe (CEE). Beirne and Bijsterboch (2009), using a cointegrated VAR framework for nine CEE countries during 1995–2008, put the average long-term pass-through to CPI at around 60 %. There are noticeable differences across countries, however. They find higher or even complete pass-through for those countries that have fixed exchange rate regimes compared to countries with more flexible regimes. Jimborean (2011) examines ERPT to import, producer, and consumer prices for a panel of ten CEE countries in the period 1996–

2010. Using GMM estimation, she establishes statistically significant pass-through only for import prices, both in the short and long run. For consumer prices, she finds, even in the individual country examination, statistically significant pass-through of around 20–30 % in the first quarter for only a few countries.

To our knowledge, the most recent paper examining multiple CIS countries is Beckmann and Fidrmuc (2013). They estimate VARs for consumer prices for seven CIS countries for a short-run estimate of pass-through, then extend the analysis to a panel cointegration framework for long-run analysis. For 1999–2010, they find that the average pass-through after one year was 30–50% for the dollar and around 20% for the euro. The long-run pass-through was around 60 % for both currencies. Again, they note wide heterogeneity among CIS countries and the results are not statistically significant for each individual country.

There are several papers focusing on exchange rate pass-through in specific CIS countries, mainly Russia. The studies for Russia, for example, provide quite a wide variety of estimates for ERPT (Dobrynskaya and Levando, 2005; Beck and Barnard 2009; Kataranova, 2010; Ponomarev et al., 2014). The estimates of ERPT to CPI for USD range between 5 and 40% after one quarter, and between 20 and 90% after four quarters. Faryna (2016) examines Russia and Ukraine, putting the ERPT for Russian CPI at 10–17% and for Ukrainian CPI at 20–40% for the dollar, euro and NEER, as well as significant spillover effects from Russia to Ukraine. Several papers deal with the significance of exchange rate pass-through for inflation in other individual CIS countries e.g. Georgia (Samkharadze, 2008).

There is ample research on factors influencing ERPT. A lower inflation rate has been found in numerous papers to be associated with lower ERPT, implying that a credible inflation targeting policy can reduce ERPT (Taylor, 2000; Gagnon and Ihrig, 2004; Bailliu and Fujii, 2004; Bitans, 2004; Choudhri and Hakura, 2006; Barhoumi and Jouini, 2008). The impact of the exchange rate regime and volatility of the exchange rate on ERPT has also been examined, but the conclusions are mixed. For emerging markets, higher exchange rate volatility is found to be associated with higher pass-through (Ca'Zorzi et al., 2007; Bussière and Peltonen, 2008; Kohlscheen, 2010). Some studies suggest that more flexible exchange rate regime tends to decrease ERPT in emerging markets (Beirne and Bijsterboch, 2009; Coulibali and Kempf, 2010). Aron et al. (2014) argue that this might be related to difficulties in disentangling the effects of the exchange rate regime.

Although ERPT is usually assumed to be linear, there is evidence on asymmetric effects. The asymmetry can be directional with different proportional effects on inflation from currency depreciation and appreciation. Directional asymmetry is associated with strategic considerations or downward price rigidities. The asymmetry can also be related to size, i.e. large movements in exchange rates can lead to proportionally larger changes in domestic prices than smaller movements due e.g. to menu costs. Significant asymmetries have been found for advanced economies (Pollard and Coughlin, 2004; Bussière, 2007; Campa and Goldberg, 2008). For emerging economies, the evidence is mixed, but it seems that depreciation may lead to stronger ERPT than appreciation and that large devaluations are associated with stronger than proportionate ERPT (Mihaljek and Krau, 2008; Razafimahefa, 2012; International Monetary Fund, 2015). Among CIS countries, asymmetric effects have been found at least for Russia (Kataranova, 2010; Ponomarev et al., 2014).

2.3 Theoretical framework

Following the model of Bailliu and Fujii (2004), we create a framework based on the pricing behavior of a profit-maximizing exporting firm. In this case, the exporting firm is from the United States and the import partner is a CIS country. The firm decides the price of its good, taking into account this static maximization function:

$$max_p: \pi = \frac{1}{s}(p \cdot q) - C(q), \tag{1}$$

where π is the profit to be maximized in US dollars, 1/s the bilateral exchange rate (measured in units of dollars per one national currency), p the price of good in national currency, q the quantity of good demanded by the CIS country, and C(q) the costs faced by the US firm.

This maximization is solved by a first-order condition:

$$FoC: \frac{\partial \pi}{\partial q} = 0 = \left(p \cdot \frac{1}{s}\right) - \frac{\partial \pi}{\partial C(q)} \cdot \frac{\partial C(q)}{\partial q}, \tag{2}$$

that gives the optimum price for the good for the US exporting firm to the CIS partner:

$$p^{opt} = MC \cdot s \cdot \mu, \tag{3}$$

where MC is the marginal cost (= ∂C(q)/∂q) of the quantity of good q and μ is the markup of price over the marginal cost (= ∂π/ ∂C(q)).

Log-linearizing the equation and taking $\eta = -\mu/(1-\mu)$ as the price elasticity of demand for the good (where μ is the mark-up), we have a simple log-linear, reduced-form of the equation, expressed as

$$p_t = \alpha + \beta s_t + \tau w_t + \eta y_t + \varepsilon_t, \quad (4)$$

where s is the nominal exchange rate (measured in units of national currency per one dollar), w is a variable for the foreign marginal cost and y is the domestic output gap.[6] The coefficient β thus measures ERPT.

Bailliu and Fujii (2004) estimate this equation with a GMM methodology,[7] which they apply to three dependent variables in first differences: import prices, producer prices, and consumer prices. Prices are regressed on their lags, on country and time dummy variables, on the nominal effective exchange rate, on the exchange rate interacted with two policy dummy variables indicating shifts in the inflation environment in the 1980s and 1990s, respectively, on foreign unit labor cost,[8] and on the output gap. As Eq. (4) was developed for import prices, the output gap is used to proxy for changes in domestic demand conditions to make it applicable to consumer price inflation. As noted by Bailliu and Fujii (2004), the equation for CPI inflation has all the elements of a backward looking Phillips curve.

We elaborate a similar model to this standard pass-through specification described in Eq. (4) for the CPI level (in logs). In our baseline specification, we use as our nominal exchange rate variable NEER vis-à-vis 67 partners in order to avoid possible biases related to the use of bilateral rates (Menon, 1995; Aron et al., 2014). As a robustness check, we include instead the bilateral rates between the currency of the country of interest and the USD.

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[6] Following Goldberg and Knetter (1997), all variables, except the gaps, are in logs.

[7] The authors stress that the standard estimators for a dynamic panel-data model with fixed effects generates estimates that are biased when the time dimension of the panel is small. Following Judson and Owen (1999), this bias can be sizable even when the number of observations per cross-sectional unit (T) reaches 20 or 30. Therefore, given that the panel-data set in Bailliu and Fujii (2004) has T= 25, the standard fixed-effects model would yield biased estimates. To overcome this problem, we use Arellano and Bond's dynamic panel-data GMM estimator, which also gives unbiased estimations when one or more of the explanatory variables are assumed to be endogenous rather than exogenous.

8 This is constructed from the real effective exchange rate deflated by unit labor costs, subtracting the nominal effective exchange rate and adding domestic unit labor costs.

As a control for changes in domestic demand conditions, we apply in the baseline specification the standard output gap. The output gap in the equation of profit maximization comes from the quantity of good demanded by the CIS country, based on regular business cycle fluctuations. However, the quantity demanded can be function of longer cycles (see Comunale and Hessel, 2014). Mendoza and Terrones (2012), for example, show that credit booms tend to boost domestic demand and widen external deficits, thereby increasing imports. Similar trends have been seen in CIS countries in recent decades as noted above in Section 2. Therefore, we also replace the output gap with its financial counterpart in our alternative specifications.[9] Moreover, as recently pointed out by Gilchrist and Zakrajšek (2015), financial frictions influence the cyclical dynamics of prices.[10] Financial distortions create an incentive for firms to raise prices in response to adverse demand or financial shocks (Gilchrist et al., 2015). Hence, the financial gap/cycle may be a factor to consider in assessing inflation dynamics.

We extend our baseline specification to include a dummy for the de facto exchange rate regime, which earlier research suggests can influence ERPT. We also do this to check for the role of commodity prices separately due to their high importance in foreign trade and the domestic economies of most CIS countries. Thus, we also include in most specifications overall commodity prices or non-energy and energy prices separately.

This framework follows the structure of a typical single-equation dynamic panel data model with lagged dependent variables, i.e. the ARDL or Autoregressive Distributed Lag Model in the spirit of Comunale (2015a). The introduction of lags is crucial in controlling for the dynamics of the process, allowing for price inertia (Bailliu and Fujii, 2004), because it is unlikely that prices completely adjust within one period especially at quarterly frequency (Bussière, 2007). We also introduce a lagged effect of exchange rates on current consumer prices as in Campa and Goldberg (2005). We use one lag for the dependent variable and one lag for the

9 As explained in Claessens et al. (2011a, 2011b) there is a strong relationship between the financial and the business cycle. Thus, having them together as explanatory variables is not in our view the best choice. Moreover, this cannot be done for the financial cycle based on real GDP data, because they would be computed on the same data series.

10 The paper focuses on producer prices. Inflation declines substantially less in response to a tightening of financial conditions in industries where firms are more likely to face significant financial frictions.

exchange rate, following the SBIC selection criterion,[11] so that the reaction of prices to a change in the exchange rate will take one period, i.e. three months.

The equation is given as

$$p_{i,t} = \gamma_{1i} p_{i,t-1} + \beta_i s_{i,t-1} + \tau_i fmc_{i,t} + \eta_i gap_{i,t} + \psi_i X_{i,t} + \omega_i regime_{i,t} + \varepsilon_{i,t}, \qquad (5)$$

where s is the nominal exchange rate (in our case, a weighted-basket of partner currencies or USD per national currency unit),[12] fmc the foreign marginal cost taken as a trade weighted measure of partners' Producer Price Index (PPI), and gap the output gap relative to the potential value or the financial gap constructed using a higher lambda in HP filtering the real GDP (400,000 instead of the regular 1600).[13] We then add commodity prices (X), i.e. general commodity prices, non-energy prices or energy prices; and a dummy for the de facto exchange rate regime (regime). All variables, except the gaps, are in logs.

The aggregate price level and the exchange rate are generally assumed to follow I (1) processes, i.e. not stationary (see test in Section 5 and the results in Table A2). It is common to use a specification with these two variables in first-difference form when estimating an aggregate inflation equation (e.g. Bailliu and Fujii, 2004). We apply Eq. (5) in levels using an estimator that controls for cross-sectional dependence and is suitable for cointegrated panels (Eberhardt and Teal, 2010), as well as in a robustness check analysis, where we provide it in first differences (also following Eberhardt and Teal, 2010). In the latter, the dependent variable is CPI inflation (first difference of CPI index) and the ERPT is the elasticity of inflation to a 1 % change in the exchange rate.

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[11] The optimum number of lags has been calculated by SBIC selection criterion (which is based on Schwarz's Bayesian Information Criterion), because it has been proven to work better with any sample size for quarterly data (Ivanov and Kilian, 2001).

[12] The sign of the bilateral rate and NEER is therefore expected to be negative. This is taken as 1/s in Eq. (1).

[13] For more details about financial cycle measures, see Comunale and Hessel (2014) or Comunale (2015b).

2.4 Empirical methodology and data

2.4.1 Data sources and description

In our empirical analysis, we use data with quarterly frequency that covers the period from 1999Q1 to 2014Q4. We begin with 1999 as most of the 1990s was a turbulent time for CIS countries. It took several years to adjust to the collapse of the Soviet Union and embarking on the transition from planned to market economy. Lack of data limits our study to seven CIS countries: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyz Republic, Russian Federation, and Ukraine.

We use consumer price from the Consumer Price Index (CPI) from IMF International Financial Statistics (IFS, index 2010=100) for all countries but Azerbaijan (for which we use IMF IFS data on percentage change from previous period to construct the index). The bilateral exchange rate vis-à-vis the USD is taken from the IMF IFS database and defined as national currency per USD, period average. We use instead the number of USD for one national currency unit in order to compare the bilateral rate with the NEER. The NEERs vis-à-vis 67 partners are from the database of Darvas (2012). We transform annual data in quarterly frequency data using cubic spline and rebase as an index 2010=100. The NEER here is expressed as the amount of a weighted basket of partner currencies per unit of national currency.

The foreign marginal cost is a trade-weighted average of partner Producer Price Index (PPI). We built the trade weights, vis-à-vis the same partners as in the NEER, from IMF Direction of Trade Statistics (DOTS). The data for partner PPIs are from IMF IFS (index 2010=100). The de facto exchange rate regime dummy is equal to one when the regime is fixed or intermediate (managed arrangements included). The (annual) information on the regimes is taken from Reinhart and Rogoff (1999–2010)14 and the IMF's 2011–2014 Annual Reports on Exchange Arrangements and Exchange Restrictions. World commodity prices are from IMF IFS (index 2010=100). We distinguish total commodity prices, non-energy prices, and energy prices.

[14] For the exchange rate regime, we use IMF and Reinhart-Rogoff de facto exchange rate regime classification (FINE and COARSE, respectively). The 1999–2010 data are taken from Reinhart and Rogoff (http://personal.lse.ac.uk/ilzetzki/IRRBack.htm)

The output gap and the financial gap are computed using real GDP (index 2010=100) data. The real GDP series have been seasonally adjusted.[15] For Georgia, Kyrgyz Republic, Russian Federation, and Ukraine, the data are taken from IMF IFS. For Armenia, Azerbaijan, and Kazakhstan, they are taken from CISSTAT (with own calculation). The output gap is computed as the difference between actual real GDP and HP-filtered real GDP (the lambda for the HP filter here is equal 1600, i.e. we have a regular short-term business cycle). As a proxy for a longer financial cycle (Alessi and Detken, 2009; Drehmann et al., 2010), we use a higher value for lambda (400,000) to filter the real GDP data.[16,17]

Table 3. Short and long-term ERPT to consumer prices in CIS economies using NEER.

Specification	Short-run ERPT (one quarter)	2-quarter ERPT (computed as in Jimborean, 2013)	Long-run ERPT (four quarters cumulative)
Baseline: Tables 3 and 4			
Table 3 Column (4) NEER; output gap; commodity prices	13.4%	30.0%	53.6%
Table 4 Column (4) NEER; financial gap; commodity prices	12.8%	28.8%	51.2%
Alternative specifications[18]			
Table 6a Column (4) NEER; financial gap; commodity prices **1999-2008**	15.1%	27.3%	60.4%
Table 6b Column (4) NEER; financial gap; commodity prices **2009-2014**	14.3%	17.6%	57.2%
Table 5a Column (4) NEER; financial gap; **without commodity prices**	17.0%	37.9%	68.0%
Table 13 Column (4) NEER; financial gap; **commodity prices; Russia excluded**	15.6%	28.7%	62.4%

[15] The series have been seasonally adjusted using X11 in RATS, which is an implementation of the Census Bureau's X11 seasonal adjustment procedure.

[16] For details about financial cycle/gaps measures, see Comunale and Hessel (2014) for the euro area or Comunale (2015b) for EU and OECD countries. A comparison with different measures for financial cycle is also provided in these studies (e.g. with lambda set at 100,000 for GDP or domestic demand, as well as a principal component analysis to compute a synthetic indicator).

[17] Even if this measure it may not have the exact same properties of house price cycles or credit cycles, we believe it is the closest proxy given data availability. Indeed, compared to methods for capturing the business cycle or output gap, there is little consensus in how to properly measure the financial cycle. Even our decision to start with 1999 data may affect our efforts to capture a long cycle. However, we should stress here that the role of cyclical components relates to financial behavior in any case. This is especially important for inflation in the pre- and post-global crisis periods. In any case, the results for ERPTs are robust whether we use output gap or our proxy for the financial gap.

[18] The results with output gaps are very similar in magnitude.

We include the Openness Index (OI) as a control variable in specification with USD to study the influence of openness toward trading partners outside the CIS. We only do this for specification with USD, since the trade composition is not included in the model (it is in the model that uses the NEER). Following Rogers (2002) our OI is as follows: OI =[Trade with World − Intra-CIS Trade]/ GDP. The trade data are taken from IMF DOTS. We apply the same concept to control for the trade within the CIS countries considered. Here, the index is computed as Intra-CIS Trade over GDP. Comparing openness within the CIS and with the rest of the world gives some idea of the role of spillovers and other global factors related to trade.

We also add the quarterly volatilities of NEER and bilateral exchange rate vis-à-vis the USD in our baseline. The calculation follows Hau (2002) in Eq. (6). The volatilities are built on monthly data with T =4 as a modified version of Hau (2002) to obtain the quarterly frequency. These are defined as the standard deviation for the percentage changes of the REER and NEER over intervals of three months. The data for the USD rates are taken daily and averaged to monthly level. The source is Macrobond FX Spot Rates.[19] For the NEER, the monthly data are taken from the database of Darvas (2012)[20] vis-à-vis 41 or 138 partners.[21]

$$VOL_{quarterly,i} = \left[\frac{1}{T}\sum_i \left(\frac{ER_{t+3,i}-ER_{t,i}}{ER_{t,i}}\right)^2\right]^{\frac{1}{2}}, \tag{6}$$

where ER can be either the NEER vis-à-vis 41 or 138 partners or the exchange rate vis-à-vis the USD.

2.4.2 Empirical diagnostics and methodology

Two approaches are generally used for estimating exchange rate pass-through. The first group of models includes the (S)VAR (Structural Vector Auto Regressive) models applied e.g. in McCarthy (1999), and the Bayesian versions with Cholesky or sign restrictions e.g. An and Wang (2012), Jovičić and Kunovac (2015) for small open

[19] Values represents a 16:00 GMT/BST snapshot of real-time interbank currency exchange rates contributed to GTIS Corporation, part of the FT Interactive Data Group, by leading market-making institutions worldwide.

[20] Dataset version updated at on November 25, 2015.

[21] The list of the partners is available in Darvas (2012).

economies, and Comunale and Kunovac (2017) for the euro area and main members separately. These methodologies are applied country by country. The second group uses panel regressions as in e.g. Bailliu and Fujii (2004), and Beckmann and Fidrmuc (2013). The SVAR approach analyzes the impact of exchange rate shocks on prices country by country by using the impulse response functions (IRFs). Its main limitation, for the non-Bayesian traditional VAR, is low effectiveness in short periods of analysis, as in our case. Moreover, our aim here is to build a framework that allows us to look at the idiosyncratic and common factors influencing consumer prices in the CIS economies.

A panel approach, even within a short observation span, allows us to take these countries as a whole while maintaining their heterogeneity in the coefficients. Indeed, if we were to take into account the full interdependencies inside the panel and the heterogeneous dynamics, we must remember that we cannot estimate our setup unrestrictedly as the number of parameters is greater than the number of data points. We can deal with these issues by imposing restrictions (e.g. Global VARs), a change in the setup (e.g. use a factor model from a panel data setup as in our case), or with a Bayesian VAR by using a partial pooling estimator or a factor structure (e.g. Canova and Ciccarelli, 2013).

In a single-equation panel regression model with lagged endogenous variables, the fixed effects estimator (FE) has been proven inconsistent for finite T (Nickell, 1981). The bias in a dynamic FE estimator only with a large enough T is negligible (Roodman, 2009a). Even if we accept this formulation, however, there is the further problem of endogeneity between the dependent variable and its lag and among explanatory variables such as between exchange rate and output gap.[22] Addressing this issue, we note that the moment conditions of the GMM estimators are only valid if there is no serial correlation in the idiosyncratic errors. In addition, GMM methodologies work only if slope coefficients are invariant across the individuals.

In the case of cross-sectional dependence, there are variables and/or residual correlations across panel entities that are normally due to common global shocks (e.g. recession, fiscal crisis) or spillover effects. Cross-sectional dependence (CSD) and heterogeneity in the slopes can lead to bias in tests results (contemporaneous correlation), not precise estimates and identification problems. Sarafidis and Wansbeek (2012) offer two methods to deal with cross-sectional dependent panel data: spatial models and dynamic factor models. In spatial econometrics, you know how entities are correlated, so you model that. A simple case would be to model the

[22] See Honohan and Lane (2004), page 4.

neighborhood. In dynamic factor models (a.k.a. interactive models or common factor models), there exists an unobserved common component in the disturbance. This affects modeled entities differently and varies over time.

Using the test developed by Pesaran (2004), we find that the hypothesis of cross-sectional independence in our dynamic panel is strongly rejected. This take use IV-GMM methods off the table, even without mentioning the fact that we also want to maintain heterogeneity across the units.[23] Using the CIPS test, we further find that some variables in our dynamic panel are non-stationary.[24] The exchange rates and the commodity prices are non-stationary in all the series, which means we accept the null hypothesis of non-stationarity; while for the dependent variable (log of CPI) we cannot reject the null (see Table A2).[25]

To overcome the limitations of IV-GMM models, Pesaran and Tosetti (2011) propose three estimators: the CCE (Common Correlated Effects) estimator, the CCEP (its pooled version), and the CCEMG (CCE Mean Group). The last estimator seems most effective in dealing with cross-sectional dependencies in both the case of spatial spillovers and unobserved common factors, and in the case of heterogeneity in slopes. The CCEMG estimator allows for the empirical setup with cross sectional dependence, time-variant unobservable factors with heterogeneous impact across panel members, and fixes problems of identification.

Eberhardt and Teal (2010) offer an alternative estimator to the CCEMG − an Augmented Mean Group (AMG) estimator – that deals with dynamic, cross-sectional dependent panels with heterogeneous coefficients and allows for cointegration.[26] The CCEMG treats the set of unobservable common factors as a nuisance, something to be accounted for which is not of particular interest for the empirical analysis. The AMG, in contrast, can be useful for the estimation of CPI, given that common factors here are key and may be related to global crises (i.e. strong cross-sectional dependence) or spillovers among the CIS countries (i.e. weak cross-sectional dependence). Commodity prices are treated as observed common factors

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[23] We include in the robustness checks the estimations by using a two-step system IV-GMM.

[24] This is a second generation t-test proposed by Pesaran (2007), which is built for analysis of unit roots in heterogeneous panel setups with cross-sectional dependence. Null hypothesis assumes that all series are non-stationary. This t-test, based on Augmented Dickey-Fuller statistics as Im, Pesaran and Shin (2003), is augmented with the cross-section averages of lagged levels and first differences of the individual series (CADF statistics). For the dependent variable and its lags, we cannot accept the null. In other cases, it is strongly rejected.

[25] In the case of CPI, we find a p value=0.148, i.e. we are very close to reject the null but not enough statistically at 10%.

[26] See also Eberhardt (2012) for some examples and Stata code xtmg.

in this model, and, given their importance in the countries of interest, explicitly included in the regression as explanatory variables.[27]

Thus, we provide our estimations using the AMG estimator. It takes into account the crucial importance of other global factors and spillovers for CPI. All these various estimators are designed for micro-panel models with "large T, small N" (Roodman, 2009b). Here, we have seven countries and 16 years with quarterly frequency (T = 64), therefore we consider that this command fixes the problems of our panel setting.

To explain the chosen estimator, we need to describe a general specification of the factor model. Following Pesaran and Tosetti (2011), this can be written as[28]

$$y_{i,t} = \alpha_i + \delta_i d_t + \beta_i x_{it} + \gamma_i f_t + e_{it}, \tag{7}$$

where $d_t = (d_{1t},\ldots,d_{nt})$is the vector of observed common effects, x_{it} is the vector of observed individual effects, and f_t is a vector of m unobserved common factors that affect all individuals at different times and to different degrees allowing for heterogeneity in the slope represented by the vector $\gamma_i = (\gamma_{i1},\ldots,\gamma_{im})$.

Given this dynamic factor model, we apply our AMG estimator. The AMG procedure is implemented in two steps (Eberhardt, 2012). In Stage (i), a pooled regression model augmented with year dummies is estimated by first difference OLS and the coefficients on the (differenced) year dummies are collected. These represent an estimated cross-group average of the evolution of unobservable factors over time, or "common dynamic process." In Stage (ii), the group-specific regression model is augmented with the common dynamic process: either a) as an explicit variable (in which we impose an additional covariate to make these factors explicit), or b) imposed on each group member with a unit coefficient by subtracting the estimated process from the dependent variable. As in the MG case, each regression model includes an intercept that captures time-invariant fixed effects. As in the CCEMG estimators, the group-specific model parameters are averaged across the panel.

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27 As reported in Eberhardt (2012), in MonteCarlo simulations (see also Eberhardt and Bond, 2009), the AMG and CCEMG performed similarly well in terms of bias or root mean squared error (RMSE) in panels with non-stationary variables (cointegrated and not) and multifactor error terms (cross-section dependence).

28 The main hypothesis of the model is that the number of factors cannot be more than the number of individuals.

We sum up the two stages for the AMG estimator, a modified version of Eberhardt and Teal (2010),[29] in the following Eqs. (8) and (9):

Stage (i):

$$y_{it} = \delta' \Delta d_t + \beta' \Delta x_{it} + \sum_{t=2}^{T} c_t \Delta D_t + e_{it}, \tag{8}$$

where d_t represents the observed common effects, D_t are the $(T-1)$ year dummies and c_t their time-varying coefficients. This is when the common dynamic process is extracted, as year dummy estimated coefficients by first difference OLS ($\hat{c}_t \equiv \hat{\mu}_t^*$) and represents the level-equivalent mean evolution of these unobserved common factors across all the countries.

Next, we apply Stage (ii):

$$y_{it} = \alpha_i + \delta_i d_t + \beta_i x_{it} + c_i t + \gamma_i \hat{\mu}_t^* + e_{it}, \tag{9}$$

We provide Stage (ii) in levels, the standard for AMG estimates. In the robustness checks, we use the equation in first differences and apply the AMG. This ends up being similar to the Augmented Random Coefficient Model (ARCM), which involves the Swamy (1970) estimator with $\Delta\hat{\mu}_t^*$.

We can therefore rewrite our general factor model as in Eq. (8) replacing ft with $\hat{\mu}_t^*$ (and it will be $\Delta\hat{\mu}_t^*$ in first differences).[30]

$$y_{it} = \alpha_i + b_i x_{it} + \gamma_i \hat{\mu}_t^* + \delta_i d_t + e_{it}, \tag{10}$$

The observed common effects across the units (d_t) are commodity prices. The idiosyncratic effects (x_{it}) are the exchange rates (vis-à-vis the USD or a basket of currencies as in the NEER), foreign marginal cost, the gap, and the de facto regime.

[29] We included here a vector of observed common effects, separated from the time dummies, to have commodity prices in our setup.

[30] In Eq. (10), we do not include the linear trend (c_{it}) in our estimations as in the baseline setup we have other observed common effects, such as commodity prices, that might share and make explicit the same trend. In the robustness checks without commodity prices, this linear trend term is instead included.

2.5 Results

2.5.1 Baseline estimation results

Our baseline estimation includes the lagged CPI index, the nominal exchange rate as measured by NEER, foreign marginal costs as measured by trade-weighted PPIs, domestic demand conditions proxied by the output gap, and the exchange rate regime. The output gap does not seem to be statistically significant. We replace it with the financial gap, which turns out to be highly significant in many of our specifications. The CPI seems to be more affected by financially-related fluctuations than the regular business cycle. Although slightly puzzling, this result is in line with Comunale (2015b). Hence, our preferred specification includes domestic demand conditions proxied by the financial gap. We also find that commodity prices, and energy prices in particular, are highly significant.

It should be emphasized, however, that the ERPT coefficient is of quite similar magnitude in all of our specifications. Our preferred specification suggests that the ERPT for NEER in the CIS countries is 13% in the first quarter, while it ranges between 13% and 17% in our alternative specifications.

Spillovers and global factors appear to be important for consumer price trends of CIS countries. Because we are interested in the significance of these common factors, we opt for AMG in our dynamic factor model. Specifically, there is a strong likelihood that unobserved common factors may affect our estimations in the case of consumer prices and can be related to some of our regressors, e.g. to the gaps. In this case, the impact of financial crisis and other shocks in the global economy may be captured by these unobserved common factors (i.e. strong-cross sectional dependence).

Our setup takes into account commodity prices, so we have also some observed common factors. This cannot cover all the possible other global influences related to our setup, and moreover, unobserved common factors include spillovers among the individuals in the panel. Indeed, the close relationships between CIS economies have to be taken into consideration in determining the price development and ERPTs (i.e. weak cross-sectional dependence). It is our view that allowing our specified panel to consider these factors makes the estimations less biased. The coefficients related to these factors are large, positive, and robust across the specification (between 0.5 and 0.7).

When the output gap is included as in Table 6 column 4–6 and it is similar in case of financial gaps (Table 7, column 4–6), our results indicate that the ERPT to consumer prices in CIS countries after two quarters is 28–31 %.[31] We can also compute a simple cumulative ERPT in four quarters, i.e. one year, to have a long-run measure of ERPT (see ECB, 2015).[32] In this case, we obtain a one year ERPT of 50%.[33] The main results are summarized in Table 3 and more specifically analyzed, together with more robustness checks, in the following sub-sections.

2.5.2 Alternative specifications

As a first alternative specification we analyze the ERPT using the bilateral exchange rate w.r.t. the USD as our nominal exchange rate variable. Unlike previous studies, we find no significant pass-through coefficient for the USD. Even the sign for the effect of USD varies in our specifications when all countries of our sample are included.[34]

Also in contradiction to earlier research on other transition and emerging economies, we find no evidence in support of significance of the exchange rate regime in estimating the ERPT in CIS countries. In our estimations, the exchange rate regime variable is not statistically significant – even its coefficient is very small. This could reflect the fact that there is little variation in the exchange rate regime indicator; most countries had some type of fixed arrangement throughout most of our sample period.

We include a time-varying dummy for countries that have adopted inflation targeting in their monetary policy regime (see Dabrowski, 2013). Here, the cases are limited to Armenia, which introduced inflation targeting in 2008, Georgia in 2010,

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[31] This ERPT is computed as in Jimborean (2011). The long-term coefficient of a variable is computed as the sum of its coefficients (of its lags and current values, where applicable) divided by one minus the sum of coefficients of the lags of the dependent variable. In our case, the measure of the long-run pass-through is computed as $LR\ ERPT = {}^{\beta}/_{1} - \left[\sum_{j=1}^{\max lag} \varphi_j\right]$, where β is the estimated ERPT, the maximum number of lags for the dependent variable, max lag, is 1 and φ is the coefficient for the lag value of CPI.

[32] The estimated elasticities of long-run ERPT in ECB (2015) have been computed as cumulated ERPT over four quarters.

[33] In case of the sub-sample 2005–2014, the pass-through is complete (100%) for the cumulative one-year ERPT. Results are available on request.

[34] We also add the interaction term between the rate vis-à-vis the USD and the de facto exchange rate regime, but the results are robust, i.e. the ERPT in this case is not significant.

and Russia in 2014.[35] The dummy itself and the interaction term with the NEER are always very small and only significant at 10 % if we look at the specification with energy prices.[36] Our sample time period for inflation targeting is short and takes place in the wake of the global financial crisis, which may explain the fact that ERPT significance and magnitude are not influenced in these setups.

Leaving out commodity prices does not change dramatically our results on ERPT (Table 8). The magnitude is slightly greater (17 %), but the main findings are robust and the role of financial gap is confirmed. If we use the specification without commodities, we can disentangle the role of the common trend in prices in CIS economies, which is, as expected, negative and significant and mainly replace the idea of a decline in commodity prices in the last periods.

The Openness Index (OI) is included as a control variable in the specification with USD to study the influence of openness toward trading partners outside the CIS. The results are quite robust and the index itself is not significant (Table 9). If we instead add trade openness within the CIS, this factor is positive and significant in all the specifications for the setup with NEER, but only true in some cases for the rate vis-à-vis the USD (Tables 10 and 11). The results concerning the ERPT coefficients again are quite robust.

For the CIS countries, an increase in trade within the group brings an increase in consumer prices in the home country. Trade among CIS countries has been relatively free, despite the lack of any comprehensive regional agreement. There have been various regional agreements in place during the time period under consideration, as well as several bilateral free trade agreements. On the opposite side, several restrictive measures have been imposed on trade between Russia and Georgia after the war in 2008 and more recently between Russia and Ukraine. In any case, these disputes largely concern bilateral relations.

A decrease in trade flows may have a deflationary effect in the CIS. Hence, the CIS countries seem to be very much interconnected trade-wise.[37] A shock to one can be transmitted to others. Comparing openness within the CIS and with the rest of the world gives an impression on the role of spillovers and global factors related to trade. In any case, these factors are completely captured in the common unobserved factor in our dynamic factor model setup. The trade spillovers among the CIS may be more important than general openness toward other countries.

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[35] The data on monetary policy regimes are from Dabrovski (2013) up to 2009, and thereafter taken from IMF's AREAER database.

[36] Results available on request.

[37] In this case exports and imports for the openness index refer to final goods.

2.5.3 Sub-periods

Our results are quite robust with respect to the various sub-periods, with some exceptions for recent years (Tables 12 and 13). In particular, we check if there is a change after the global financial crisis. The impact of NEER remains statistically significant in most cases, and the ERPT estimate lies in the range of 14–16 % in various specifications for the time periods of 1999–2008, and 2009–2014. In the latter period, the statistical significance of the ERPT estimate becomes weaker or vanishes in some specifications.[38] This could be related to the exceptional nature of the period in the wake of the global financial crisis. The result is in line with the recent study by Jašova et al. (2016), who find that ERPT in emerging economies decreased or was not significant after the financial crisis, while it has remained fairly stable over time in advanced economies.

2.5.4 Asymmetry

Finally, we control for possible asymmetries, i.e. test whether the direction and the size of exchange rate changes affect pass-through. In the spirit of Bussière (2007) and Pollard and Coughlin (2004), this is computed using interactive dummy variables for appreciation vs. depreciation and small vs. large changes in rates.[39] The setup is as follows:

$$p_{i,t} = \gamma_{1i} p_{i,t-1} + \beta_{1i} s_{i,t-1} D_{1i,t-1} + \beta_{2i} s_{i,t-1} D_{2i,t-1} + \tau_i fmc_{i,t} + \eta_i gap_{i,t} + \psi_i X_{i,t} + \omega_i regime_{i,t} + \varepsilon_{i,t} \quad (11)$$

where the variables are the same as in the baseline Eq. (5) and the dummies are $D_{1i,t-1}$ and $D_{2i,t-1}$. The dummy variables for appreciation vs. depreciation are the following:

$$D_{1i,t-1} = 1 \; if \; \Delta s_{i,t-1} = s_{i,t-1} - s_{i,t-2} > 0$$

$$D_{2i,t-1} = 1 \; if \; \Delta s_{i,t-1} = s_{i,t-1} - s_{i,t-2} \leq 0 \quad (12)$$

[38] We have a relatively small number of observations even in our full sample. As a result, small sample size in estimations for sub-periods could cause problems.

[39] We use the model here in levels. The cited authors use the model in first differences.

Concerning the dummy for small vs. large changes (positive or negative) in the rates,[40] the dummies are:

$$D_{1i,t-1} = 1 \; if \; \|\Delta s_{i,t-1}\| = \|s_{i,t-1} - s_{i,t-2}\| > 0$$

$$D_{2i,t-1} = 1 \; if \| \Delta s_{i,t-1}\| = \|s_{i,t-1} - s_{i,t-2}\| \leq 0 \qquad (13)$$

The results using dummy variables for appreciation vs. depreciation interacted with the different exchange rates are quite similar with respect to the preferred setup. The differences in their coefficients are not significantly different from zero.[41] In case of using dummies for small vs. large changes in the rates, the ERPTs are similar with the NEER while asymmetric if we apply the bilateral USD rate. If the change in absolute value is greater than 2%, the ERPT is significant and around 13%, which is similar to the one for the short-run NEER (Table 14). It is only 5% in case of small changes in the bilateral rate with the USD. If we use output gap instead of the financial gap, asymmetry is confirmed, but the ERPT in case of small changes is not significant.

2.5.5 Robustness checks

2.5.5.1 Estimation in differences

As a first robustness check, we estimate our preferred specification in differences instead of levels (Tables 15 and 16), since some of our variables were found to be non-stationary. Moreover, estimation in differences is used almost universally in previous studies, so we can compare our results with outcomes from earlier research.

Our results are of similar magnitude as the ERPT estimates reported in the earlier literature for emerging countries. The short-run ERPT is in the same order of magnitude (12–13%) and the long-run versions are quite similar to those reported in Table 3 for the baseline.

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[40] The threshold in Bussière (2007) and Pollard and Coughlin (2004) is 3%. In our estimations, this 3 % rate is exceeded in very few cases.

[41] Results available on request.

With the specification in differences, the ERPTs with NEER and bilateral USD rate remain robust. However, the prices of commodities and energy become negative even if extremely small. Therefore, changes in commodity prices have different impact on inflation than the level of them on price levels. While the impact of their change is small with regard to inflation, their level matters for CPI levels in our countries of interest.

2.5.5.2 Estimation with IV-GMM

As a robustness check of the validity of our empirical method, we include in the robustness checks the estimations by using a twostep system IV-GMM. Because the standard errors in two-step estimation tend to be significantly downward biased because of the large number of instruments involved, we follow Jimborean (2011) and we apply Windmeijer (2005) finite-sample correction. To avoid the bias that arises when the number of instruments is relatively too high in small samples, we collapse the instruments as suggested by Roodman (2009a). We assume all the variables in the baseline (Tables 6 and 7) are endogenous and we use only the second lag as instruments.[42]

The results with the two-step system IV-GMM estimator confirm the main findings of our analysis with the AMG estimator (Tables 6 and 7) if we include the commodity prices measure.[43] The ERPT based on the NEER is again significant, but much higher (55 % for short-run with output gap and 60 % with financial gap). The ERPT with the bilateral exchange rate vis-à-vis the USD is significant only if we include output gap and in any case it is much smaller (7.6 % in the short run) than the ERPT with NEER (Table A11). In case of estimation with energy prices, the ERPT with NEER is the only one significant and around 33 %, which is three times as big as the coefficient we found with the AMG estimator. In all the specifications the commodity prices and the gaps are not significant. The regime dummy becomes negative and significant in the specification with NEER and financial gap; meaning that in case it is equal to one, i.e. when the regime is fixed or intermediate (managed arrangements included), the consumer price index decreases.

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[42] We apply only the second lag of the endogenous variables as instruments. The small number of countries in our sample and the large number of instruments weakens the Sargan test results. Thus, we make a rule of thumb to keep the number of instruments less or equal to the number of groups.

[43] Results with energy prices and non-energy prices are available upon request.

Summing up the outcome for the ERPT, if you do not take into account the heterogeneity across individuals and the presence of cross-sectional dependence (which can hide some key common global factors or spillovers effects); the ERPT with NEER is much higher than the preferred setup and also not comparable with the average estimates from the literature (Table 2 in the text).

2.5.5.3 Dynamic factor model

We include a dynamic version of the factor model setup to account for possible endogeneity between variables such as exchange rate and commodity prices.[44] We applying the dynamic CCE (MG)-GMM estimator of Neal (2015) to fully correct for both endogeneity and cross-sectional dependence while maintaining heterogeneity in the coefficients. The cross-section averages of the variables (together with the averages with one and two lags) are included to deal with cross-sectional dependence. All variables (except the exogenous regime dummy) are instrumented using one and two lags. The GMM estimator is applied. The ERPT with NEER in most specifications is significant, and the magnitude of the coefficient is larger in these cases than in the preferred setup (in a range between 17% and 30%). The significance of adding the regime dummy is seen in just two cases: in the setup with energy prices and output gap and non-energy prices and financial gap. The ERPT with the USD rate is significant and around 30% only if we consider general commodity prices and financial gap.

2.5.5.4 Other robustness checks

We also perform additional robustness checks leaving Russia out of the sample (as it is a notably larger economy compared to the others), controlling for oil-exporting v. oil-importing countries with a dummy variable and controlling for exchange rate volatility. The magnitude of the ERPT estimates for NEER remains at 15% and statistical tests show that the additional control variables should be omitted from the model.

Moreover, leaving Russia out of the sample, the ERPT with USD becomes significant and just slightly smaller than the NEER case (Tables 19 and 20). This

[44] All results available on request.

result is somewhat puzzling. Firstly, it might reflect the fact that the role of domestic currency as well as the euro as an invoicing currency is higher in Russia than in the other countries of the sample. In 2013–2014, the share of both RUB and EUR was about 30 % in the invoicing currencies of Russian imports. Secondly, it might be related to the close relationship between Russia's exchange rate and oil price. Exchange rate tends to appreciate when oil price increases dampening inflation pressures. For oil exporters, this has been referred to as one of the possible reasons for finding non-significant or quantitatively very small results for ERPT. At least our oil-exporter dummy, however, is not providing support for this explanation because it is not significant in any of our specifications. On the opposite side, the consumer prices of oil importers may be influenced more by the price of oil, literally importing inflation (deflation) in case of an increase (decrease) in oil prices. Hence we checked for a possible asymmetry between oil importers and exporters in that regards, adding an interaction term between energy prices and a dummy for importers. This term is again not significant and the ERPT coefficient very robust with respect to the preferred baseline setup. Hence, we do not find any evidence of the abovementioned behavior.[45]

We also add volatilities of the rate vis-à-vis the USD and the NEER into our preferred setup.[46] The ERPT to USD is still not significant (Table 21) and all the coefficients very robust w.r.t. the baseline (Tables 6 and 7). The ERPT to NEER is also robust w.r.t. the baseline (Table 22 with financial gap).[47] However, non-energy prices become significant in the case of the output gap. Moreover, in the case of non-energy prices, the financial cycle is no longer be significant in some specifications. The volatilities of rates are never significant.

For the sake of completeness, we should also check the robustness of the results for dependent variables other than the plain vanilla CPI (e.g. core inflation and CPI excluding administered prices). Unfortunately, this is not possible due to lack of data for some countries in our sample. To some extent, however, this deficiency can be overcome in some estimations by controlling for energy price development.

As a final robustness check we apply a simple homogeneous panel VAR setup,[48] with dependent variables (in Cholesky order): financial gap, foreign marginal cost, commodity prices, NEER, and CPI. We use the setup as in Abrigo and Love (2015), who apply GMM-type estimators to this setup. The results are similar to our

[45] Results available on request.

[46] The volatilities are computed as in Section 4.1.

[47] The results are robust if output gap is added.

[48] Results available on request.

preferred specification, with the coefficients for the lagged value of the NEER significant and equal to 18%. Looking at the IRFs on a horizon of eight periods (two years), the pass-through is complete in less than two years. The ERPT after four quarters is also well in line with our estimates.

2.6 Conclusions and implications

We find that after one quarter ERPT is still relatively high and rapid in the CIS countries (12–13%), and for NEER climbs to over 50 % after four quarters. These results for ERPT are broadly in line with earlier studies of emerging economies. They are quite robust with respect to different sub-periods, weakening only in the last quarters, in line with the recent literature. Common factors are found to be important for ERPT estimation in the CIS countries and commodity prices in particular are also explicitly significant. We find that especially financial gaps need to be accounted for in the estimation of ERPT for CIS countries. On the other hand, we could not establish a statistically significant impact from the exchange rate regime, volatility of the exchange rate, or the fact that a particular country was a commodity exporter.

We also examined the possibility of asymmetry in ERPT for the first time in a cross-country setting for the CIS countries. We found little support for asymmetric effects of appreciation and depreciation. For NEER, our results point to symmetric effects from large and small changes in the exchange rate. For the USD, there was some evidence of a higher ERPT coefficient in the event of large exchange rate changes. The fact that we cannot find much evidence for asymmetric effects is a bit surprising. On the other hand, there are only a few instances of very large changes in our sample period.

From the policy point of view, our results confirm that ERPT is still an important factor for price development in the CIS countries and should be taken into account when evaluating the inflation outlook. Our results suggest that there are several factors influencing ERPT in CIS countries that need to be accounted for when estimating the effects. Recent significant changes in the monetary policy regimes in some CIS countries may also affect ERPT although we did not find much evidence of that. Currently too little time has yet passed to evaluate the full effects of these changes, but they will undoubtedly be an important topic in future studies.

APPENDIX. TABLES AND FIGURES

Table 4. Test for cross-sectional dependence: Pesaran test

	Test	**Probability**
Table 3 - Column 1 – ln_usd; ln_fmc;gapy_sa; ln_comm; regime	18.981	0.000
Table 3 - Column 2 – ln_usd; ln_fmc;gapy_sa; ln_en; regime	18.959	0.000
Table 3 - Column 3 – ln_usd; ln_fmc;gapy_sa; ln_non_en; regime	18.408	0.000
Table 3- Column 4 – ln_neer; ln_fmc;gapy_sa; ln_comm; regime	18.387	0.000
Table 3 - Column 5 – ln_neer; ln_fmc;gapy_sa; ln_en; regime	18.501	0.000
Table 3 - Column 6 – ln_neer; ln_fmc;gapy_sa; ln_non_en; regime	17.877	0.000
Table 4 - Column 1 – ln_usd; ln_fmc;gapfiny_sa; ln_comm; regime	18.815	0.000
Table 4 - Column 2 – ln_usd; ln_fmc;gapfiny_sa; ln_en regime	18.778	0.000
Table 4 - Column 3 – ln_usd; ln_fmc;gapfiny_sa; ln_non_en; regime	18.302	0.000
Table 4 - Column 4 – ln_neer; ln_fmc;gapfiny_sa; ln_comm; regime	18.209	0.000
Table 4 - Column 5 – ln_neer; ln_fmc;gapfiny_sa; ln_en regime	18.303	0.000
Table 4 - Column 6 – ln_neer; ln_fmc;gapfiny_sa; ln_non_en; regime	17.728	0.000

Note: The methods for Pesaran's test for cross-sectional independence are set out in Pesaran (2004). Pesaran's statistic follows a standard normal distribution and can handle both balanced and unbalanced panels. The exchange rates used here are *usd* and *neer*; *fmc* is the foreign marginal cost; *gapy_sa* is the output gap; *gapfiny_sa* is the financial gap; *comm* is commodity prices; *en* is energy prices and *non_en* is non-energy prices; *regime* is the dummy for de facto fixed/intermediate regimes. All variables, except the gaps, are in logs.

Table 5. Stationarity test: second generation t-test by Pesaran (2007) for unit roots in heterogeneous panels with cross-section dependence (CIPS)

Variable		
	Z[t-bar]	p-value
ln_cpi	**-1.043**	**0.148**
ln_usd*	1.411	0.921
ln_neer*	2.037	0.979
ln_fmc	-6.285	0.000
gapy_sa	-6.722	0.000
gapfiny_sa	-3.112	0.001
ln_comm*	12.625	1.000
ln_en*	12.625	1.000
ln_non_en*	12.625	1.000

Note: **Null hypothesis assumes that all series in the panel are non-stationary.** This t-test is also based on Augmented Dickey-Fuller statistics as IPS (2003) but it is augmented with the cross section averages of lagged levels and first-differences of the individual series (CADF statistics).[49] ***means non-stationarity for all series.** The exchange rates used are *usd* and *neer*; *fmc* is the foreign marginal cost; *gapy_sa* is the output gap; *gapfiny_sa* is the financial gap; *comm* is commodity prices; *en* is energy prices and *non_en* is non-energy prices; *regime* is the dummy for de facto fixed/intermediate regimes. We added 1 lag for *cpi*, *usd* and *neer*. All variables, except the gaps, are in logs.

[49] The *pescadf*- command in Stata was built by Piotr Lewandowski of the Warsaw School of Economics Institute for Structural Research.

Table 6. ERPT with output gap

VARIABLES	(1) ln_cpi	(2) ln_cpi	(3) ln_cpi	(4) ln_cpi	(5) ln_cpi	(6) ln_cpi
ln_cpi1	0.518***	0.524***	0.500***	0.554***	0.559***	0.544***
	(0.092)	(0.090)	(0.0956)	(0.107)	(0.104)	(0.112)
ln_usd1	**-0.005**	**-0.045**	**-0.046**			
	(0.055)	**(0.055)**	**(0.052)**			
ln_neer1				**-0.134****	**-0.137*****	**-0.131****
				(0.052)	**(0.053)**	**(0.051)**
ln_fmc	-0.010	-0.011	-0.009	-0.021	-0.012	-0.021
	(0.024)	(0.023)	(0.024)	(0.024)	(0.023)	(0.027)
gapy_sa100	**0.041**	**0.045**	**0.040**	**0.045**	**0.052**	**0.041**
	(0.027)	**(0.029)**	**(0.031)**	**(0.035)**	**(0.035)**	**(0.030)**
ln_comm	0.420***			0.348***		
	(0.067)			(0.068)		
ln_en		0.310***			0.258***	
		(0.050)			(0.050)	
ln_non_en			0.018			0.024
			(0.019)			(0.017)
regime	0.006	0.006	0.004	0.011	0.011	0.001
	(0.008)	(0.009)	(0.008)	(0.007)	(0.007)	(0.007)
Constant	0.117	0.591**	2.023***	1.263**	1.660***	2.768***
	(0.220)	(0.254)	(0.374)	(0.498)	(0.556)	(0.771)
Common dynamic process	0.571***	0.571***	0.580***	0.531***	0.537***	0.526***
	(0.085)	(0.087)	(0.080)	(0.106)	(0.105)	(0.103)
Observations	419	419	419	419	419	419
Number of countries	7	7	7	7	7	7
RMSE	0.014	0.015	0.014	0.015	0.015	0.015

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
The exchange rates used are *usd* and *neer*; *fmc* is the foreign marginal cost; *gapy_sa100* is the output gap multiplied by 100; *gapfiny_sa100* is the financial gap multiplied by 100; *comm* is commodities price; *en* is energy price and *non_en* is non-energy price; *regime* is the dummy for de facto fixed/intermediate regimes. RMSE is the root mean square error.

Table 7. ERPT with financial gap

VARIABLES	(1) ln_cpi	(2) ln_cpi	(3) ln_cpi	(4) ln_cpi	(5) ln_cpi	(6) ln_cpi
ln_cpi1	0.508***	0.514***	0.486***	0.555***	0.560***	0.543***
	(0.092)	(0.092)	(0.096)	(0.104)	(0.102)	(0.108)
ln_usd1	**-0.061**	**-0.061**	**-0.061**			
	(0.047)	**(0.048)**	**(0.045)**			
ln_neer1				**-0.128*** **	**-0.129*** **	**-0.126*** **
				(0.042)	**(0.044)**	**(0.041)**
ln_fmc	-0.003	-0.007	0.000	-0.018	-0.021	-0.016
	(0.025)	(0.0244)	(0.024)	(0.029)	(0.028)	(0.028)
gapfiny_sa100	**0.086*** **	**0.086*** **	**0.078** **	**0.066** **	**0.068*** **	**0.051* **
	(0.029)	**(0.026)**	**(0.036)**	**(0.029)**	**(0.025)**	**(0.030)**
ln_comm	0.425***			0.336***		
	(0.064)			(0.062)		
ln_en		0.313***			0.248***	
		(0.048)			(0.045)	
ln_non_en			0.010			0.020
			(0.019)			(0.019)
Regime	0.004	0.004	0.003	0.006	0.007	0.007
	(0.008)	(0.008)	(0.008)	(0.006)	(0.006)	(0.006)
Constant	0.091	0.587**	2.065***	1.276***	1.666***	2.752***
	(0.213)	(0.257)	(0.382)	(0.436)	(0.495)	(0.644)
Common dynamic process	0.586***	0.584***	0.600***	0.521***	0.524***	0.518***
	(0.080)	(0.083)	(0.076)	(0.092)	(0.093)	(0.089)
Observations	419	419	419	419	419	419
Number of countries	7	7	7	7	7	7
RMSE	0.014	0.014	0.014	0.015	0.015	0.015

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; en is energy price and non_en is non-energy price; regime is the dummy for de facto fixed/intermediate regimes. RMSE is the root mean square error.

Table 8. ERPT estimation without commodities

	(1)	(2)	(3)	(4)
VARIABLES	ln_cpi	ln_cpi	ln_cpi	ln_cpi
ln_cpi1	0.510***	0.549***	0.508***	0.551***
	(0.084)	(0.092)	(0.084)	(0.089)
ln_usd1	**0.073**		**0.080**	
	(0.058)		**(0.059)**	
ln_neer1		**-0.173*** **		**-0.170*** **
		(0.062)		**(0.056)**
ln_fmc	0.024	0.011	0.008	-0.009
	(0.017)	(0.018)	(0.026)	(0.030)
gapy_sa100	0.022	0.031		
	(0.034)	(0.035)		
gapfiny_sa100			0.061***	0.051*
			(0.019)	(0.028)
regime	0.003	0.010	0.000	0.005
	(0.006)	(0.006)	(0.006)	(0.006)
Constant	1.955***	3.036***	2.008***	3.089***
	(0.417)	(0.723)	(0.407)	(0.641)
Common dynamic process	0.772***	0.692***	0.755***	0.666***
	(0.134)	(0.137)	(0.124)	(0.128)
Linear trend	-0.003**	-0.002*	-0.002**	-0.002
	(0.001)	(0.001)	(0.001)	(0.001)
Observations	419	419	419	419
Number of countries	7	7	7	7
RMSE	0.013	0.014	0.013	0.014

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are *usd* and *neer*; *fmc* is the foreign marginal cost; *gapy_sa100* is the output gap multiplied by 100; *gapfiny_sa100* is the financial gap multiplied by 100; *regime* is the dummy for de facto fixed/intermediate regimes. RMSE is the root mean square error.

Table 9. ERPT with openness index toward the rest of the world

VARIABLES	(1) ln_cpi	(2) ln_cpi	(3) ln_cpi	(4) ln_cpi	(5) ln_cpi	(6) ln_cpi
ln_cpi1	0.524***	0.531***	0.505***	0.514***	0.521***	0.490***
	(0.081)	(0.080)	(0.085)	(0.082)	(0.081)	(0.086)
ln_usd1	**-0.032**	**-0.031**	**-0.032**	**-0.048**	**-0.046**	**-0.046**
	(0.057)	**(0.058)**	**(0.056)**	**(0.051)**	**(0.051)**	**(0.050)**
ln_fmc	-0.006	-0.006	-0.007	0.003	-0.000	0.003
	(0.023)	(0.022)	(0.022)	(0.022)	(0.021)	(0.020)
gapy_sa100	0.036	0.038	0.033			
	(0.024)	(0.026)	(0.025)			
gapfiny_sa100				0.078***	0.077***	0.070**
				(0.028)	(0.026)	(0.033)
ln_comm	0.421***			0.428***		
	(0.068)			(0.067)		
ln_en		0.184***			0.186***	
		(0.032)			(0.032)	
ln_non_en			0.011			0.005
			(0.019)			(0.019)
Regime	0.008	0.008	0.006	0.006	0.006	0.005
	(0.008)	(0.008)	(0.007)	(0.008)	(0.008)	(0.008)
Oi	**0.021**	**0.024**	**0.019**	**0.019**	**0.022**	**0.016**
	(0.020)	**(0.020)**	**(0.020)**	**(0.021)**	**(0.021)**	**(0.021)**
Constant	0.102	0.967***	1.576***	0.069	0.961***	1.597***
	(0.230)	(0.294)	(0.326)	(0.224)	(0.302)	(0.339)
Common dynamic process	0.581***	0.578***	0.589***	0.596***	0.591***	0.610***
	(0.087)	(0.088)	(0.082)	(0.086)	(0.088)	(0.084)
Observations	419	419	419	419	419	419
Number of countries	7	7	7	7	7	7

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; en is energy price and non_en is non-energy price; regime is the dummy for de facto fixed/intermediate regimes; oi is the Openness Index as the difference between total trade with the world and intra-CIS trade over GDP.

Table 10. ERPT with openness index within the CIS (rate vis-à-vis the USD)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	ln_cpi	ln_cpi	ln_cpi	ln_cpi	ln_cpi	ln_cpi
ln_cpi1	0.541***	0.547***	0.523***	0.530***	0.536***	0.509***
	(0.078)	(0.077)	(0.083)	(0.080)	(0.079)	(0.085)
ln_usd1	**-0.041**	**-0.040**	**-0.042**	**-0.056**	**-0.055**	**-0.056**
	(0.053)	**(0.054)**	**(0.050)**	**(0.048)**	**(0.048)**	**(0.045)**
ln_fmc	-0.015	-0.017	-0.014	-0.009	-0.013	-0.007
	(0.022)	(0.022)	(0.022)	(0.023)	(0.022)	(0.021)
gapy_sa100	0.039	0.043	0.039			
	(0.029)	(0.032)	(0.032)			
gapfiny_sa100				0.084***	0.083***	0.079***
				(0.025)	(0.024)	(0.028)
ln_comm	0.406***			0.411***		
	(0.064)			(0.063)		
ln_en		0.300***			0.304***	
		(0.048)			(0.048)	
ln_non_en			0.017			0.008
			(0.019)			(0.019)
Regime	0.009	0.009	0.007	0.007	0.008	0.006
	(0.006)	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)
oi_cis	**0.089***	**0.092***	**0.082**	**0.081**	**0.084**	**0.070**
	(0.053)	**(0.054)**	**(0.051)**	**(0.052)**	**(0.053)**	**(0.051)**
Constant	0.098	0.560**	1.942***	0.074	0.558**	1.995***
	(0.211)	(0.239)	(0.351)	(0.206)	(0.245)	(0.379)
Common dynamic process	0.550***	0.549***	0.562***	0.566***	0.564***	0.583***
	(0.079)	(0.081)	(0.077)	(0.078)	(0.081)	(0.078)
Observations	419	419	419	419	419	419
Number of countries	7	7	7	7	7	7

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are *usd* and *neer*; *fmc* is the foreign marginal cost; *gapy_sa100* is the output gap multiplied by 100; *gapfiny_sa100* is the financial gap multiplied by 100; *comm* is commodities price; *en* is energy price and *non_en* is non-energy price; *regime* is the dummy for de facto fixed/intermediate regimes; *oi_cis* is the Openness Index as intra-CIS trade over GDP.

Table 11. ERPT with openness index within the CIS (with the NEER)

VARIABLES	(1) ln_cpi	(2) ln_cpi	(3) ln_cpi	(4) ln_cpi	(5) ln_cpi	(6) ln_cpi
ln_cpi1	0.584***	0.587***	0.571***	0.591***	0.594***	0.576***
	(0.087)	(0.085)	(0.094)	(0.084)	(0.082)	(0.091)
ln_neer	**-0.136*** **	**-0.138*** **	**-0.132*** **	**-0.124*** **	**-0.126*** **	**-0.122*** **
	(0.048)	**(0.048)**	**(0.048)**	**(0.040)**	**(0.041)**	**(0.040)**
ln_fmc	-0.033	-0.033	-0.032	-0.035	-0.039	-0.035
	(0.023)	(0.023)	(0.025)	(0.026)	(0.027)	(0.027)
gapy_sa100	0.051	0.056	0.043			
	(0.042)	(0.043)	(0.041)			
gapfiny_sa100				0.067**	0.068***	0.055*
				(0.028)	(0.026)	(0.028)
ln_comm	0.343***			0.327***		
	(0.059)			(0.053)		
ln_en		0.255***			0.243***	
		(0.044)			(0.039)	
ln_non_en			0.0240			0.0193
			(0.017)			(0.019)
regime	0.014**	0.014**	0.012**	0.009**	0.010**	0.008*
	(0.006)	(0.006)	(0.006)	(0.004)	(0.005)	(0.004)
oi_cis	**0.145** **	**0.146** **	**0.146** **	**0.140** **	**0.141** **	**0.140** **
	(0.070)	**(0.072)**	**(0.065)**	**(0.070)**	**(0.070)**	**(0.059)**
Constant	1.192***	1.587***	2.686***	1.190***	1.579***	2.646***
	(0.353)	(0.400)	(0.549)	(0.316)	(0.361)	(0.480)
Common dynamic process	0.519***	0.523***	0.519***	0.500***	0.504***	0.504***
	(0.086)	(0.086)	(0.087)	(0.075)	(0.076)	(0.076)
Observations	419	419	419	419	419	419
Number of countries	7	7	7	7	7	7

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are *usd* and *neer*; *fmc* is the foreign marginal cost; *gapy_sa100* is the output gap multiplied by 100; *gapfiny_sa100* is the financial gap multiplied by 100; *comm* is commodities price; *en* is energy price and *non_en* is non-energy price; *regime* is the dummy for de facto fixed/intermediate regimes; *oi_cis* is the Openness Index as intra-CIS trade over GDP.

Table 12. ERPT time sub-samples: 1999–2008 with financial gap

VARIABLES	(1) ln_cpi	(2) ln_cpi	(3) ln_cpi	(4) ln_cpi	(5) ln_cpi	(6) ln_cpi
ln_cpi1	0.422***	0.426***	0.413***	0.447***	0.450***	0.444***
	(0.088)	(0.086)	(0.088)	(0.094)	(0.093)	(0.092)
ln_usd1	**-0.124****	**-0.123****	**-0.119****			
	(0.053)	**(0.054)**	**(0.051)**			
ln_neer1				**-0.151*****	**-0.152*****	**-0.152*****
				(0.054)	**(0.055)**	**(0.053)**
ln_fmc	0.0157	0.0231	0.005	-0.021	-0.017	-0.011
	(0.055)	(0.055)	(0.055)	(0.048)	(0.044)	(0.054)
gapfiny_sa100	-0.002	0.010	-0.034	-0.016	0.011	-0.085
	(0.089)	(0.085)	(0.105)	(0.120)	(0.113)	(0.142)
ln_comm	0.008			0.018***		
	(0.010)			(0.006)		
ln_en		0.321***			0.228***	
		(0.039)			(0.026)	
ln_non_en			0.020			0.043***
			(0.026)			(0.015)
Regime	-0.002	-0.002	-0.001	0.005	0.004	0.005
	(0.002)	(0.002)	(0.001)	(0.005)	(0.004)	(0.005)
Constant	1.625***	0.627	1.664***	2.934***	2.274***	2.805***
	(0.526)	(0.438)	(0.508)	(0.700)	(0.622)	(0.697)
Common dynamic process	0.718***	0.716***	0.729***	0.645***	0.648***	0.638***
	(0.082)	(0.083)	(0.080)	(0.078)	(0.080)	(0.072)
Observations	254	254	254	254	254	254
Number of countries	7	7	7	7	7	7

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; en is energy price and non_en is non-energy price; regime is the dummy for de facto fixed/intermediate regimes.

Table 13. ERPT time sub-samples: 2009–2014 with financial gap

VARIABLES	(1) ln_cpi	(2) ln_cpi	(3) ln_cpi	(4) ln_cpi	(5) ln_cpi	(6) ln_cpi
ln_cpi1	0.322***	0.331***	0.302***	0.192	0.192	0.195
	(0.109)	(0.111)	(0.112)	(0.150)	(0.153)	(0.150)
ln_usd1	**-0.084**	**-0.109**	**-0.029**			
	(0.063)	**(0.068)**	**(0.071)**			
ln_neer1				**-0.143***	**-0.136**	**-0.144***
				(0.083)	**(0.084)**	**(0.087)**
ln_fmc	0.016	0.028	-0.000	0.024**	0.029*	0.015*
	(0.013)	(0.021)	(0.010)	(0.012)	(0.017)	(0.009)
gapfiny_sa100	-0.023	-0.009	-0.042	-0.027	-0.014	-0.052
	(0.084)	(0.088)	(0.088)	(0.062)	(0.065)	(0.066)
ln_comm	0.009			0.015		
	(0.019)			(0.015)		
ln_en		0.004			0.012	
		(0.016)			(0.014)	
ln_non_en			0.015			0.019
			(0.020)			(0.014)
Regime	-0.002	-0.001	-0.003	0.001	0.003	-0.001
	(0.008)	(0.009)	(0.008)	(0.006)	(0.007)	(0.001)
Constant	2.849***	2.791***	2.970***	4.157***	4.114***	4.172***
	(0.442)	(0.471)	(0.413)	(0.980)	(0.996)	(1.000)
Common dynamic process	0.708***	0.709***	0.723***	0.854***	0.867***	0.837***
	(0.168)	(0.172)	(0.153)	(0.150)	(0.155)	(0.143)
Observations	165	165	165	165	165	165
Number of countries	7	7	7	7	7	7

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; en is energy price and non_en is non-energy price; regime is the dummy for de facto fixed/intermediate regimes.

Table 14. Using dummies for small vs. large changes (with financial cycle)

	(1)	(2)	(3)	(4)	(5)	(6)	
VARIABLES	ln_cpi	ln_cpi	ln_cpi	ln_cpi	ln_cpi	ln_cpi	
ln_cpi1	0.561***	0.569***	0.542***	0.550***	0.556***	0.541***	
	(0.087)	(0.085)	(0.093)	(0.105)	(0.102)	(0.108)	
int_1	**-0.136***	**-0.140***	**-0.115***				**usd*D1**
	(0.072)	**(0.075)**	**(0.066)**				
int_2	**-0.055****	**-0.055****	**-0.049***				**usd*D2**
	(0.025)	**(0.024)**	**(0.027)**				
int_3				**-0.132*****	**-0.134*****	**-0.127*****	**neer*D1**
				(0.041)	**(0.043)**	**(0.039)**	
int_4				**-0.131*****	**-0.133*****	**-0.127*****	**neer*D2**
				(0.041)	**(0.042)**	**(0.039)**	
ln_fmc	-0.039	-0.041	-0.044	-0.014	-0.016	-0.013	
	(0.033)	(0.031)	(0.043)	(0.026)	(0.025)	(0.026)	
gapfiny_sa100	0.071*	0.078**	0.063	0.069**	0.072***	0.058*	
	(0.039)	(0.035)	(0.046)	(0.029)	(0.025)	(0.030)	
ln_comm	0.403***			0.339***			
	(0.047)			(0.062)			
ln_en		0.296***			0.251***		
		(0.035)			(0.046)		
ln_non_en			0.024			0.021	
			(0.019)			(0.017)	
Regime	0.0071	0.0072	0.004	0.007	0.008	0.008	
	(0.010)	(0.010)	(0.008)	(0.006)	(0.007)	(0.006)	
Constant	0.212	0.675***	2.065***	1.280***	1.676***	2.375***	
	(0.200)	(0.228)	(0.293)	(0.422)	(0.485)	(0.560)	
Common dynamic process	0.576***	0.575***	0.583***	0.524***	0.529***	0.517***	
	(0.060)	(0.063)	(0.052)	(0.091)	(0.093)	(0.086)	
Observations	353	353	353	419	419	419	
Number of countries	7	7	7	7	7	7	

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; en is energy price and non_en is non-energy price; regime is the dummy for de facto fixed/intermediate regimes; oi_cis is the Openness Index as intra-CIS trade over GDP. For the interaction terms: int_1 and int_3 are the exchange rate vis-à-vis the USD or NEER multiplied by the dummy D1 in equation 13 (large changes), int_2 and int_4 are the exchange rate vis-à-vis the USD or NEER multiplied by the dummy D2 in equation 13 (small changes).

Table 15. Estimations in first differences – ERPT with output gap

VARIABLES	(1) dcpi	(2) dcpi	(3) dcpi	(4) dcpi	(5) dcpi	(6) dcpi
dcpi1	-0.079	-0.078	-0.092	-0.062	-0.061	-0.074
	(0.101)	(0.101)	(0.099)	(0.101)	(0.101)	(0.100)
dusd1	**0.059**	**0.059**	**0.057**			
	(0.077)	**(0.076)**	**(0.077)**			
dneer1				**-0.130****	**-0.131****	**-0.129***
				(0.065)	**(0.065)**	**(0.066)**
Dfmc	0.031	0.029	0.019	0.016	0.013	0.008
	(0.024)	(0.023)	(0.014)	(0.021)	(0.019)	(0.015)
gapy_sa100	-0.062	-0.060	-0.065	-0.061*	-0.059	-0.063*
	(0.043)	(0.043)	(0.040)	(0.036)	(0.036)	(0.032)
Dcomm	-0.015**			-0.013**		
	(0.006)			(0.006)		
Den		-0.012**			-0.010**	
		(0.004)			(0.004)	
dnon_en			-0.016			-0.013
			(0.014)			(0.013)
Regime	-0.002	-0.002	-0.001	-0.002	-0.002	-0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Constant	0.025***	0.025***	0.025***	0.022***	0.022***	0.022***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)
Common dynamic process	0.977***	0.972***	0.984***	0.967***	0.962***	0.974***
	(0.166)	(0.167)	(0.158)	(0.158)	(0.159)	(0.151)
Observations	417	417	417	417	417	417
Number of countries	7	7	7	7	7	7
RMSE	0.012	0.012	0.012	0.012	0.012	0.012

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; en is energy price and non_en is non-energy price; regime is the dummy for de facto fixed/intermediate regimes. All variables, except the gaps, are in log first differences. RMSE is the root mean square error.

Table 16. Estimations in first differences – ERPT with financial gap

VARIABLES	(1) dcpi	(2) dcpi	(3) dcpi	(4) dcpi	(5) dcpi	(6) dcpi
dcpi1	-0.100	-0.100	-0.113	-0.078	-0.077	-0.091
	(0.102)	(0.101)	(0.099)	(0.100)	(0.100)	(0.100)
dusd1	**0.066**	**0.066**	**0.065**			
	(0.067)	**(0.066)**	**(0.068)**			
dneer1				**-0.123***	**-0.124***	**-0.122***
				(0.066)	**(0.066)**	**(0.066)**
dfmc	0.030	0.027	0.020*	0.016	0.013	0.009
	(0.021)	(0.019)	(0.012)	(0.020)	(0.018)	(0.015)
gapfiny_sa100	-0.052	-0.051	-0.052	-0.054	-0.053	-0.054
	(0.042)	(0.042)	(0.040)	(0.038)	(0.038)	(0.036)
dcomm	-0.014**			-0.012**		
	(0.006)			(0.006)		
den		-0.011***			-0.010**	
		(0.004)			(0.004)	
dnon_en			-0.013			-0.012
			(0.014)			(0.012)
regime	-0.001	-0.001	-0.0009	-0.002	-0.002	-0.001
	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
Constant	0.024***	0.024***	0.024***	0.022***	0.022***	0.022***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Common dynamic process	0.973***	0.969***	0.978***	0.970***	0.966***	0.975***
	(0.161)	(0.162)	(0.151)	(0.156)	(0.157)	(0.148)
Observations	417	417	417	417	417	417
Number of countries	7	7	7	7	7	7
RMSE	0.012	0.012	0.012	0.012	0.012	0.012

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; en is energy price and non_en is non-energy price; regime is the dummy for de facto fixed/intermediate regimes. All variables, except the gaps, are in log first differences. RMSE is the root mean square error.

Table 17. Estimations in first differences – ERPT without commodities

	(1)	(2)	(3)	(4)
VARIABLES	dcpi	dcpi	dcpi	dcpi
dcpi1	-0.131*	-0.113*	-0.151**	-0.132**
	(0.067)	(0.068)	(0.066)	(0.065)
dusd1	**0.061**		**0.068**	
	(0.066)		**(0.055)**	
dneer1		**-0.135***		**-0.124***
		(0.069)		**(0.067)**
dfmc	-0.009	-0.023	-0.008	-0.021
	(0.015)	(0.023)	(0.015)	(0.021)
gapy_sa100	-0.054	-0.053		
	(0.042)	(0.035)		
gapfiny_sa100			-0.052	-0.053
			(0.044)	(0.039)
regime	-0.001	-0.003	0.0003	-0.003
	(0.003)	(0.003)	(0.001)	(0.002)
Constant	0.025***	0.024***	0.023***	0.024***
	(0.004)	(0.005)	(0.002)	(0.004)
Common dynamic process	0.971***	0.969***	0.971***	0.973***
	(0.166)	(0.161)	(0.160)	(0.156)
Linear trend	2.31e-05	6.51e-06	4.93e-05	1.18e-05
	(7.18e-05)	(8.32e-05)	(8.59e-05)	(8.26e-05)
Observations	417	417	417	417
Number of countries	7	7	7	7
RMSE	0.012	0.012	0.012	0.011

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; regime is the dummy for de facto fixed/intermediate regimes. All variables, except gaps, are in log first differences. RMSE is the root mean square error.

Table 18. IV-GMM estimations

VARIABLES	(1) ln_cpi	(2) ln_cpi	(3) ln_cpi	(4) ln_cpi
L.ln_cpi	0.466	0.369	0.649***	0.336
	(0.365)	(0.437)	(0.232)	(0.442)
ln_usd1	**-0.076***		**0.003**	
	(0.041)		**(0.017)**	
ln_neer1		**-0.555***		**-0.592***
		(0.322)		**(0.343)**
ln_fmc	-1.621	2.408	-4.772	2.318
	(1.216)	(1.692)	(3.488)	(1.630)
gapy_sa100	-6.821	1.746		
	(4.965)	(1.461)		
gapfiny_sa100			-8.598	1.177
			(6.232)	(0.977)
ln_comm	0.873	-0.338	1.699	-0.299
	(0.641)	(0.256)	(1.237)	(0.227)
regime	-0.812	-0.0970	-0.703	-0.248***
	(0.529)	(0.117)	(0.451)	(0.090)
Constant	6.699	-3.805	15.98	-3.129
	(4.747)	(3.537)	(11.46)	(3.043)
Observations	419	419	419	419
Number of countries	7	7	7	7

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Two-step System GMM with Windmeijer (2005) finite-sample correction. Instruments for first differences equation: GMM-type (missing=0, separate instruments for each period unless collapsed). L2.(L.ln_cpi ln_neer1 ln_fmc gapfiny_sa100 ln_comm) collapsed. Instruments for levels equation with constant GMM-type (missing=0, separate instruments for each period unless collapsed). DL.(L.ln_cpi ln_neer1 ln_fmc gapfiny_sa100 ln_comm) collapsed.

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; regime is the dummy for de facto fixed/intermediate regimes.

Table 19. ERPT excluding Russia – with output gap

VARIABLES	(1) ln_cpi	(2) ln_cpi	(3) ln_cpi	(4) ln_cpi	(5) ln_cpi	(6) ln_cpi
ln_cpi1	0.421***	0.427***	0.411***	0.452***	0.457***	0.447***
	(0.087)	(0.087)	(0.085)	(0.106)	(0.105)	(0.107)
ln_usd1	**-0.102****	**-0.103****	**-0.100***			
	(0.0520)	**(0.0515)**	**(0.0537)**			
ln_neer1				**-0.157****	**-0.159****	**-0.157****
				(0.068)	**(0.069)**	**(0.069)**
ln_fmc	0.023	0.022	0.030	0.013	0.015	0.016
	(0.027)	(0.027)	(0.028)	(0.026)	(0.025)	(0.027)
gapy_sa100	0.005	0.012	0.0061	0.026	0.033	0.027
	(0.052)	(0.053)	(0.051)	(0.049)	(0.048)	(0.043)
ln_comm	0.466***			0.406***		
	(0.061)			(0.067)		
ln_en		0.346***			0.301***	
		(0.046)			(0.050)	
ln_non_en			0.021			0.020
			(0.023)			(0.022)
Regime	0.008	0.008	0.006	0.010	0.010	0.0090
	(0.009)	(0.009)	(0.008)	(0.007)	(0.007)	(0.007)
Constant	0.0651	0.596**	1.585***	1.437**	1.894***	2.765***
	(0.262)	(0.284)	(0.317)	(0.566)	(0.620)	(0.785)
Common dynamic process	0.635***	0.635***	0.639***	0.635***	0.638***	0.629***
	(0.086)	(0.087)	(0.081)	(0.110)	(0.111)	(0.107)
Observations	356	356	356	356	356	356
Number of countries	6	6	6	6	6	6

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; en is energy price and non_en is non-energy price; regime is the dummy for de facto fixed/intermediate regimes.

Table 20. ERPT excluding Russia – with financial gap

VARIABLES	(1) ln_cpi	(2) ln_cpi	(3) ln_cpi	(4) ln_cpi	(5) ln_cpi	(6) ln_cpi
ln_cpi1	0.426***	0.432***	0.407***	0.456***	0.462***	0.446***
	(0.093)	(0.093)	(0.090)	(0.108)	(0.107)	(0.108)
ln_usd1	**-0.118*** **	**-0.118*** **	**-0.118*** **			
	(0.0427)	**(0.0424)**	**(0.0443)**			
ln_neer1				**-0.156** **	**-0.155** **	**-0.157** **
				(0.065)	**(0.066)**	**(0.063)**
ln_fmc	0.019	0.015	0.032	-0.001	-0.002	0.006
	(0.028)	(0.029)	(0.028)	(0.034)	(0.034)	(0.033)
gapfiny_sa100	0.075***	0.077***	0.073**	0.084**	0.085***	0.074**
	(0.024)	(0.021)	(0.033)	(0.034)	(0.029)	(0.032)
ln_comm	0.457***			0.393***		
	(0.058)			(0.063)		
ln_en		0.338***			0.290***	
		(0.043)			(0.047)	
ln_non_en			0.005			0.007
			(0.024)			(0.023)
Regime	0.006	0.006	0.006	0.005	0.006	0.006
	(0.008)	(0.008)	(0.008)	(0.006)	(0.006)	(0.006)
Constant	0.101	0.634**	1.652***	1.540***	1.977***	2.873***
	(0.242)	(0.273)	(0.339)	(0.545)	(0.603)	(0.741)
Common dynamic process	0.638***	0.636***	0.650***	0.632***	0.632***	0.629***
	(0.084)	(0.085)	(0.081)	(0.108)	(0.109)	(0.103)
Observations	356	356	356	356	356	356
Number of countries	6	6	6	6	6	6

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; en is energy price and non_en is non-energy price; regime is the dummy for de facto fixed/intermediate regimes.

Table 21. USD volatility

VARIABLES	(1) ln_cpi	(2) ln_cpi	(3) ln_cpi	(4) ln_cpi	(5) ln_cpi	(6) ln_cpi
ln_cpi1	0.517***	0.523***	0.498***	0.507***	0.514***	0.484***
	(0.092)	(0.090)	(0.097)	(0.094)	(0.092)	(0.095)
ln_usd1	**-0.043**	**-0.042**	**-0.045**	**-0.058**	**-0.057**	**-0.058**
	(0.056)	**(0.056)**	**(0.053)**	**(0.048)**	**(0.049)**	**(0.046)**
ln_fmc	-0.008	-0.008	-0.009	-0.001	-0.004	0.0005
	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.024)
gapy_sa100	0.035	0.038	0.035			
	(0.028)	(0.031)	(0.029)			
gapfiny_sa100				0.078***	0.079***	0.072**
				(0.029)	(0.026)	(0.035)
ln_comm	0.421***			0.427***		
	(0.067)			(0.065)		
ln_en		0.311***			0.314***	
		(0.050)			(0.049)	
ln_non_en			0.019			0.011
			(0.019)			(0.020)
vol_usd	**-0.012**	**-0.015**	**-0.0084**	**-0.008**	**-0.012**	**-0.008**
	(0.023)	**(0.024)**	**(0.022)**	**(0.015)**	**(0.017)**	**(0.015)**
Regime	0.006	0.006	0.004	0.004	0.004	0.003
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Constant	0.108	0.583**	2.024***	0.0839	0.582**	2.065***
	(0.225)	(0.261)	(0.388)	(0.217)	(0.261)	(0.390)
Common dynamic process	0.574***	0.573***	0.582***	0.588***	0.586***	0.602***
	(0.086)	(0.088)	(0.081)	(0.081)	(0.084)	(0.077)
Observations	419	419	419	419	419	419
Number of countries	7	7	7	7	7	7

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; en is energy price and non_en is non-energy price; vol_usd is the quarterly volatility of the bilateral rate vis-à-vis the USD; regime is the dummy for de facto fixed/intermediate regimes.

Table 22. NEER volatility (with financial gap)

VARIABLES	(1) ln_cpi	(2) ln_cpi	(3) ln_cpi	(4) ln_cpi	(5) ln_cpi	(6) ln_cpi
ln_cpi1	0.549***	0.548***	0.555***	0.554***	0.537***	0.537***
	(0.106)	(0.106)	(0.104)	(0.104)	(0.110)	(0.110)
ln_neer1	**-0.133*** **	**-0.136*** **	**-0.133*** **	**-0.137*** **	**-0.133*** **	**-0.136*** **
	(0.043)	**(0.043)**	**(0.044)**	**(0.044)**	**(0.042)**	**(0.042)**
ln_fmc	-0.018	-0.016	-0.022	-0.020	-0.017	-0.014
	(0.029)	(0.029)	(0.028)	(0.028)	(0.028)	(0.028)
gapfiny_sa100	0.063**	0.064**	0.066**	0.067***	0.049	0.049
	(0.030)	(0.030)	(0.026)	(0.026)	(0.030)	(0.030)
ln_comm	0.338***	0.338***				
	(0.063)	(0.03)				
ln_en			0.250***	0.250***		
			(0.046)	(0.046)		
ln_non_en					0.023	0.024
					(0.019)	(0.019)
vol_neer138	**-0.008**		**-0.009**		**0.005**	
	(0.040)		**(0.038)**		**(0.042)**	
vol_neer41		**0.006**		**0.005**		**0.022**
		(0.038)		**(0.036)**		**(0.040)**
Regime	0.006	0.006	0.007	0.006	0.006	0.006
	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)
Constant	1.318***	1.328***	1.707***	1.720***	2.802***	2.798***
	(0.449)	(0.447)	(0.510)	(0.508)	(0.648)	(0.643)
Common dynamic process	0.524***	0.525***	0.527***	0.528***	0.522***	0.520***
	(0.091)	(0.091)	(0.093)	(0.093)	(0.089)	(0.088)
Observations	419	419	419	419	419	419
Number of countries	7	7	7	7	7	7

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The exchange rates used are usd and neer; fmc is the foreign marginal cost; gapy_sa100 is the output gap multiplied by 100; gapfiny_sa100 is the financial gap multiplied by 100; comm is commodities price; en is energy price and non_en is non-energy price; vol_neer138 and vol_neer41are the quarterly volatility of the NEER with respectively 138 and 41 partners; regime is the dummy for de facto fixed/intermediate regimes.

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ESSAY
II

The Transmission of International Shocks to CIS Economies: A Global VAR Approach

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BOFIT Discussion Papers 17/2018.

3 ESSAY 2: THE TRANSMISSION OF INTERNATIONAL SHOCKS TO CIS ECONOMIES: A GLOBAL VAR APPROACH

Abstract

This paper employs a Global Vector Auto Regressive (GVAR) model to study the evolution of the response of the Commonwealth of Independent States (CIS) to foreign output and oil price shocks. During a two-decade observation period, cross-country trade and financial linkages experience notable changes. We find CIS countries highly sensitive to global and regional shocks, with that sensitivity increasing after the global financial crisis. CIS countries show strongest responses to output shocks originating in the US, Russia and within the region itself, but their sensitivity to euro area shocks also increases substantially. Despite growing trade relations with China, the responses of CIS countries to output shocks originating in China are still relatively moderate.

Keywords: international shocks, cross-country spillovers, CIS, Global VAR.

JEL codes: C32, F42, F43, E32.

3.1 Introduction

The economies associated with the Commonwealth of Independent States (CIS) provide an interesting but relatively little studied region for examining the transmission and impacts of global and regional shocks. After the break-up of the Soviet Union, CIS economies have experienced highly volatile development when shifting from transition to market economies over the past three decades (Roaf et al. 2014). With the liberalization of foreign trade and financial flows the economies have also integrated much more closely with the global economy. Although significant structural changes in domestic economies and global integration resulted in the development of a set of heterogeneous emerging economies with specific features, CIS countries are deeply interrelated due to common economic, geographic and political issues. This emphasizes the importance of a multilateral perspective that considers cross-country linkages in analyzing the response of CIS economies to international shocks.

To illustrate the increasing importance of the global economy for the CIS region, Table 23 provides real GDP cross-country correlations for the periods before and after the global financial crisis of 2007-09. It shows considerable changes for the major economies and CIS countries, as also suggested in earlier literature (e.g. Ductor & Leiva-Leon, 2016; Fidrmuc et al., 2014). For the CIS region, average cross-country output correlations with all countries have doubled since the global financial crisis. Average cross-country correlation within the region also increased substantially from 0.08 to 0.41. Foreign trade and international capital flows of the CIS economies have grown substantially during past couple of decades. Today many CIS economies are more dependent on foreign trade than the world average. There have been notable changes also in the geographical composition of trade and financial flows of the CIS economies, see Figure 5 in the Appendix. China's share of CIS trade has more than doubled from an average share of 5 % during 2001–04 to 11 % during 2013–16. The share of euro area countries in CIS trade has also increased, while the Russian share has shrunk. For most of CIS countries, the share of intra-region trade has increased. On the financial side, the US and euro area see growing shares, while Russia's share decreases.

Taking into account the potentially high vulnerability of the CIS economies to external shocks and the notable shifts in their international economic relations, we want to examine the impacts of external shocks on CIS economies and whether the transmission of shocks has changed during past couple of decades. Therefore, we construct a Global Vector Auto Regressive (GVAR) model to analyze the response of several CIS countries to output shocks in the US, euro area, China and Russian Federation, as well as to regional CIS output shocks. We follow a model approach similar to that used in Feldkircher (2015) and Feldkircher and Korhonen (2014), complemented with features allowing to examine the changes in responses to shocks in a similar vein to Fadejeva et al. (2017) and Cesa-Bianchi et al. (2012).

Regarding the most relevant previous literature, Feldkircher (2015) examines the transmission of the US and EU shocks to Central, Eastern and Southeastern Europe (CESEE) and CIS with a GVAR model comprising 43 countries and based on the time period of 1995–2011. Following a 1 % shock to euro area or US output, he finds that the GDP in the CIS countries increases in long term on average by 0.9 % and 0.7 %, respectively. He further supports the importance of regional interdependencies within CIS. Feldkircher & Korhonen (2014) study the transmission of Chinese shocks to the rest of the world, including CIS countries. Their findings, which are based on a GVAR model of 52 economies covering the period 1995–2011 suggest that a 1 % shock to Chinese real output translates to a roughly 0.2 % rise in output of CIS countries over the long term.

More recently, Fadejeva et al. (2017) examine spillovers from the euro area and the US to other regions in the global economy, including a number of CIS countries. Their GVAR model, which includes 42 countries and covers 1995–2013, focuses on the effects of credit shocks and aggregate demand shocks. The analysis extends to separate direct and indirect channels of influence. The results suggest that the CIS countries are among the economies experiencing the most pronounced spillovers from foreign credit and demand shocks. These shocks have historically played an important role in GDP fluctuations of CIS countries. The median long-term response of the CIS countries to a 1 % aggregate demand shock in the U.S. is found amounting to about 4 % and in the euro area to 3 %. The large role of US shocks mostly reflects the indirect impacts of US shocks on CIS economies.

The impact of regional or Russia-originated shocks has not been examined in the GVAR framework, but there exists some evidence on the significance of these shocks on various CIS economies. Alturki et al. (2009) find from a panel specification that a 1 % shock to Russian GDP is associated with a 0.35–0.45 % increase in the GDP of CIS countries. They also estimate separate VAR models for several CIS countries to examine the effect of Russian growth on them. They find that a 2 % shock on Russian output is associated with a 0.6–2 % response in the GDP of some CIS countries, but the effect is not statistically significant for all countries.

The main contributions of this paper relate to analysis of CIS economies. First, we examine the changes in the responses of CIS economies to output shocks originating in different regions for the first time. Second, we examine the effects of shocks originating specifically from Russia, with developments in recent years providing topical insights. To our best knowledge, this work is the first to examine the evolution of the decomposition of direct and indirect effects from trade and financial linkages by extending slightly the approaches applied in Fadejeva et al. (2017) and Cesa-Bianchi et al. (2012).

The rest of the paper proceeds as follows. Section 2 outlines the analytical framework. The data and model setup are presented in section 3. Results are discussed in section 4, and section 5 concludes.

3.2 The Global VAR model

In this section, we describe the analytical framework used for studying the transmission of international shocks to CIS economies from the global perspective. Given that CIS economies are closely linked with each other and integrated with the rest of the world, our analysis requires a tool that can explicitly handle cross-unit interdependencies. Panel VAR (PVAR) models that facilitate study of transmission of shocks across units have emerged as powerful tools in examining economic issues in an interdependent world. The complexity of panel VARs generates several estimation problems related to dimensionality and shock identification issues.

Thus, empirical literature usually does not utilize all distinguishing features of PVARs simultaneously. In particular, a Global VAR model provides a practical macroeconomic framework that accounts for cross-country interdependencies, maintains a simple structure and deals with dimensionality problems. Chudik & Pesaran (2016) provide a comprehensive survey of GVAR modeling and examine both the theoretical foundations of the approach and its numerous empirical applications.

We follow the GVAR approach presented in Pesaran, Schuermann & Weiner (2004), and further developed in Dees, di Mauro, Pesaran & Smith (2007, hereafter DdPS). The DdPS model has become a starting point for various studies which deal with GVAR models. The model is usually elaborated by composing a set of individual VAR models representing each N country in the panel. Each individual model includes domestic endogenous variables along with weakly exogenous foreign and global variables. This implies the following structure of $VARX^{*}(p_i, q_i)$:

$$\Phi_i(L,p_i)X_{it} = a_{i0} + \Lambda_i(L,q_i)X^*_{it} + \Psi_i(L,q_i)D_t + u_{it}, \quad (1)$$

for i=1,…,N and t=1,…,T, where X_{it} is a set of country-specific variables (domestic) and Φ_i (L,p_i) is the matrix lag polynomial of related coefficients; a_{i0} is a $k_i \times 1$ vector of fixed intercepts; X^*_{it} is a set of foreign-specific variables and Λ_i (L,q_i) is the matrix lag polynomial of the associated coefficients; D_t is a set of common global variables and Ψ_i (L,q_i) is the matrix lag polynomial of the associated coefficients; u_{it} is a $k_i \times 1$ vector of idiosyncratic, serially uncorrelated country-specific shocks with $u_{it} \sim iid(0,\Sigma_{ii})$.

The lag order of p_i is associated with domestic variables and may differ for each *i*. For foreign-specific and global variables the lag order is determined by q_i. For each country *i*, p_i and q_i are chosen by minimizing the Akaike information criterion (AIC) with the assumption that $p_i \geq q_i$ to ensure the relative importance of domestic variables. Recent studies that utilize a GVAR framework also assume long-run relationships among variables and include cointegration relationships in each individual model. This, in turn, results in the estimation of a set of individual vector error correction models with weakly exogenous components (VECMX*). In such models, weakly exogenous variables are included in the cointegration equation to account for the log-run relationships between domestic variables and their foreign counterparts.

A set of domestic variables X_{it} typically includes inflation, real output, real exchange rate, nominal short-term interest rate and other key macroeconomic indicators (see e.g. Pesaran, Schuermann and Weiner, 2004; DdPS, 2007). A set of foreign specific variables X^*_{it} are constructed by weighting corresponding domestic variables of other countries in the panel. More specifically, each foreign-specific variable for individual country is a weighted average of domestic variables of other countries:

$$X^*_{it} = \sum_{j=1}^{N} \omega_{ij} X_{it}, \quad (2)$$

where j=1,…,N; ω_{ij} is a set of weights such that $\sum_{j=1}^{N} \omega_{ij} = 1$ that are typically based on the bilateral trade flows across countries in the panel.

After the estimation of individual country-specific VECMX* models they are linked through the weight matrix and then combined in a GVAR model. The weight matrix comprises individual sets of weights ω_{ij} and represents the strength of cross-country relationships. Existing studies provide two ways of constructing a weight matrix: fixed or time-varying. A fixed-weight matrix is constructed using the data for cross-country weights for a specific year or a period average. Weights remain constant for the entire period of the estimation. In contrast, a time-varying matrix comprises a set of weight matrices computed for each period of the dataset. This makes it possible to capture structural changes in cross-country relationships. As discussed in Chudik & Pesaran (2016), time-varying weights to construct foreign variables are practically important in cases where there are important shifts in the trade weights and allowing for such time variations is also important in analyzing the propagation of international shocks across the globe.

Given, as seen from Figures 5 and 6 (Appendix), that international trade composition and financial linkages change over time, the assumption of constant weights might be too restrictive for CIS economies and thus would affect the robustness of results. In addition, trade and financial relationships of major developed economies have changed in recent years due to the growing importance of China and other emerging economies. Hence, we use time-varying weights and analyze how structural changes in the trade composition and financial linkages affect the propagation of foreign shocks to specific countries.

Time-varying trade-weights are constructed using annual bilateral trade data, i.e., export plus import, from the IMF Direction of Trade Statistics. Trade weights are further used to construct foreign output variables for each individual VARX* model. Time-varying financial weights are constructed using outstanding amounts of total short- and long-term assets and liabilities from the IMF Coordinated Portfolio Investment Survey. Financial weights are further used to construct foreign interest rate variables for each individual VARX* model. See section 3.1 for further details on the data used to construct time-varying weights.

Global variables usually include oil prices, prices for other commodities or both. There are several ways to model global variables in the GVAR framework. One way is to treat them as domestic variables for a specific country. Here, their dynamics are determined endogenously in an individual VECMX* model. Global variables are typically included in the US individual model as the US plays a dominant role in the world economy. For other economies in the panel global variables are weakly exogenous. However, this assumption may be too restrictive if the importance of other developed and emerging economies is crucial.

Alternatively, one can use a dominant unit model (Chudik & Pesaran, 2013; Smith & Yamagata, 2011). This type of model structure allows the inclusion of endogenous relationships between global variables within the VAR model, as well as feedback variables from all countries in the panel based on their importance on the world market. In particular, a dominant unit model is a separate VECM model with endogenous global variables and weakly exogenous feedback variables. Feedback variables, in turn, can be constructed using weighted domestic countries' variables. These weights can be constructed using PPP-GDP data to determine the role and size of each individual country in the feedback variables for a dominant unit model. In this paper we use the following form of a dominant unit model:

$$\Theta(L,\tilde{p})D_t = \tilde{a}_0 + \Gamma(L,\tilde{q})\sum_{i=1}^{N}\widetilde{\omega}_i X_{it} + \tilde{u}_t, \quad (3)$$

where D_t is a set of global variables and $\Theta(L,\tilde{p})$ is the matrix lag polynomial of related coefficients; $\tilde{a}_0$ is a k×1 vector of fixed intercepts; $\tilde{X}_{it} = \sum_{i=1}^{N}\widetilde{\omega}_i X_{it}$ is a set of weighted average feedback variables and $\Gamma(L,\tilde{q})$ is the matrix lag polynomial of the associated coefficients; and $\tilde{u}_t$ a k×1 vector of idiosyncratic, serially uncorrelated country-specific shocks with $u_{it} \sim iid(0,\Sigma_{ii})$.

The estimated GVAR model can now be used to compute Generalized Impulse Response Functions (GIRFs) that account for important interdependencies across countries as in Pesaran & Shin (1998). GIRFs are insensitive to ordering of variables, so they are not used for identification of structural shocks in the VAR model. However, the GVAR framework incorporates a weak exogeneity assumption that allows identification of country-specific shocks where cross-country residual correlation and country-specific serial residual correlation is low.

3.3 Data and model setup

This section introduces our data used for estimating the model. We then present the GVAR model setup and discuss the main diagnostic tests conducted for the model. The key features of our GVAR model are summarized in Table 24 and descriptive statistics of individual country data are specified in Tables 25 and 26.

3.3.1 Data

Our GVAR model includes five CIS economies: Azerbaijan, Belarus, Georgia, Kazakhstan, and Ukraine. We do not include Russia in the CIS group as its size affects analysis for the rest of CIS countries. Instead, we treat Russia separately and study the response of our CIS region to Russian output shocks. We also include 23 other developed, developing and emerging economies: United States, euro area (modeled as a single region), Australia, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, Denmark, Hungary, Iceland, India, Indonesia, Japan, Korea, Mexico, New Zealand, Norway, Poland, Romania, Sweden, Turkey and United Kingdom. Thus, we have a total of 30 cross-section units in the GVAR model with the countries covering about 80% of world PPP-adjusted GDP according to the World Bank database.

Each individual country model includes four domestic variables: consumer inflation, real output, nominal short-term interest rate and real exchange rate. Our dataset covers the period 2001Q1 – 2016Q4, which gives 64 quarterly observations. The time span for the analysis covers both the global financial crisis of 2007–2008 and the recent drop in oil prices accompanied with the recession in CIS economies. Our starting point reflects the data limitations. Most of the country data comes from the IMF IFS database. Like Feldkircher (2013), we use the regional aggregate for the euro area from the IMF IFS calculated on a rolling basis.

For the real output (y), we use logarithms of seasonally adjusted real GDP $y=\ln(GDP_t)$ indexed to annual average of 2010=100. The data for Australia, Brazil, Canada, Chile, India, Indonesia, Japan, Korea, Mexico, New Zealand, Turkey and Russian Federation are taken from the OECD database in real terms and seasonally adjusted. The data for the euro area, Czech Republic, Denmark, Bulgaria, Hungary, Iceland, Norway, Romania, Sweden and United Kingdom comes from the Eurostat in real terms and seasonally adjusted. The US real and seasonally adjusted GDP data come from the US Bureau of Economic Analysis. Real, but not seasonally adjusted, data for China and Georgia come from the IFS IMF. For Belarus, we take nominal GDP from the IFS IMF and deflate it by CPI. The data for real GDP for Ukraine, Kazakhstan and Azerbaijan come from national sources. For the seasonal adjustment of the data, we use the X12 multiplicative method.

For consumer price inflation (dp) (in line with earlier studies using the GVAR approach), we take the first log-differences of seasonally adjusted Consumer Price Index: $\Delta p= \ln(CPI_t) - \ln(CPI_{(t-1)})$ to obtain percentage change of consumer prices. For all countries, we use the CPI index from IMF IFS. All CPI time series have been seasonally adjusted using the X12 additive method.

For real exchange rate (e), we use logarithms of nominal exchange rate indexed to 2010 average and deflated by domestic consumer price index: $e= \ln(NFX_t) - \ln(CPI_t)$. The data on nominal bilateral exchange rate with respect to the US dollar comes from IMF IFS.

For nominal short-term interest rates (r), we mainly rely on the 3-month or 90-day interbank interest rates from the OECD database. For the US, we use the 3-

month treasury bill secondary market rate. Money market interest rates for Brazil, Chile and Georgia are taken from the IFS IMF. For other countries, we use deposit interest rate from the IFS (except Kazakhstan, where the data are taken from national sources).

For foreign-specific variables, we follow Feldkircher (2013) and use weighted foreign output (y*) and interest rates (r*) as weakly exogenous variables. To take into account bilateral trade interlinkages and financial exposure between countries we use both trade- and financial-weight matrices to construct, respectively, foreign output variables and foreign interest variables.

The weights used to construct foreign output variables are based on annual bilateral goods trade flows (i.e. exports plus imports in US dollars). The trade data come from the IMF Direction of Trade Statistics database, which provides data on the geographical distribution of countries' exports and imports.

For construction of foreign interest rate variables, we use financial weights. The use of financial weights in GVAR models has recently gained popularity as they provide the information on how financial markets of different countries are linked with each other. In GVAR models, financial weights reduce the amplification of impulse responses; a common problem when only trade weights are used. Existing studies mostly rely on financial weights from the Bank of International Settlement (BIS) consolidated or locational banking statistics. They provide total foreign claims of reporting banks on individual countries and represent the information on the degree of financial exposures of countries banking system. BIS statistics, however, only include data only for reporting banks and Russian Federation; CIS countries are not represented.

Therefore, to incorporate financial exposures of CIS economies, we use the IMF's Coordinated Portfolio Investment Survey (CPIS), a dataset on the stock of cross-border holdings of equities and long- and short-term debt securities broken down by issuer residence. Although the BIS statistics and CPIS differ in their data collection methods, financial weight matrices have a high correlation for BIS reporting countries (correlation between BIS statistics and CIPS statistics for selected economies is 0.89, see Table 27 in the Appendix). As with trade, we use time-varying weights for financial linkages. This approach allows us account for financial market trends in the CIS.

Global variables in GVAR models are commonly represented by oil prices. In our analysis, we use logarithms of seasonally adjusted Brent oil price indexed to the 2010 average. We model oil prices in a dominant unit univariate model, where we also include feedback variables on real output based on PPP-adjusted GDP weights.

This helps incorporate the effect of each individual country on the dynamics of oil prices with respect to the country's size.

3.3.2 Model setup

Before setting up individual VECMX* models and combining them into a global model, we first run a set of statistical tests to explore data properties and ensure the suitability of our analytical framework.

To test for the order of integration of variables, we run several unit-root test, such as Augmented Dickey-Fuller (ADF) test, Dickey-Fuller test with GLS detrending (DF-GLS), Phillips-Perron (PP) test, and Elliot, Rothenberg, and Stock point optimal (ERS) test. Summary results for variables in levels and first differences are presented in Tables 28 and 29 (Appendix), respectively. The results suggest that real output, real exchange rate and interest rate, as well as their foreign counterparts in levels, are integrated of first order for most countries. At the same time, the unit-root hypothesis for consumer inflation in levels can be rejected in most cases. Following existing studies on GVAR modeling and pursuing VECM econometric framework, we conclude that most time series are integrated of order one. This ensures the stability of the final GVAR model. In particular, according to ADF test results, 34 of the 209 time series are integrated of order zero, while 197 of the 209 time series are integrated of order one. These results also correspond to the results of DF-GLS, PP, and ERS tests.

We next choose a lag length for domestic, foreign and global variables in each individual VECMX* model. Although the lag length is usually determined by minimizing AIC, we set the lag length for domestic, foreign as well as global variables equal to one in our analysis due to the relatively short dataset. We determine the rank of cointegration relationships according to Johansen trace statistics and the type of deterministic components using the likelihood ratio (LR) test. Tables 30 and 31 (Appendix) present summary results for the choice of cointegration rank and the type of deterministic components. Individual VECMX* specifications are provided in Table 32 (Appendix).

We run a set of diagnostics tests to verify the final specifications of individual VECMX* models. Foreign variables are tested for weak exogeneity, which in the VECMX* framework implies no feedback from domestic variables to the foreign counterparts in the long run. Results for the test, presented in Table 33 (Appendix), suggest that the hypothesis of no weak exogeneity can be rejected for most countries, supporting the econometric approach used here. The F-test rejects the hypothesis of no weak exogeneity for 72 of 87 foreign variables at the 5% significance level. In addition to weak exogeneity tests, we test each individual VECMX* models for residual serial correlation. As mentioned, a relatively short dataset limits the ability to include additional lags to deal with residual serial correlation. Following the F-test results (see Table 34 in the Appendix), the hypothesis of first-order serial correlation can be rejected for 87 of 120 equations at the 5% significance level.

Our final test examines the cross-country correlation of the residuals. Average pairwise cross-section correlations are presented in Table 35 (Appendix). Our results generally are quite similar to those of Feldkircher (2013). The cross-country correlations are low with the exception of the equation of the real exchange rate (correlations range from 0.2 to 0.4 for some countries).

To sum up, diagnostic tests carried out in the paper in general support the final setup of the GVAR model. Foreign specific counterparts of domestic variables in each individual model deal with cross-country residual correlation. Nevertheless, a relatively high number of individual country models with first order serial correlation of residuals limits the ability for structural interpretation of exogenous shocks.

3.4 Results

In this section, we compute generalized impulse response functions (GIRFs) to examine the propagation of foreign shocks across CIS economies. In particular, we explore the response of real activity in the CIS region to output shocks in the US, euro area, China, and Russian Federation, as well as CIS regional shocks. We also present GIRFs for an oil price shock, which, like for most countries (see Fernández et al., 2017), is potentially an important driver for the CIS region.

3.4.1 Results with time-invariant weights

As a baseline estimation, we first compute the GIRFs using trade and financial weights computed as averages over the entire time span of our analysis, 2001–16. Our baseline estimation is quite similar to those presented in the previous literature (Feldkircher, 2015; Feldkircher & Korhonen, 2014), making our results readily comparable to estimates obtained from earlier models.

3.4.1.1 Responses to output shocks

Figure 1 plots the response of real activity in the CIS region and in major economies to 1% output shocks in corresponding economies with a perspective of 30 quarters. The results are largely in line with the earlier literature (Feldkircher, 2015). A 1% shock to output in the US results in an output increase of similar size in the CIS region, whereas the impact for the euro area and Russia is around 0.5%. The response of Chinese output is near zero. Responses to an output shock originating in the euro area are more moderate. Following a 1% euro area output shock, output of the CIS region increases by 0.5% and output of Russia by 0.2%. Somewhat surprisingly, the responses of US and Chinese output are tiny. This may reflect the fact that these countries are relatively less involved in foreign trade. Responses of all countries and regions to an output shock in China are also quite small (0–0.2%), but the result is in line with estimates from the earlier literature (Feldkircher & Korhonen, 2014; Dreger & Zhang, 2014).

Figure 2 provides impulse responses of each individual CIS country. The strongest output responses in most individual CIS countries are caused by output shocks in the US and CIS region. The responses to a US shock vary from 0.4% in Kazakhstan to nearly 2% in Azerbaijan and correspondingly, between 0.4-1.5% to a shock in the CIS region itself.

A notable exception is, however, Belarus, where output reaction is the strongest by far to a shock originating from Russia, reaching over 2%. This could be expected, however, as the Belarussian economy remains closely linked to the Russian economy in terms of both trade and financial linkages. The responses to a Chinese output shock are relatively moderate in most CIS countries, ranging from 0.1% for Ukraine to 0.5% for Azerbaijan. These results, too, are largely in line earlier studies (Feldkircher, 2015; Feldkircher & Korhonen, 2014).

Figure 1. Generalized Impulse Responses of real activity in major economies to 1% output shocks in the US, euro area, China, Russia and CIS (affected region in the heading, shock origins depicted by lines).

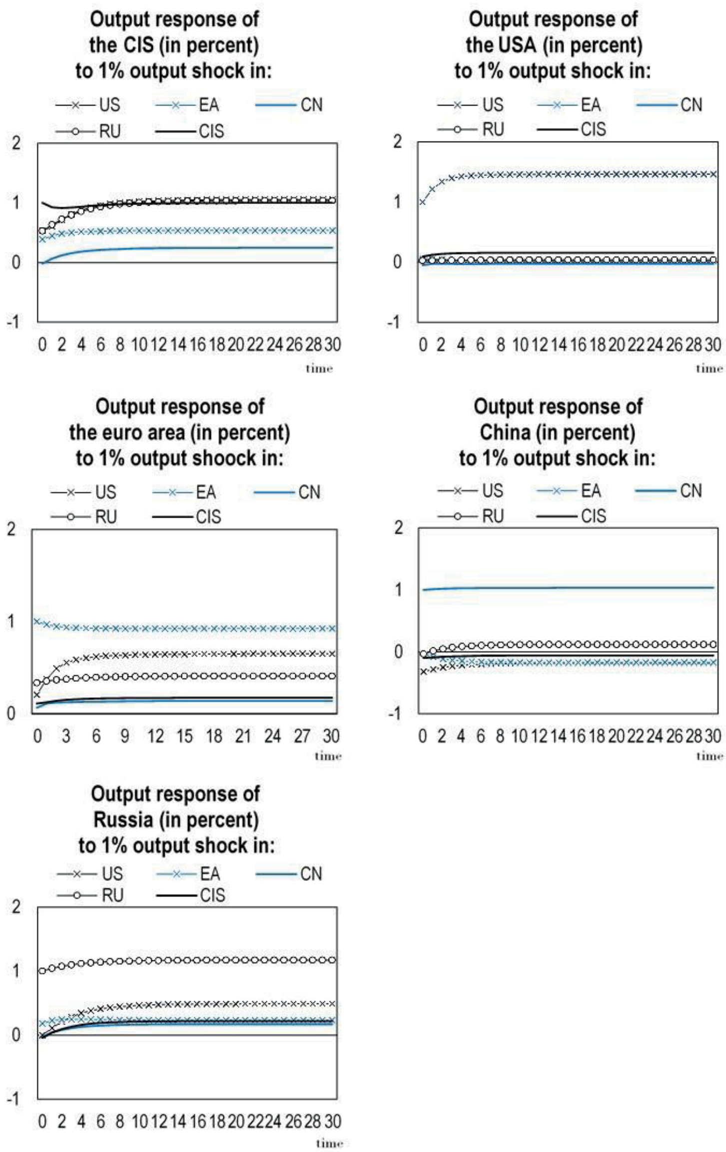
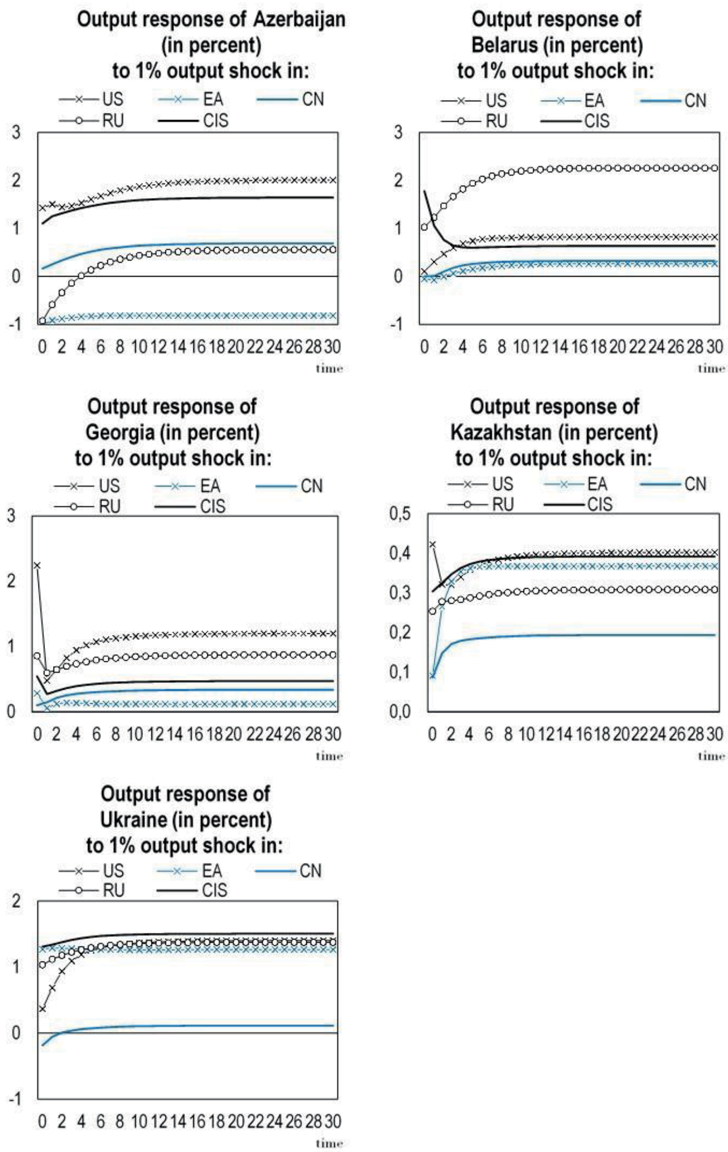


Figure 2. Generalized Impulse Responses of real activity in individual CIS countries to 1% output shocks in the US, euro area, China, Russia and CIS (affected region in the heading, shock origins depicted by lines).



3.4.1.2 Responses to an oil price shock

We now consider the output responses of our selected economies to an oil price shock; specifically, a 50% increase in the oil price. The impulse responses are shown in Figure 7 (Appendix). The results are largely in line with previous research, both qualitatively and quantitatively (Feldkircher, 2015). The output response is somewhat negative for net oil importers such as the US (-0.4%) and the euro area (-0.6%), and clearly positive for an oil exporter like Russia (4%).

The strongly positive response of the CIS region to an oil price shock is somewhat surprising, but may reflect several factors. Unlike in Feldkircher (2015), our CIS aggregate includes Azerbaijan and Kazakhstan, both substantial oil exporters. The positive response is also affected by Belarus, which, despite its lack of hydrocarbon resources, processes considerable amounts of Russian crude oil and then exports refined products. As suggested by Feldkircher (2015), the negative impact of an oil price increase for oil-importing Ukraine and Georgia may be overcome by the spillover effect from the positive impact on the Russian economy.

3.4.2 Results with time-varying weights

Up to this point, we have analyzed the sensitivity of CIS economies to foreign shocks using time-invariant trade composition and financial linkages. However, as discussed in section 3, the CIS region and the world economy in general over the last two decades have experienced considerable changes in trade and financial integration that could affect the transmission of international shocks.

Therefore, after we first use time-varying weights to construct weakly exogenous variables and then estimate each individual VARX* model over the full sample 2001-2016, we link all the models through different solution matrices to compute GIRFs. In particular, we use trade and financial weights for four periods (i.e., 2001–2004, 2005–2008, 2009–2012 and 2013-2016) to examine how the propagation of foreign output shocks depend on the trade and financial interlinkages. Note that for this exercise we do not re-estimate the model but only change the solution matrices to compute GIRFs. Long-run GIRFs computed at the 30th period for the larger regions and economies are presented in Figure 3. Figure 4 displays the results for the individual CIS countries.

Figure 3. Evolution of long-run responses in major economies to 1% output shocks in the US, euro area, China, Russia and CIS (affected region in the heading, shock origins depicted by lines). Note: long-run responses are computed at the 30th period.

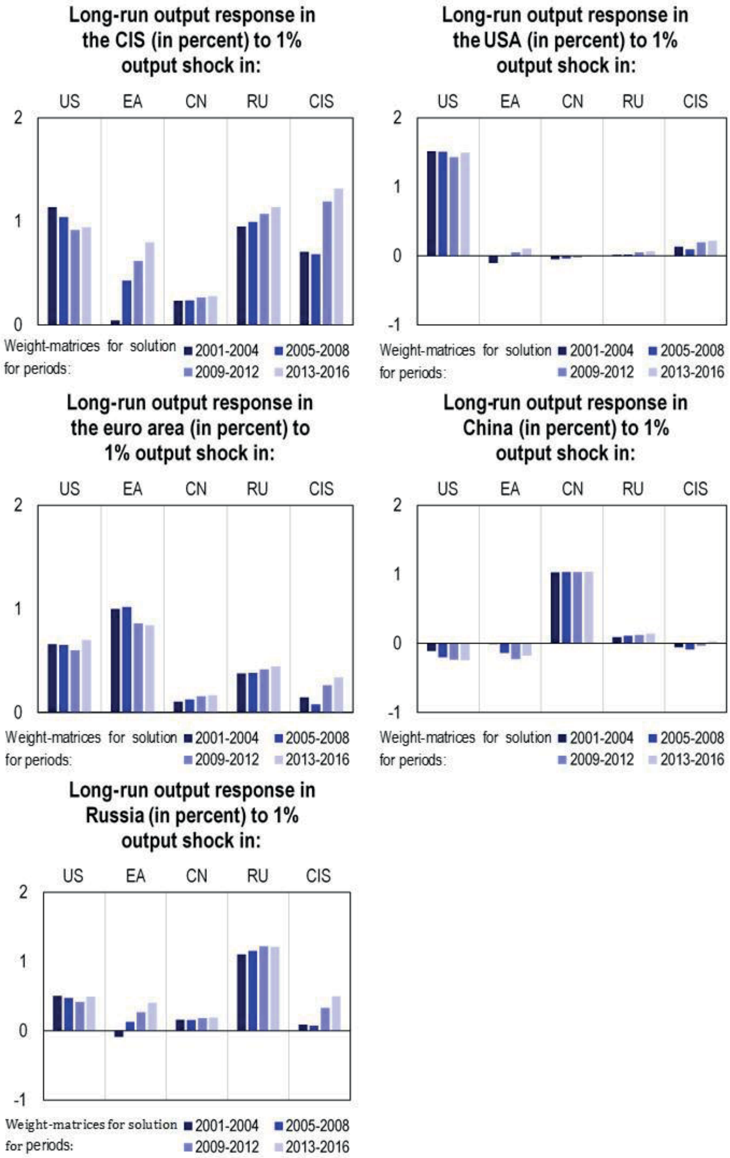
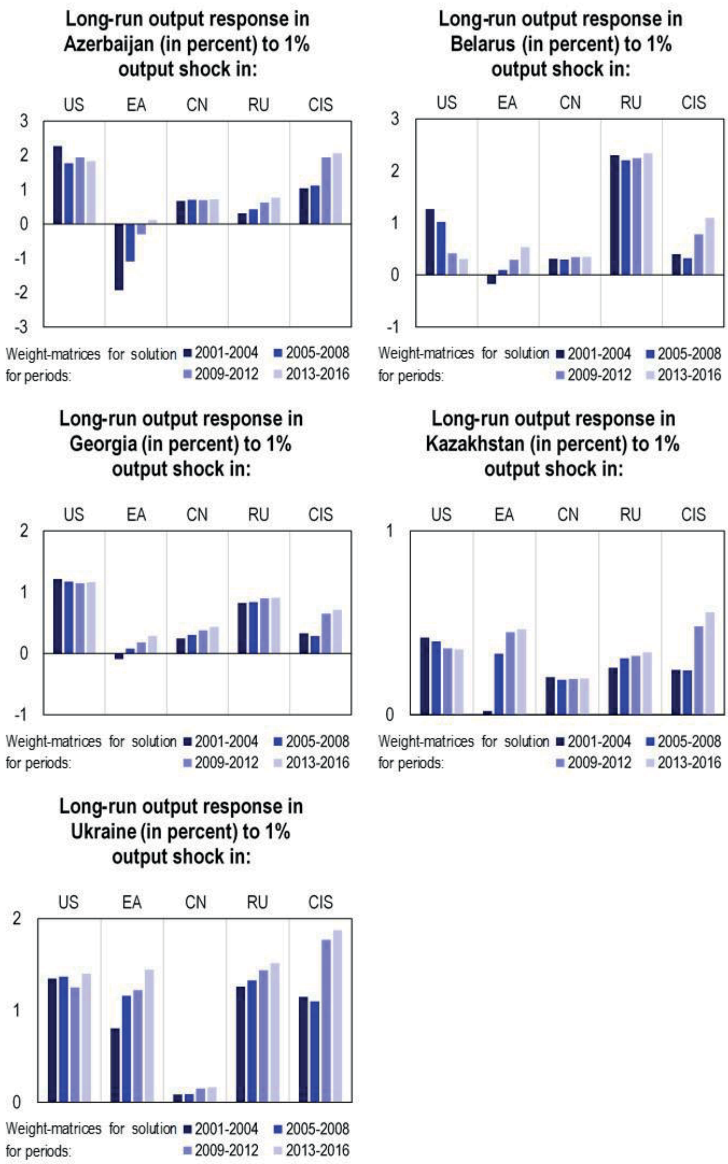


Figure 4. Evolution of long-run responses in individual CIS countries to 1% output shocks in the US, euro area, China, Russia and CIS (affected region in the heading, shock origins depicted by lines). Note: long-run responses are computed at the 30th period.



3.4.2.1 Responses to output shocks

As Figure 3 shows, the output responses of the CIS region to output shocks of various economies have changed substantially over the past two decades. The CIS output response to a shock from the euro area output increases steadily from about 0.1% with the 2001–04 weights to 0.8% with the 2013–16 weights. Response to a shock in the CIS region itself has also intensified notably, in particular after the global financial crisis. Responses to output shocks in Russia and China have also increased slightly. Even with the latest weights, however, the response to Chinese shocks is quite moderate at about 0.2%. In contrast, the response of the CIS output to a shock on US output has declined gradually from 1.2% with the 2001–04 weights to 0.9% with the 2013–16 weights.

Taken individually, the developments in CIS countries, as seen from Figure 4, are quite similar. The output response to a shock originating in the euro area increases steadily in all countries, ranging from 0.1% for Azerbaijan to 1.5% for Ukraine when using the latest weights. The sensitivity to the local output shocks in the CIS region also increases substantially after the global financial crisis in all individual CIS countries. The impact of US shocks declines, especially for Belarus, while the impact of Chinese shocks increases, particularly for Georgia and Ukraine (but still quite moderate at less than 0.5%).

Figure 3 shows changes in output responses of other regions are much smaller than for the CIS region. The reactions of Russian output to shocks in the euro area and the CIS region increase a bit, reaching 0.5% when estimated using the latest weights. For the US, euro area and China, changes over time are small. The growing role of China is reflected in the slightly increasing response of the euro area output to a Chinese output shock.

3.4.2.2 Decomposition of output shock responses

To better understand the reasons behind the changes in responses of the CIS countries, we decompose the changes to effects originating from direct and indirect trade and financial linkages by extending the approaches of Fadejeva et al. (2017) and Cesa-Bianchi et al. (2012).

We compute GIRFs for the CIS countries using a number of time-specific counterfactual weights. For this purpose, after we construct weakly exogenous foreign variables using time-varying trade and financial weights and estimate each individual VARX* model for a full sample 2001-2016, we link all the models through different solution matrices to compute GIRFs. The VARX* estimated coefficients remain unchanged. In contrast to the previous sub-sections, this time we construct trade and financial weights to account also for regional and global changes separately. For example, we first solve the model to compute GIRFs using trade and financial matrices for the baseline period (2001-2004). Thereafter, we compute GIRFs using trade-weight matrices for the CIS region for the second period (2005-2008) while trade-weight matrices for other countries as well as financial-weigh matrices for all countries remain unchanged. This exercise allows the separation of a direct trade effect by subtracting the resulting response from the baseline response. Similarly, we can examine the effect of indirect trade channel using trade-weight matrices for the CIS region for the baseline period and trade-weigh matrices for the rest of the countries for the period 2005-2008, while keeping financial-weight matrices for all the countries unchanged. To explore the effect of direct and indirect financial channel we repeat this exercise but changing financial-weight matrices instead of trade-weight matrices.

Figure 8 (in the Appendix) decomposes the changes of responses of the CIS aggregate to direct trade, direct financial, indirect trade and indirect financial effects over four periods of interest (i.e., 2001–2004, 2005–2008, 2009–2012 and 2013-2016). The reinforcing effect refers to the residual that cannot be allocated to any particular effect. The results of the decomposition are slightly puzzling in several cases. This could be related to the brevity of the observation period, especially since it includes large fluctuations in the CIS economies.

Starting from the most notable change, the decomposition in Figure 8 suggests that the substantial increase in the response of the CIS countries to an output shock in the euro area comes mainly through the trade channel, particularly the indirect trade channel, while the contribution of the financial channels (both direct and indirect) is slightly negative. The result for the trade channel is slightly puzzling, given that the euro area's share of trade with CIS countries has increased slightly and declined for trade with the other regions. Our Rest of the World aggregate includes EU members and associates outside the euro area, e.g. the CEE countries, UK and Turkey. Moreover, the trade share of the euro area with these countries may have increased, even if its trade share has declined with other countries included in the Rest of the World aggregate (e.g. Japan and Korea). These countries are important trading partners for most CIS countries. Therefore, the impact of an output shock to the euro area for the CIS countries may have been magnified indirectly through increased trade integration between the euro area and the CEE countries. Fadejeva et al. (2017) point to a similar possibility in the case of Baltic countries. They find indirect effects contributing more than direct effects.

As Figure 8 shows, the growing sensitivity of the CIS countries to intra-regional shocks seems mainly related to increasing trade and financial linkages among the CIS countries. The effect is surprisingly strong, given the modest increase in their mutual trade shares and marginal increase in mutual financial linkages. However, the residual effect is quite large, especially in the latter half of the observation period. As expected, the contribution of the indirect trade effect is clearly negative as the trade share of the CIS countries for other regions was small to begin with and declines slightly.

The modest increase in the CIS response to a Chinese output shock is mainly due to indirect effects as expected. The direct role of China is still quite limited in trade and financial linkages with the CIS countries in our sample. This finding comports with the results of Cesa-Bianchi et al. (2012), who suggest that the impact of shocks originating in China on Latin American countries has increased largely due to the indirect channel. For the CIS economies, also in the case of an increased impact from a Russian output shock, the main contribution comes from the indirect financial effect. This could again be related to some countries in the Rest of the World bloc as the share of Russia has not increased in the financial linkages for any of the major economies. The residual effect is also quite large in the case of Russia.

We can see from Figure A4 that the sensitivity of the CIS countries has declined slightly only for output shocks originating in the US. This development, which seems mainly due to the direct financial effect, is quite baffling as the share of the US has increased in the financial linkages of the CIS region. On the other hand, the effect is relatively small and seems driven mainly by. In contrast, the indirect financial effect of a US shock on the CIS aggregate is almost as large and positive. This is quite in line with Fadejeva et al. (2017), who conclude that indirect effects dominate in the transmission of US shocks to CIS economies.

3.4.2.3 Responses to an oil price shock

As our final exercise, we apply the time-varying weights to the analysis of an oil price shock, aware that changes in the geographical composition of trade and financial linkages may alter the responses of economies to oil price shocks. This seems to be the case, but with slightly different implications for different regions as shown in Figure 9 (in the Appendix).

The responses of the US and the euro area output are negative for all different time weights, but the responses become slightly milder over time. For the euro area in particular, this may reflect the increasing spillover effects from China. Since an oil price shock has a positive effect on Chinese output, spillovers from China may mitigate the negative effect of an oil price shock for the euro area. In the US, the milder response could also relate to the increasing domestic oil production and declining dependence on oil imports.

On the other hand, the positive responses of the CIS countries and Russia to an oil price shock are somewhat strengthened when using the trade and financial weights for the later parts of the observation period. This may reflect the increased sensitivity of the CIS economies and Russia to each other's shocks; the positive effect of an oil price shock reinforces spillover effects across the region. In addition, the role of oil increases e.g. in the Russian economy in the latter part of the observation period compared to the early years. The development of the responses to oil price shocks is fairly similar across the individual CIS countries, although distinctly pronounced for Belarus (probably because the country has such close linkages with the Russian economy).

3.4.3 Comparing the results across CIS economies

As our focus is on the CIS countries, we discuss the results regarding them in a bit more detail. As noted in section 4.1, there is substantial variation across individual CIS economies in the impacts of external shocks. Concerning foreign output shocks, in general the responses are strongest for Azerbaijan and Belarus, whereas for Georgia and Ukraine the responses are slightly milder and much more moderate in the case of Kazakhstan. This can reflect differences in certain structural features of the economies, like trade and financial openness as suggested by Georgiadis (2016) and Crespo Cuaresma et al. (2018) in the context of U.S. monetary policy shocks. In the business cycle synchronization literature, there is also plenty of evidence on the importance of trade and financial integration for business cycle co-movement (Baxter and Kouparitsas 2005, Ductor and Leiva-Leon 2016, Gong and Kim 2018).

Our narrow sample hampers a formal investigation of the importance of various structural factors on the propagation of shocks to CIS countries, but we make some simple comparisons to analyze the issue. As an example, we examine in more detail the impact of U.S. output shocks, as they are very important for all CIS countries. The U.S. is not a particularly important trading partner for the CIS countries directly (in latest years of our sample the share of the U.S. in their goods exports varied between 0.4 % and 5 %). Therefore, it is not surprising that the U.S. export share appears to explain only moderately the strength of the CIS output responses to a U.S. shock (a positive correlation of 0.32). The indirect impacts of the U.S. shocks thus seem to be more important, as discussed above.

Taking this into account and guided by the previous literature, we examine next the relationship of the magnitude of the output response with trade openness (as measured by the trade to GDP ratio) and with financial openness (as measured by net foreign assets to GDP ratio). This analysis suggests that Kazakhstan is an outlier in the sample. When we exclude Kazakhstan, it seems that among the other CIS countries higher trade integration and lower financial integration cushion the propagation of U.S. shocks (Figure 10 in the Appendix), analogically to findings of Georgiadis (2016) and Crespo Cuaresma et al. (2018) for the transmission of U.S. monetary policy shocks.

As another case study we take Russian shocks which also have a relatively strong effect on most CIS countries and in particular on Belarus. As the region's largest economy, Russia has traditionally been an important trading partner for most CIS countries. Russia's share in the exports of CIS countries has varied between 3.5 and 42.9 % in the latest years of our sample with the lowest share recorded for oil-exporting Azerbaijan and the highest share for Belarus. In the case of Russia, the export share indeed seems to explain largely the shock transmission from Russia to CIS countries with a positive correlation of 0.92 (see Figure 11 in the Appendix). From the more structural viewpoint, this appears to be largely associated with the share of manufacturing in the economy. As a country with abundant oil and other resources, Russian imports are more concentrated on manufactured goods. Therefore, Russia's share tends to be higher in the exports of CIS countries where the share of manufacturing in GDP is larger. As Figure 11 shows, higher share of manufacturing appears to be associated with higher sensitivity to Russian output shocks (a positive correlation of 0.89). This is also similar to the findings of Georgiadis (2016).

3.5 Conclusions

This paper examined the sensitivity of the CIS economies to global and regional shocks with a global VAR model, concentrating particularly on output shocks originating in select major economies and oil price shocks. Complementing previous literature, we considered in detail changes over time in the output responses of the CIS economies by applying time-varying trade and financial weights. We also investigated separately the significance of shocks originating in Russia for the CIS economies. In addition, we have decomposed the changes in responses of CIS countries to direct and indirect trade and financial effects to better understand the origins of the changes.

Our results show that the CIS region continues to be highly sensitive to both regional and global shocks. Throughout our two-decade observation period, CIS responses were strongest to output shocks originating within the region itself, or in Russia and the US. These responses are all roughly of similar magnitude. The CIS region also responds strongly to oil price shocks. Notably, the response is positive across the individual countries, even if they are not net exporters of oil. This reflects the importance of the spillover effects within the CIS region and from Russia.

The sensitivity of the CIS economies to regional and global shocks has increased in past decades, particularly since the global financial crisis. The increase in sensitivity has been most pronounced for shocks originating within the region and shocks coming from the euro area. The increased impact of regional shocks is mainly due to direct trade and financial channels as the CIS economies have integrated extensively with the global economy. For euro area shocks, the main channel contributing to stronger CIS responses seems to be the indirect trade effect. This is slightly puzzling, but could be due to transmission effects through the CEE countries outside the euro area.

Despite some decrease in trade and financial linkages between the CIS region and Russia in past years, the sensitivity of the CIS countries to Russian shocks has not decreased. On the other hand, despite the increase in economic linkages between the CIS countries and China, the output responses of the CIS economies to shocks originating in China still seem to be quite small even when indirect effects are considered.

We also tried to examine more closely which structural features could affect the strength of the CIS responses to external shocks, taking as case studies shocks originating in the US and Russia. Our analysis suggests that those CIS countries that have lower global trade integration and higher financial integration tend to be more vulnerable to US shocks. Concerning Russia, its significance as an export market appears to mainly determine the strength of shock responses in CIS countries. This is also associated with higher share of manufacturing in GDP as Russia imports mainly manufactured products instead of raw materials.

Our results suggest that the CIS countries need to pay close attention to global and regional economic developments in their policy planning. They are relatively small countries with minor influence over global developments. Thus, the policy challenge is preparedness. The implementing of prudent policies and creation of adequate buffers can help CIS countries deal with potential shocks at the regional level and from global markets.

APPENDIX. FIGURES AND TABLES

Table 23. Real GDP cross-country correlations (annual growth rates)

Pre-crisis 2001–2008	USA	EA	CHINA	RUSSIA	CIS
USA	1	0.36	0.28	0.52	0.14
EA	-	1	0.66	0.66	0.17
CHINA	-	-	1	0.85	0.19
RUSSIA	-	-	-	1	0.25
CIS	-	-	-	-	0.08*
Post-crisis 2009–2016	**USA**	**EA**	**CHINA**	**RUSSIA**	**CIS**
USA	1	0.87	-0.31	0.70	0.30
EA	-	1	-0.20	0.61	0.25
CHINA	-	-	1	0.22	0.30
RUSSIA	-	-	-	1	0.58
CIS	-	-	-	-	0.41*

Source: World Bank Open Data – World Development Indicators

* shows average cross-country correlations within CIS economies

Table 24. Description of the GVAR model main features and variables

Time coverage	2001Q1 - Q2016Q4
Countries and regions	US
	China
	Russia
	Euro area (block with 12–19 countries): Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain (2001–2006); *plus* Slovenia (2007), Cyprus, Malta (2008), Slovakia (2009), Estonia (2011), Latvia (2014), Lithuania (2015)
	CIS (5 countries): Azerbaijan, Belarus, Georgia, Kazakhstan, Ukraine
	Rest of the World (21 separate countries): Australia, Brazil, Bulgaria, Canada, Chile, Czech Rep., Denmark, Hungary, Iceland, India, Indonesia, Japan, Korea, Mexico, New Zealand, Norway, Poland, Romania, Sweden, Turkey, UK
Variables	***y*** = real GDP, index (average of 2010=100), seasonally adjusted, in logs
	dp = consumer price inflation, seasonally adjusted, first log-differences
	e = real exchange rate (nominal exchange rate w.r.t USD deflated by domestic CPI), index (average of 2010=100), in logs
	r = nominal short-term interest rate, typically 3-month or 90-day interbank interest rate
	f = Brent oil price, index (average of 2010=100), seasonally adjusted, in logs
Weights	Trade: shares of partner countries in total goods trade (sum of exports and imports)
	Financial: shares of partner countries in the stock of cross-border holdings of equities and long- and short-term debt securities

Table 25. Country data descriptive statistics: Real GDP and Inflation

Country	Real GDP				Inflation, %			
	Min	Mean	Max	SD	Min	Mean	Max	SD
USA	4.46	4.61	4.75	0.08	-2.18	0.51	1.41	0.56
EMU	4.35	4.58	4.75	0.11	-0.39	0.42	1.19	0.33
CHN	3.65	4.41	5.07	0.44	-1.1	0.58	2.57	0.67
RUS	4.16	4.54	4.73	0.18	0.35	2.5	6.98	1.13
AZE	3.57	4.49	4.97	0.50	-2.68	1.62	7.75	1.94
BLR	3.67	4.44	4.95	0.43	0.52	4.84	24.04	4.5
GEO	4.18	4.68	5.03	0.26	-4.35	1.14	4.64	1.56
KAZ	3.94	4.54	4.92	0.29	0.32	1.98	8.31	1.32
UKR	4.24	4.55	4.75	0.13	-1.68	2.78	19.64	3.23
AUS	4.32	4.57	4.78	0.13	0.03	0.64	1.43	0.35
BRA	4.27	4.53	4.73	0.15	0.53	1.64	5.59	0.82
BGR	4.20	4.54	4.75	0.16	-0.77	0.92	5.47	1.21
CAN	4.45	4.61	4.75	0.09	-1.07	0.45	1.4	0.45
CHL	4.26	4.59	4.86	0.19	-2.13	0.78	2.56	0.73
CZE	4.33	4.56	4.73	0.12	-0.41	0.5	2.76	0.57
DNK	4.54	4.62	4.70	0.04	-0.09	0.41	1.35	0.31
HUN	4.44	4.62	4.74	0.07	-0.62	0.98	2.66	0.8
ISL	4.35	4.60	4.85	0.12	-0.19	1.22	5.34	1.06
IND	3.94	4.51	5.06	0.34	-0.11	1.64	4.84	0.94
IDN	4.14	4.55	4.96	0.25	-0.03	1.74	9.33	1.31
JPN	4.55	4.62	4.68	0.04	-0.93	0.02	2.01	0.42
KOR	4.21	4.55	4.81	0.17	-0.04	0.64	1.85	0.39
MEX	4.42	4.61	4.79	0.11	0.29	1.01	1.7	0.34
NZL	4.33	4.57	4.77	0.11	-0.19	0.52	2.8	0.47
NOR	4.45	4.58	4.69	0.07	-1.9	0.49	2.62	0.61
POL	4.26	4.55	4.82	0.18	-0.66	0.51	1.63	0.55
ROU	4.22	4.56	4.79	0.16	-1.65	1.79	7.86	1.84
SWE	4.44	4.61	4.78	0.09	-0.9	0.3	1.38	0.43
TUR	4.16	4.62	5.03	0.25	0.54	3.16	19.43	3.18
GBR	4.48	4.62	4.74	0.07	-0.3	0.51	1.75	0.39

Table 26. Country data descriptive statistics: Real exchange rate and interest rate

Country	Real exchange rate				Interest rate, %			
	Min	Mean	Max	SD	Min	Mean	Max	SD
USA	-	-	-	-	0.01	1.37	4.98	1.65
EMU	4.46	4.68	4.99	0.13	-0.33	1.88	4.98	1.63
CHN	4.45	4.66	4.84	0.15	1.50	2.53	4.14	0.69
RUS	4.48	4.83	5.38	0.27	3.37	5.59	11.57	1.64
AZE	4.53	4.88	5.29	0.30	5.35	9.97	12.54	1.52
BLR	4.41	4.75	5.18	0.18	6.97	15.86	42.43	7.96
GEO	4.40	4.74	5.13	0.22	3.46	9.61	30.33	6.45
KAZ	4.49	4.78	5.14	0.23	3.77	7.35	13.00	2.21
UKR	4.35	4.76	5.23	0.22	6.43	10.03	17.11	2.56
AUS	4.46	4.77	5.24	0.22	1.76	4.48	7.80	1.54
BRA	4.49	4.92	5.57	0.28	7.13	13.84	26.24	4.38
BGR	4.50	4.78	5.33	0.23	0.11	2.98	6.49	1.40
CAN	4.55	4.74	5.00	0.14	0.38	2.16	5.14	1.37
CHL	4.51	4.72	5.03	0.14	0.43	4.04	8.99	1.81
CZE	4.44	4.79	5.32	0.22	0.29	1.99	5.41	1.43
DNK	4.47	4.68	4.99	0.13	-0.20	2.13	5.81	1.74
HUN	4.42	4.74	5.21	0.19	0.31	6.54	12.44	3.18
ISL	4.16	4.49	4.74	0.16	4.00	8.55	17.96	3.72
IND	4.54	4.77	5.02	0.15	8.00	11.12	13.75	1.20
IDN	4.54	4.80	5.34	0.18	5.66	8.98	17.22	3.04
JPN	4.54	4.73	5.00	0.12	0.03	0.38	1.05	0.24
KOR	4.43	4.59	4.82	0.10	1.35	3.59	5.95	1.24
MEX	4.45	4.61	4.94	0.10	3.30	6.64	18.15	2.77
NZL	4.45	4.69	5.19	0.20	2.08	4.82	8.83	2.14
NOR	4.49	4.70	4.98	0.14	0.99	3.29	7.45	1.99
POL	4.34	4.71	4.95	0.15	1.68	5.22	18.17	3.32
ROU	4.42	4.73	5.16	0.21	0.98	8.61	28.90	6.62
SWE	4.43	4.64	4.90	0.13	-0.78	1.81	4.41	1.55
TUR	4.51	4.84	5.44	0.23	12.13	25.01	87.36	16.34
GBR	4.37	4.55	4.81	0.09	0.38	2.74	6.31	2.13
	Global variables							
	Min	Mean	Max	SD				
Brent	3.65	4.69	5.41	0.50				

Table 27. Correlation between BIS locational banking statistics[a] and IMF Coordinated Portfolio Investment Survey[b] for selected economies for different periods

Country	2001-2004	2005-2008	2009-2012	2013-2016	Full period
Australia	0.69	0.74	0.64	0.63	0.68
Chile	0.89	0.94	0.88	0.93	0.91
Brazil	0.96	0.91	0.96	0.98	0.99
Japan	0.98	0.99	0.99	0.99	0.99
Denmark	0.76	0.75	0.75	0.74	0.75
Mexico	0.98	0.99	0.99	0.92	0.98
Sweden	0.82	0.85	0.89	0.84	0.85
UK	0.97	0.98	0.98	0.99	0.98
USA	0.87	0.77	0.73	0.73	0.78
EA	0.85	0.80	0.83	0.78	0.82
All selected countries	**0.89**	**0.88**	**0.87**	**0.87**	**0.89**

[a] BIS locational banking statistics report outstanding amounts of total cross-border claims for all type of instruments in all currencies for all reporting banks for all counterparty sectors.

[b] Coordinated Portfolio Investment Survey reports outstanding amounts of total cross-border investment-assets and investment-liabilities (including short- and long-term investments) in US dollars for all counterparty sectors.

Note. The number of countries is limited in BIS statistics compared to CIPS statistics. The euro area region here includes Germany, Spain, Portugal, Italy, Netherlands, Finland, Ireland, Greece, Luxembourg. Other EA countries were excluded due to data limitation.

Table 28. Unit-root tests in levels: ADF, DF-GLS, PP, and ERS

Country	Unit root test	y	dp	e	r	y*	r*	f
AUS	ADF	-2.20	-5.17*	-1.86	-1.20	-1.72	-1.35	-1.57
	DF-GLS	-1.32	-5.05*	-1.73	-1.04	-1.66	-0.93	-1.70
	PP	-2.10	-5.35*	-1.15	-0.99	-1.72	-1.92	-1.08
	ERS	33.73	0.33*	16.69	7.44	27.67	20.16	14.28
AZE	ADF	-1.51	-4.83*	-1.29	-0.87	-2.22	-2.07	-1.57
	DF-GLS	-1.88	-4.58*	-2.11	-0.91	-1.80	-0.28	-1.70
	PP	0.03	-4.75*	1.31	-1.08	-1.72	-2.35	-1.08
	ERS	15.42	1.42*	1.4*	9.48	19.09	52.04	14.28
BLR	ADF	-0.14	-2.60	-1.13	-2.56	-1.89	-1.01	-1.57
	DF-GLS	-0.56	-1.77	-1.32	-0.29	-1.61	-0.66	-1.70
	PP	0.00	-2.78	-1.16	-3.58*	-1.23	-1.01	-1.08
	ERS	33.42	3.73	55.57	49.25	55.84	15.12	14.28
BRS	ADF	0.09	-2.10	-1.74	-1.55	-2.93	-1.37	-1.57
	DF-GLS	-0.83	-1.88	-1.91	-1.42	-2.82	-0.94	-1.70
	PP	0.84	-3.36*	-1.34	-1.68	-1.96	-2.00	-1.08
	ERS	28.21	3.37	12.41	8.40	1.42*	22.47	14.28
BGR	ADF	-1.88	-4.25*	-0.35	-0.70	-2.36	-1.69	-1.57
	DF-GLS	-1.36	-2.77*	-0.93	-0.80	-1.92	-0.74	-1.70
	PP	-1.47	-4.39*	-0.43	-0.47	-1.72	-1.81	-1.08
	ERS	39.34	1.42*	203.62	8.30	17.63	16.44	14.28
CAN	ADF	-2.68	-6.91*	-1.09	-1.28	-2.24	-1.57	-1.57
	DF-GLS	-2.48	-6.47*	-1.19	-0.72	-2.29	-1.17	-1.70
	PP	-1.97	-7.29*	-0.60	-2.24	-1.80	-2.13	-1.08
	ERS	8.04	0.55*	25.38	25.05	7.97	20.91	14.28
CHL	ADF	-1.11	-4.12*	-1.66	-4.01*	-3.57*	-1.31	-1.57
	DF-GLS	-1.41	-4.13*	-1.85	-3.03*	-2.95	-0.88	-1.70
	PP	-0.92	-4.25*	-1.54	-2.69	-2.56	-1.90	-1.08
	ERS	15.40	1.19*	12.15	1.07*	0.8*	20.38	14.28
CHN	ADF	0.56	-4.58*	-1.28	-2.44	-3.13	-1.36	-1.57
	DF-GLS	-0.53	-3.66*	-1.68	-2.37*	-2.40	-0.94	-1.70
	PP	0.20	-4.26*	-1.49	-2.03	-2.11	-1.85	-1.08
	ERS	96.14	0.12*	5.44*	1.64*	5.14*	18.42	14.28
CZE	ADF	-1.95	-4*	-0.74	-2.91	-2.29	-1.81	-1.57
	DF-GLS	-1.77	-2.96*	-0.62	-0.85	-2.08	-0.70	-1.70
	PP	-1.45	-4.78*	-0.35	-1.99	-1.65	-1.72	-1.08
	ERS	16.67	0.46*	228.04	27.31	12.52	18.89	14.28

Country	Unit root test	y	dp	e	r	y*	r*	f
DNK	ADF	-2.09	-4.58*	-1.66	-1.73	-2.58	-1.19	-1.57
	DF-GLS	-2.10	-4.14*	-0.73	-0.68	-2.37	-0.54	-1.70
	PP	-1.91	-4.65*	-1.06	-1.57	-1.92	-1.72	-1.08
	ERS	8.26	1.3*	138.11	18.73	9.13	20.68	14.28
GEO	ADF	-1.16	-5.35*	-0.07	-1.70	-1.62	-1.35	-1.57
	DF-GLS	-1.54	-4.57*	-0.81	-1.55	-1.45	-0.47	-1.70
	PP	-1.64	-5.35*	0.64	-1.74	-1.01	-1.68	-1.08
	ERS	24.65	1.31*	47.11	5.77	28.12	23.53	14.28
HUN	ADF	-2.07	-4.00*	-1.55	-1.35	-2.31	-1.83	-1.57
	DF-GLS	-1.45	-2.99*	-0.81	-0.59	-2.14	-0.81	-1.70
	PP	-1.96	-3.92*	-1.14	-0.96	-1.65	-1.71	-1.08
	ERS	31.25	2.67*	133.66	13.69	11.34	16.63	14.28
ISL	ADF	-2.08	-3.86*	-3.36	-2.00	-2.51	-1.21	-1.57
	DF-GLS	-1.98	-3.82*	-2.65	-1.68	-2.41	-0.57	-1.70
	PP	-1.74	-3.90*	-2.10	-1.71	-1.87	-1.60	-1.08
	ERS	4.75*	1.26*	5.92	4.95	8.05	18.41	14.28
IND	ADF	-2.05	-1.30	-1.19	-1.98	-3.88*	-1.23	-1.57
	DF-GLS	-2.08	-0.98	-1.51	-1.58	-3.41*	-0.78	-1.70
	PP	-2.26	-4.83*	-1.87	-1.98	-2.51	-1.99	-1.08
	ERS	11.49	14.90	17.09	6.18	0.19*	24.82	14.28
IDN	ADF	-3.02	-6.28*	-2.60	-4.19*	-2.65	-1.21	-1.57
	DF-GLS	-1.57	-5.97*	-1.66	-1.77	-2.38	-0.75	-1.70
	PP	-3.04	-6.30*	-1.73	-2.10	-1.98	-1.90	-1.08
	ERS	37.13	1.03*	27.05	8.44	9.00	23.84	14.28
JAP	ADF	-2.49	-5.66*	-1.66	-2.50	-3.67*	-1.22	-1.57
	DF-GLS	-2.54	-5.68*	-1.77	-1.86	-2.92	-0.75	-1.70
	PP	-2.25	-5.75*	-1.67	-1.96	-2.82	-1.94	-1.08
	ERS	6.93	1.15*	13.78	2.84*	1.17*	24.90	14.28
KAZ	ADF	-1.32	-5.63*	1.41	-2.63	-1.52	-1.33	-1.57
	DF-GLS	-1.33	-5.63*	-0.94	-0.90	-1.35	-0.90	-1.70
	PP	-1.31	-5.64*	0.01	-2.52	-1.22	-1.97	-1.08
	ERS	90.57	0.89*	215.93	14.95	26.71	21.95	14.28
KOR	ADF	-2.65	-2.76	-2.59	-1.82	-3.17	-1.40	-1.57
	DF-GLS	-1.71	-1.91	-2.37	-0.68	-1.96	-1.00	-1.70
	PP	-2.39	-5.13*	-2.13	-1.43	-3.11	-1.99	-1.08
	ERS	20.62	3.49	9.40	15.86	10.63	21.36	14.28
MEX	ADF	-3.10	-3.02*	-1.22	-2.28	-2.18	-1.50	-1.57
	DF-GLS	-3.08	-1.46	-1.51	-0.30	-2.26	-1.10	-1.70
	PP	-2.44	-7.12*	-1.48	-4.71*	-1.72	-2.10	-1.08
	ERS	4.9*	2.97*	15.08	78.39	8.14	22.14	14.28

Country	Unit root test	y	dp	e	r	y*	r*	f
NZL	ADF	-2.15	-6.03*	-2.70	-1.27	-2.35	-1.23	-1.57
	DF-GLS	-1.25	-5.14*	-2.10	-1.06	-2.18	-0.80	-1.70
	PP	-3.03	-6.11*	-1.91	-1.21	-2.00	-1.80	-1.08
	ERS	41.22	1.32*	14.58	7.46	10.17	19.71	14.28
NOR	ADF	-1.59	-8.93*	-1.17	-2.78	-2.67	-1.26	-1.57
	DF-GLS	-1.33	-3.06*	-1.70	-1.34	-2.56	-0.70	-1.70
	PP	-2.27	-8.94*	-1.20	-2.05	-1.86	-1.81	-1.08
	ERS	27.21	1.22*	102.03	11.49	7.23	19.48	14.28
POL	ADF	-2.24	-3.84*	-0.49	-4.34*	-2.40	-1.73	-1.57
	DF-GLS	-2.48	-3.36*	-1.11	-0.38	-2.12	-0.72	-1.70
	PP	-1.41	-3.79*	-0.47	-5.36*	-1.68	-1.69	-1.08
	ERS	6.37	1.77*	46.97	159.38	12.84	17.95	14.28
ROU	ADF	-1.92	-3.60*	-0.87	-2.43	-2.39	-1.90	-1.57
	DF-GLS	-1.43	-0.18	-0.68	-0.60	-2.04	-0.89	-1.70
	PP	-1.70	-3.81*	-0.68	-3.28*	-1.73	-1.67	-1.08
	ERS	30.78	83.89	64.12	90.74	14.61	14.84	14.28
RUS	ADF	-1.53	-4.25*	-0.64	-2.65	-1.32	-1.13	-1.57
	DF-GLS	-1.10	-2.23*	-0.49	-2.45*	-1.18	-0.60	-1.70
	PP	-0.81	-4.17*	-0.64	-1.99	-2.07	-1.86	-1.08
	ERS	68.21	3.72	61.23	2.29*	32.15	24.70	14.28
SWE	ADF	-3.45	-4.78*	-1.66	-1.68	-2.58	-1.14	-1.57
	DF-GLS	-2.43	-4.77*	-1.37	-0.68	-2.36	-0.55	-1.70
	PP	-2.16	-4.8*	-1.22	-1.39	-1.80	-1.71	-1.08
	ERS	1.6*	0.98*	24.51	12.60	9.59	21.48	14.28
TUR	ADF	-2.58	-6.46*	-0.73	-8.84*	-2.64	-1.22	-1.57
	DF-GLS	-2.76	-0.97	-0.67	-0.11	-2.41	-0.66	-1.70
	PP	-2.34	-3.10*	-0.25	-9.68*	-1.89	-1.65	-1.08
	ERS	9.95	98.14	43.19	570.71	9.10	17.91	14.28
UKR	ADF	-1.86	-3.82*	-0.66	-2.87	-2.09	-1.64	-1.57
	DF-GLS	-1.32	-3.84*	-0.92	-2.89*	-1.64	-0.83	-1.70
	PP	-1.56	-3.84*	-0.85	-2.89	-1.50	-1.64	-1.08
	ERS	35.50	1.48*	52.69	1.81*	24.41	15.60	14.28
GBR	ADF	-2.02	-4.62*	-1.66	-1.45	-2.47	-1.21	-1.57
	DF-GLS	-1.56	-1.11	-1.40	-0.86	-2.35	-0.66	-1.70
	PP	-1.91	-4.62*	-1.44	-1.33	-1.87	-1.95	-1.08
	ERS	18.94	2.96*	22.25	12.97	8.70	24.08	14.28
USA	ADF	-1.88	-6.06*	-	-2.02	-3.63*	-1.47	-1.57
	DF-GLS	-1.76	-5.64*	-	-1.55	-2.99	-0.62	-1.70
	PP	-1.72	-6.01*	-	-2.31	-2.72	-1.57	-1.08
	ERS	15.02	0.96*	-	13.39	0.5*	16.54	14.28

Country	Unit root test	y	dp	e	r	y*	r*	f
EMU	ADF	-2.22	-4.63*	-1.73	-1.94	-3.07	-1.23	-1.57
	DF-GLS	-1.91	-4.42*	-0.77	-0.96	-3.12	-0.80	-1.70
	PP	-1.71	-4.71*	-1.17	-1.61	-2.24	-1.88	-1.08
	ERS	16.28	1.17*	137.94	13.15	4.45*	23.81	14.28
Share of variables with a unit root								
All countries	ADF	100%	13%	100%	87%	87%	100%	100%
	DF-GLS	100%	27%	100%	87%	97%	100%	100%
	PP	100%	3%	100%	83%	100%	100%	100%
	ERS	90%	23%	93%	83%	77%	100%	100%

Note. Table reports statistics for Augmented Dickey-Fuller (ADF) test, Dickey-Fuller test with GLS detrending (DF-GLS), Phillips-Perron (PP) test, and Elliot, Rothenberg, and Stock point optimal (ERS) test. Tests for inflation and interest rate include constant term (Fcrit. 0.05: ADF = -2.91, DF-GLS = -1.95, PP = -2.91, ERS = 3.01), while tests for out-put, real exchange rate, and fuel prices include constant as well as trend term (Fcrit. 0.05: ADF = -3.48, DF-GLS = -3.15, PP = -3.48, ERS = 5.70). Tests for variables with test-statistics lowest than critical value are marked with *

Table 29. Unit-root tests in first differences: ADF, DF-GLS, PP, and ERS

Country	Unit root test	y	dp	e	r	y*	r*	f
AUS	ADF	-8.19*	-6.17*	-5.78*	-4.96*	-6.56*	-3.63*	-5.94*
	DF-GLS	-7.63*	-5.99*	-5.14*	-3.73*	-6.61*	-1.43	-5.98*
	PP	-8.19*	-28.72*	-5.58*	-3.83*	-6.55*	-3.99*	-5.74*
	ERS	0.89*	6.67	1.13*	1.16*	0.79*	9.37	0.86*
AZE	ADF	-1.17	-6.01*	-1.81	-8.9*	-4.62*	-4.15*	-5.94*
	DF-GLS	-1.23	-6.01*	-1.77	-0.82	-4.58*	-3.51*	-5.98*
	PP	-6.59*	-19.32*	-6.32*	-8.96*	-4.73*	-4.02*	-5.74*
	ERS	10.67	0.48*	5.47	5.31	1.08*	1.97*	0.86*
BLR	ADF	-7.71*	-6.77*	-4.1*	-4.14*	-3.56*	-7.85*	-5.94*
	DF-GLS	-2.45*	-6.75*	-4.05*	-1.20	-3.43*	-7.36*	-5.98*
	PP	-7.71*	-8.03*	-6.83*	-5.79*	-3.33*	-7.85*	-5.74*
	ERS	0.88*	0.02*	1.2*	3.73	0.89*	0.88*	0.86*
BRS	ADF	-4.84*	-6.74*	-5.15*	-7.25*	-3.87*	-3.67*	-5.94*
	DF-GLS	-4.32*	-6.18*	-1.23	-3.72*	-3.82*	-1.38	-5.98*
	PP	-4.87*	-8.41*	-5.05*	-2.96*	-5.27*	-4*	-5.74*
	ERS	1.28*	1.42*	0.59*	0.48*	0.05*	11.02	0.86*
BGR	ADF	-2.39	-5.39*	-2.39	-4.97*	-4.04*	-3.97*	-5.94*
	DF-GLS	-2.4*	-2.37*	-1.91	-4.77*	-4*	-2.8*	-5.98*
	PP	-5.68*	-11.5*	-4.88*	-4.99*	-4.04*	-3.9*	-5.74*
	ERS	2.2*	4.20	3.38	1.07*	1.28*	3.25	0.86*
CAN	ADF	-4.93*	-7.57*	-5.19*	-3.25*	-4.42*	-3.71*	-5.94*
	DF-GLS	-4.94*	-0.91	-5.02*	-2.43*	-4.45*	-1.02	-5.98*
	PP	-4.73*	-26.97*	-5.07*	-4.37*	-4.38*	-4.07*	-5.74*
	ERS	0.96*	7.50	1*	1.75*	1.04*	16.63	0.86*
CHL	ADF	-5.42*	-8.77*	-6.22*	-4.37*	-6.14*	-3.64*	-5.94*
	DF-GLS	-5.41*	-8.57*	-4.56*	-1.21	-6.05*	-1.50	-5.98*
	PP	-5.43*	-11.87*	-6.08*	-7.25*	-6.09*	-4.07*	-5.74*
	ERS	1.03*	0.82*	1.72*	0.18*	0.87*	8.22	0.86*
CHN	ADF	-9.01*	-4.9*	-1.28	-6.27*	-4.65*	-3.53*	-5.94*
	DF-GLS	-1.98*	-9.89*	-1.29	-6.32*	-4.63*	-1.57	-5.98*
	PP	-8.99*	-10.75*	-3.06*	-6.3*	-3.72*	-3.88*	-5.74*
	ERS	1.21*	0.62*	4.80	0.8*	0.68*	7.96	0.86*
CZE	ADF	-3.17*	-5.2*	-2.83	-3.6*	-3.34*	-4.19*	-5.94*
	DF-GLS	-3.19*	-3.72*	-2.61*	-3.59*	-3.37*	-3.9*	-5.98*
	PP	-3.17*	-11.51*	-4.85*	-5.09*	-3.44*	-4.12*	-5.74*
	ERS	1.58*	1.05*	2.41*	1.42*	1.48*	1.44*	0.86*

Country	Unit root test	y	dp	e	r	y*	r*	f
DNK	ADF	-4.03*	-5.91*	-2.79	-4.6*	-3.47*	-3.62*	-5.94*
	DF-GLS	-3.93*	-1.32	-1.99*	-4.59*	-3.5*	-2.58*	-5.98*
	PP	-6.59*	-17.7*	-5.23*	-4.56*	-3.5*	-3.86*	-5.74*
	ERS	1.22*	15.47	2.52*	1.05*	1.42*	2.49*	0.86*
GEO	ADF	-11.64*	-7.07*	-4.31*	-7.71*	-4.68*	-3.84*	-5.94*
	DF-GLS	-11.7*	-1.94	-4.24*	-2.27*	-3.95*	-3.87*	-5.98*
	PP	-11.45*	-22.34*	-4.33*	-7.72*	-4.68*	-3.82*	-5.74*
	ERS	0.9*	1.86*	1.34*	1.77*	1.71*	1.23*	0.86*
HUN	ADF	-4.65*	-6.63*	-5.83*	-5.4*	-3.48*	-4.16*	-5.94*
	DF-GLS	-4.55*	-7.98*	-5.87*	-5.45*	-3.5*	-3.86*	-5.98*
	PP	-4.6*	-20.7*	-5.04*	-5.38*	-3.59*	-4.09*	-5.74*
	ERS	1.06*	0.05*	0.5*	0.87*	1.4*	1.48*	0.86*
ISL	ADF	-2.21	-5.44*	-4.07*	-5.49*	-3.7*	-4.17*	-5.94*
	DF-GLS	-1.71	-1.39	-1.62	-5.28*	-3.73*	-3.81*	-5.98*
	PP	-9.53*	-10.84*	-7.62*	-5.53*	-3.82*	-3.96*	-5.74*
	ERS	7.79	0.03*	0.03*	1.02*	1.3*	1.02*	0.86*
IND	ADF	-7.8*	-7.77*	-5.34*	-7.91*	-4.06*	-3.89*	-5.94*
	DF-GLS	-7.76*	-2.3*	-5.04*	-7.53*	-4.08*	-1.42	-5.98*
	PP	-7.81*	-18.34*	-6.31*	-7.92*	-5.65*	-4.03*	-5.74*
	ERS	0.81*	4.86	0*	0.87*	0.01*	9.48	0.86*
IDN	ADF	-5.53*	-5.85*	-8.22*	-4.84*	-6.02*	-3.76*	-5.94*
	DF-GLS	-4.1*	-11.41*	-1.37	-3.09*	-5.99*	-1.49	-5.98*
	PP	-7.88*	-30.96*	-8.19*	-3.31*	-5.85*	-3.98*	-5.74*
	ERS	1.85*	7.32	3.98	0.82*	0.86*	8.66	0.86*
JAP	ADF	-6.71*	-9.28*	-5.61*	-2.67	-3.36*	-3.74*	-5.94*
	DF-GLS	-6.07*	-3.06*	-1.91	-1.70	-3.34*	-1.54	-5.98*
	PP	-6.66*	-12.61*	-5.65*	-8.76*	-6.48*	-3.9*	-5.74*
	ERS	1.04*	0.84*	1.94*	6.74	0.63*	8.70	0.86*
KAZ	ADF	-7.19*	-6.92*	-4.73*	-7.02*	-4.41*	-3.7*	-5.94*
	DF-GLS	-0.68	-6.3*	-4.72*	-6.9*	-4.34*	-1.40	-5.98*
	PP	-7.3*	-18.28*	-3.99*	-9.26*	-4.39*	-4.01*	-5.74*
	ERS	4.16	18.02	0.67*	0.55*	1.11*	10.04	0.86*
KOR	ADF	-5.95*	-8.58*	-6.03*	-5.99*	-3.66*	-3.77*	-5.94*
	DF-GLS	-5.5*	-8.57*	-5.26*	-5.99*	-3.49*	-1.29	-5.98*
	PP	-5.77*	-14.63*	-6.01*	-5.86*	-6.79*	-4.14*	-5.74*
	ERS	1.13*	0.67*	1.13*	0.87*	0.45*	11.80	0.86*

Country	Unit root test	y	dp	e	r	y*	r*	f
MEX	ADF	-4.95*	-12.02*	-7.17*	-5.48*	-4.74*	-3.73*	-5.94*
	DF-GLS	-4.01*	-12.12*	-2.19*	-1.25	-4.77*	-1.12	-5.98*
	PP	-4.55*	-18.33*	-7.17*	-6.26*	-4.69*	-4*	-5.74*
	ERS	1.01*	0.33*	2.17*	17.21	0.97*	15.35	0.86*
NZL	ADF	-7.14*	-6.36*	-5.42*	-4.23*	-3.66*	-3.83*	-5.94*
	DF-GLS	-0.59	-1.31	-4.92*	-3.58*	-3.65*	-1.37	-5.98*
	PP	-7.16*	-22.51*	-5.45*	-3.84*	-5.48*	-4.29*	-5.74*
	ERS	5.87	1.57*	1.13*	1.17*	0.15*	9.11	0.86*
NOR	ADF	-2.57	-6.04*	-4.95*	-4.26*	-3.43*	-3.65*	-5.94*
	DF-GLS	-2.24*	-9.79*	-5.02*	-4.19*	-3.46*	-2.17*	-5.98*
	PP	-10.52*	-30.15*	-5.12*	-3.84*	-3.36*	-3.94*	-5.74*
	ERS	8.20	12.87	0.01*	0.44*	1.11*	3.86	0.86*
POL	ADF	-3.07*	-7.58*	-6.15*	-3.56*	-3.57*	-4.32*	-5.94*
	DF-GLS	-1.35	-1.84	-5.59*	-1.90	-3.57*	-3.86*	-5.98*
	PP	-7.05*	-10.78*	-4.63*	-3.44*	-3.37*	-4.26*	-5.74*
	ERS	4.77	1.02*	0.57*	4.17	1.03*	1.58*	0.86*
ROU	ADF	-4.85*	-4.67*	-5.12*	-4.06*	-3.66*	-4.13*	-5.94*
	DF-GLS	-4.89*	-1.86	-5.15*	-4.1*	-3.69*	-4.03*	-5.98*
	PP	-4.84*	-13.03*	-4.76*	-3.75*	-3.66*	-4.06*	-5.74*
	ERS	0.97*	0.96*	0.64*	1.21*	1.34*	1.26*	0.86*
RUS	ADF	-3.42*	-5.46*	-6.68*	-5.97*	-3.45*	-3.74*	-5.94*
	DF-GLS	-3.25*	-3.16*	-6.43*	-5.82*	-3.49*	-1.77	-5.98*
	PP	-2.99*	-11.18*	-6.71*	-5.77*	-6.41*	-3.87*	-5.74*
	ERS	1.15*	3.61	0.86*	0.92*	0.67*	6.20	0.86*
SWE	ADF	-4.19*	-8.4*	-5.37*	-3.9*	-3.24*	-3.7*	-5.94*
	DF-GLS	-4.22*	-1.37	-4.09*	-3.92*	-3.27*	-2.39*	-5.98*
	PP	-5.45*	-11.69*	-4.27*	-4.32*	-3.24*	-3.91*	-5.74*
	ERS	0*	1.55*	0.84*	0.3*	1.58*	2.96*	0.86*
TUR	ADF	-8.08*	-6.91*	-6.98*	-4.64*	-3.82*	-3.5*	-5.94*
	DF-GLS	-0.98	-0.99	-1.27	-1.07	-3.77*	-2.53*	-5.98*
	PP	-8.1*	-15.76*	-6.98*	-4.43*	-3.58*	-4.13*	-5.74*
	ERS	5.52	0.33*	3.08	3.26	0.04*	2.65*	0.86*
UKR	ADF	-4.63*	-5.62*	-6.43*	-7.2*	-3.86*	-4.44*	-5.94*
	DF-GLS	-4.45*	-9.85*	-6.23*	-7.15*	-3.89*	-3.85*	-5.98*
	PP	-4.65*	-10.25*	-6.52*	-8.81*	-3.83*	-4.33*	-5.74*
	ERS	1.12*	2.81*	0.87*	0.57*	1.2*	1.69*	0.86*

Country	Unit root test	y	dp	e	r	y*	r*	f
GBR	ADF	-4.07*	-6.53*	-2.33	-4.15*	-3.73*	-3.74*	-5.94*
	DF-GLS	-3.94*	-0.85	-2.23*	-3.78*	-3.76*	-1.81	-5.98*
	PP	-3.18*	-22.24*	-4.48*	-4.14*	-3.76*	-3.77*	-5.74*
	ERS	0.45*	50.98	2.44*	1.51*	1.29*	6.21	0.86*
USA	ADF	-4.84*	-6.51*	-	-3.47*	-3.85*	-4.14*	-5.94*
	DF-GLS	-4.87*	-6.11*	-	-0.89	-5.14*	-3.57*	-5.98*
	PP	-4.83*	-37.68*	-	-4.39*	-5.01*	-3.85*	-5.74*
	ERS	0.96*	12.68	-	17.94	0.06*	1.14*	0.86*
EMU	ADF	-3.41*	-11.9*	-2.73	-4.12*	-4.16*	-3.65*	-5.94*
	DF-GLS	-3.41*	-1.10	-2*	-4.13*	-4.08*	-1.33	-5.98*
	PP	-3.43*	-14.74*	-5.1*	-4.07*	-3.94*	-4.04*	-5.74*
	ERS	1.46*	3.86	2.67*	1.15*	0*	10.64	0.86*

Share of variables with a unit root

All countries	ADF	13%	0%	24%	3%	0%	0%	0%
	DF-GLS	20%	37%	28%	27%	0%	50%	0%
	PP	0%	0%	0%	0%	0%	0%	0%
	ERS	23%	40%	17%	23%	0%	57%	0%

Note. Table reports statistics for Augmented Dickey-Fuller (ADF) test, Dickey-Fuller test with GLS detrending (DF-GLS), Phillips-Perron (PP) test, and Elliot, Rothenberg, and Stock point optimal (ERS) test. Tests for variables in first differences include a constant term only (Fcrit. 0.05: ADF = -2.91, DF-GLS = -1.95, PP = -2.91, ERS = 3.01). Tests for variables with test-statistics lower than critical value are marked with *.

Table 30. Trace statistics for testing the cointegration rank

Country	H0: r=0 H1: r≥1	H0: r=1 H1: r≥2	H0: r=2 H1: r≥3	H0: r=3 H1: r≥4	Selected rank
USA	164.48	80.89	17.89*	-	2
EMU	179.23	94.58	42.41	10.15*	3
CHN	202.03	82.25	38.19*	11.87	2
RUS	122.19	63.42*	35.57	11.77	1
AZE	172.17	103.3	49.84	9.300*	3
BLR	129.33	72.33	37.07*	13.51	2
GEO	146.72	87.07	45.16	11.30*	3
KAZ	153.95	94.73	53.04	20.17*	3
UKR	115.95	61.67*	30.71	13.48	1
AUS	116.69	51.78*	25.29	8.370	1
BRA	175.27	102.8	51.92	14.91*	3
BGR	148.41	93.78	49.37	14.60*	3
CAN	168.85	69.24	24.87*	10.41	2
CHL	145.24	76.64	31.20*	12.92	2
CZE	133.32	58.46*	26.65	7.280	1
DNK	121.70	73.83	33.56*	14.05	2
HUN	117.47	63.38*	33.83	10.67	1
ISL	166.55	91.29	42.22	11.45*	3
IND	122.32	61.62*	35.36	15.16	1
IDN	191.92	92.89	47.95	18.32*	3
JPN	106.32	42.40*	20.02	3.170	1
KOR	144.00	76.49	38.21*	10.40	2
MEX	152.48	89.75	33.72*	12.77	2
NZL	200.74	122.5	54.99	25.87	3
NOR	154.99	91.59	48.39	12.74*	3
POL	175.94	70.55	28.71*	10.22	2
ROU	115.79	69.65	36.07*	10.80	2
SWE	134.09	68.37	40.43*	15.47	2
TUR	236.94	125.7	39.21*	15.94	2
GBR	117.54	55.39*	25.82	8.630	1

Note. Critical values for null hypotheses r=1,2,3,4 are (91.81), (64.54), (41.03), and (20.98) respectively.

Table 31. Likelihood ratio test on type of deterministic components in the cointegration equations

Country	H0: Case III		H0: Case II		Selected case
	LR	CV	LR	CV	
USA	10.6	(5.99)	7.78	(9.49)	IV
EMU	27.5	(7.82)	1.48	(9.49)	IV
CHN	12.7	(5.99)	25.1	(11.1)	IV
RUS	0.05	(3.84)	6.68	(12.6)	II
AZE	41.9	(7.82)	4.48	(9.49)	IV
BLR	0.90	(5.99)	1.00	(11.1)	II
GEO	22.3	(7.82)	2.36	(9.49)	IV
KAZ	27.4	(7.82)	11.7	(9.49)	IV
UKR	4.49	(3.84)	10.5	(12.6)	IV
AUS	1.43	(3.84)	36.4	(12.6)	III
BRA	13.6	(7.82)	0.02	(9.49)	IV
BGR	6.84	(7.82)	1.63	(9.49)	IV
CAN	3.21	(5.99)	1.53	(11.1)	II
CHL	15.5	(5.99)	15.9	(11.1)	IV
CZE	8.01	(3.84)	2.82	(12.6)	IV
DNK	6.44	(5.99)	1.01	(11.1)	IV
HUN	0.06	(3.84)	3.38	(12.6)	II
ISL	0.03	(7.82)	2.07	(9.49)	II
IND	9.53	(3.84)	26.7	(12.6)	IV
IDN	1.52	(7.82)	18.4	(9.49)	III
JPN	4.27	(3.84)	0.30	(12.6)	IV
KOR	9.12	(5.99)	14.4	(11.1)	IV
MEX	15.0	(5.99)	5.87	(11.1)	IV
NZL	41.5	(7.82)	10.1	(9.49)	IV
NOR	6.27	(7.82)	2.24	(9.49)	II
POL	14.7	(5.99)	7.62	(11.1)	IV
ROU	0.16	(5.99)	0.03	(11.1)	II
SWE	3.63	(5.99)	1.90	(11.1)	II
TUR	2.82	(5.99)	3.40	(11.1)	II
GBR	0.07	(3.84)	16.3	(12.6)	III

Table 32. Final individual VECMX* specifications

Country	Domestic	p	Foreign	q	r	Case
USA	y, dp, r	1	y*, r*, f*	1	1	IV
EMU	y, dp, e, r	1	y*, r*, f*	1	1	IV
CHN	y, dp, e, r	1	y*, r*, f*	1	1	IV
RUS	y, dp, e, r	1	y*, r*, f*	1	1	II
AZE	y, dp, e, r	1	y*, r*, f*	1	2	IV
BLR	y, dp, e, r	1	y*, r*, f*	1	2	II
GEO	y, dp, e, r	1	y*, r*, f*	1	2	IV
KAZ	y, dp, e, r	1	y*, r*, f*	1	2	IV
UKR	y, dp, e, r	1	y*, r*, f*	1	1	IV
AUS	y, dp, e, r	1	y*, r*, f*	1	1	III
BRA	y, dp, e, r	1	y*, r*, f*	1	1	IV
BGR	y, dp, e, r	1	y*, r*, f*	1	0	IV
CAN	y, dp, e, r	1	y*, r*, f*	1	2	II
CHL	y, dp, e, r	1	y*, r*, f*	1	1	IV
CZE	y, dp, e, r	1	y*, r*, f*	1	1	IV
DNK	y, dp, e, r	1	y*, r*, f*	1	2	IV
HUN	y, dp, e, r	1	y*, r*, f*	1	1	II
ISL	y, dp, e, r	1	y*, r*, f*	1	2	II
IND	y, dp, e, r	1	y*, r*, f*	1	1	IV
IDN	y, dp, e, r	1	y*, r*, f*	1	2	III
JPN	y, dp, e, r	1	y*, r*, f*	1	1	IV
KOR	y, dp, e, r	1	y*, r*, f*	1	2	IV
MEX	y, dp, e, r	1	y*, r*, f*	1	2	IV
NZL	y, dp, e, r	1	y*, r*, f*	1	1	IV
NOR	y, dp, e, r	1	y*, r*, f*	1	1	II
POL	y, dp, e, r	1	y*, r*, f*	1	2	IV
ROU	y, dp, e, r	1	y*, r*, f*	1	1	II
SWE	y, dp, e, r	1	y*, r*, f*	1	1	II
TUR	y, dp, e, r	1	y*, r*, f*	1	2	II
GBR	y, dp, e, r	1	y*, r*, f*	1	1	III

Table 33. Test for weak exogeneity of foreign-specific variables

Country	Fcrit. 0.05	y*	r*	f
USA	(4.02)	2.79*	1.39*	3.76*
EMU	(4.02)	0.59*	1.17*	1.43*
CHN	(4.02)	6.11	4.76	1.05*
RUS	(4.02)	0.03*	0.72*	5.63
AZE	(3.18)	1.49*	1.14*	2.11*
BLR	(3.18)	1.08*	0.60*	0.71*
GEO	(3.18)	1.62*	0.73*	0.45*
KAZ	(3.18)	0.32*	0.07*	1.06*
UKR	(4.02)	0.00*	0.40*	1.07*
AUS	(4.02)	2.74*	0.61*	0.24*
BRA	(4.02)	0.07*	4.11	1.44*
BGR	-	-	-	-
CAN	(3.18)	4.78	3.65	3.76
CHL	(4.02)	0.87*	1.66*	0.86*
CZE	(4.02)	0.02*	1.43*	0.00*
DNK	(3.18)	0.51*	0.01*	0.98*
HUN	(4.02)	0.00*	0.03*	0.62*
ISL	(3.18)	4.06	2.10*	1.01*
IND	(4.02)	0.19*	0.25*	0.14*
IDN	(3.18)	0.16*	1.10*	2.87*
JPN	(4.02)	0.15*	0.53*	0.67*
KOR	(3.18)	3.46	1.30*	0.58*
MEX	(3.18)	2.30*	3.39	2.56*
NZL	(4.02)	2.36*	0.54*	1.11*
NOR	(4.02)	0.65*	2.17*	8.17
POL	(3.18)	1.67*	3.57	1.42*
ROU	(4.02)	0.20*	0.02*	0.65*
SWE	(4.02)	7.52	4.39	4.43
TUR	(3.18)	1.14*	1.10*	1.20*
GBR	(4.02)	3.98*	0.32*	0.39*

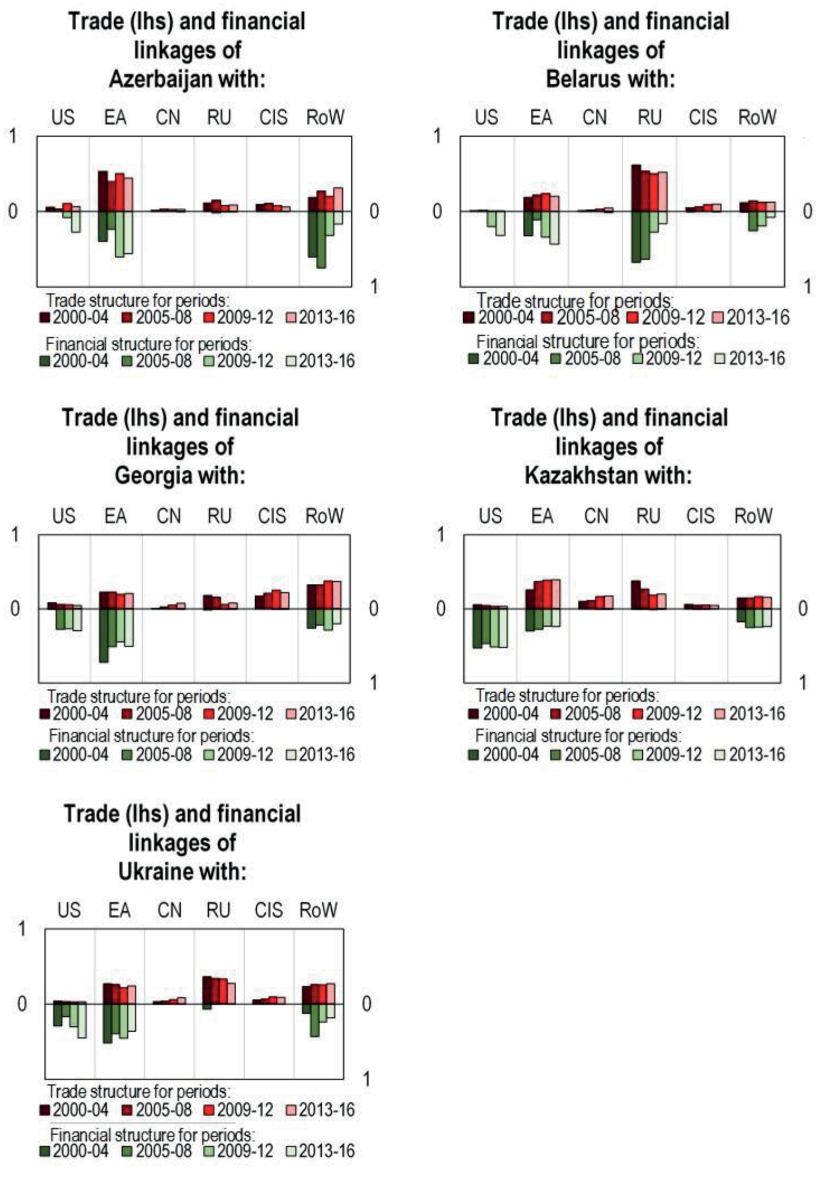
Table 34. Test for serial correlation of the VECMX residuals

Country	Fcrit. 0.05	y	p	e	r
USA	(2.54)	1.06*	1.95*	-	5.05
EMU	(2.54)	3.35	1.24*	2.33*	3.36
CHN	(2.54)	1.57*	3.85	0.71*	1.19*
RUS	(2.54)	1.18*	1.70*	2.02*	2.07*
AZE	(2.55)	3.28	4.68	4.09	1.16*
BLR	(2.54)	2.16*	3.61	2.66	5.86
GEO	(2.55)	1.82*	2.55	2.29*	1.33*
KAZ	(2.55)	2.41*	1.16*	4.13	2.58
UKR	(2.54)	0.19*	0.86*	2.43*	1.29*
AUS	(2.54)	0.64*	1.92*	0.45*	2.63
BRA	(2.54)	1.50*	4.00	3.02	7.60
BGR	(2.54)	4.11	5.13	1.90*	3.12
CAN	(2.54)	0.51*	0.60*	1.60*	2.57
CHL	(2.54)	1.82*	2.89	0.26*	0.11*
CZE	(2.54)	3.31	1.14*	0.94*	1.14*
DNK	(2.55)	0.97*	0.39*	2.84	0.28*
HUN	(2.54)	1.27*	1.21*	0.87*	1.95*
ISL	(2.54)	0.87*	0.75*	1.90*	1.24*
IND	(2.54)	0.68*	3.36	2.07*	2.39*
IDN	(2.55)	1.04*	1.10*	0.41*	1.59*
JPN	(2.54)	0.84*	2.16*	2.32*	2.99
KOR	(2.55)	1.24*	1.47*	1.06*	0.51*
MEX	(2.55)	1.87*	2.41*	0.43*	2.19*
NZL	(2.54)	0.77*	2.65	1.18*	1.85*
NOR	(2.54)	5.82	0.96*	0.55*	7.21
POL	(2.55)	2.12*	0.44*	1.60*	1.18*
ROU	(2.54)	1.55*	1.65*	1.79*	2.58
SWE	(2.54)	1.14*	1.58*	3.39	1.79*
TUR	(2.54)	2.08*	4.15	0.71*	0.87*
GBR	(2.54)	1.52*	0.14*	2.07*	5.22

Table 35. Average pairwise cross-section residual correlations

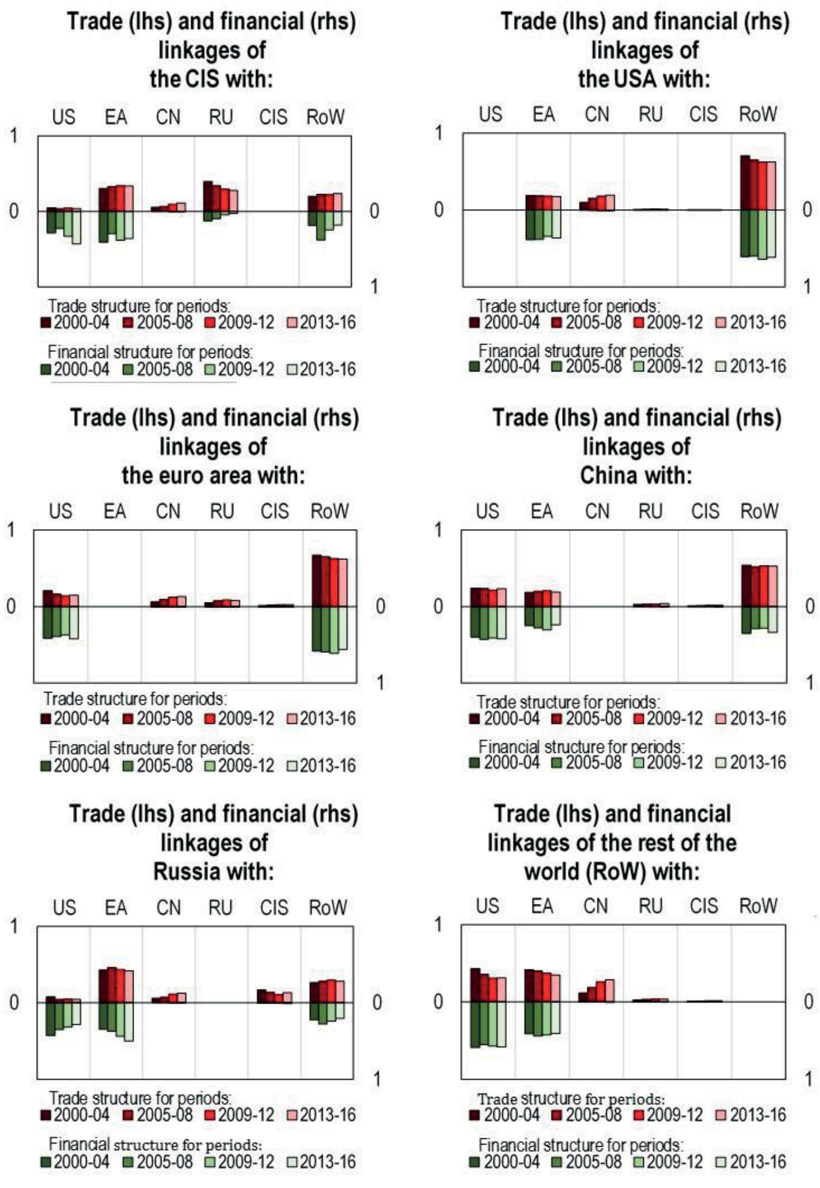
Country	y	dp	e	r
USA	0.068	0.120	-	-0.128
EMU	0.095	0.162	0.448	0.109
CHN	-0.051	0.013	0.037	-0.055
RUS	0.067	0.040	0.151	-0.014
AZE	0.009	0.061	0.020	0.006
BLR	-0.024	0.041	0.101	0.039
GEO	-0.014	0.074	0.189	0.006
KAZ	0.050	0.078	-0.083	0.016
UKR	0.044	0.066	0.060	0.013
AUS	0.038	0.062	0.439	-0.043
BRA	0.043	0.085	0.277	0.001
BGR	0.030	-0.015	0.456	0.027
CAN	0.014	0.123	0.384	0.019
CHL	0.082	0.078	0.272	0.041
CZE	0.050	0.041	0.413	0.031
DNK	0.010	0.154	0.450	0.047
HUN	0.073	0.078	0.418	-0.020
ISL	0.031	0.076	0.206	0.020
IND	0.007	0.047	0.286	0.032
IDN	-0.020	0.027	0.209	0.038
JPN	0.060	0.036	0.090	-0.066
KOR	0.070	0.122	0.315	0.056
MEX	0.079	0.000	0.237	0.013
NZL	0.089	0.095	0.389	0.016
NOR	-0.005	0.134	0.406	0.079
POL	-0.022	0.118	0.344	0.027
ROU	0.054	0.026	0.434	0.006
SWE	0.017	0.222	0.452	0.026
TUR	0.006	0.098	0.275	0.042
GBR	0.030	0.168	0.351	0.045

Figure 5. Evolution of trade and financial linkages in CIS economies. Note: the red bars depict trade shares by partners in different time periods summing up to 1 in each period, whereas the green bars give the corresponding development for financial linkages.



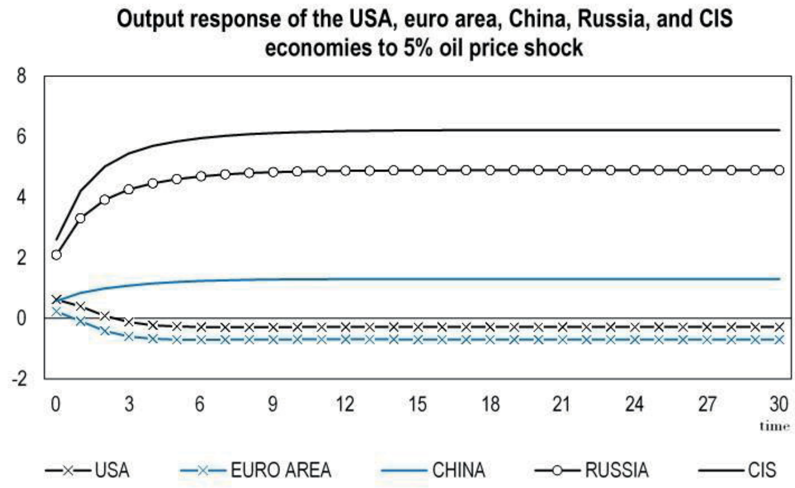
Sources: Trade structure – IMF Direction of Trade Statistics – annual bilateral goods trade flows (i.e. exports plus imports in US dollars). Financial structure – IMF Coordinated Portfolio Investment Survey, a dataset on the stock of cross-border holdings of equities and long- and short-term debt securities broken down by issuer residence.

Figure 6. Evolution of trade and financial linkages in the world economy. Note: the red bars depict trade shares by partners in different time periods summing up to 1 in each period, whereas the green bars give the corresponding development for financial linkages.



Sources: Trade structure – IMF Direction of Trade Statistics – annual bilateral goods trade flows (i.e. exports plus imports in US dollars). Financial structure – IMF Coordinated Portfolio Investment Survey – the stock of cross-border holdings of equities and long- and short-term debt securities broken down by issuer residence.

Figure 7. Generalized impulse responses of real activity to 50% oil price shock.



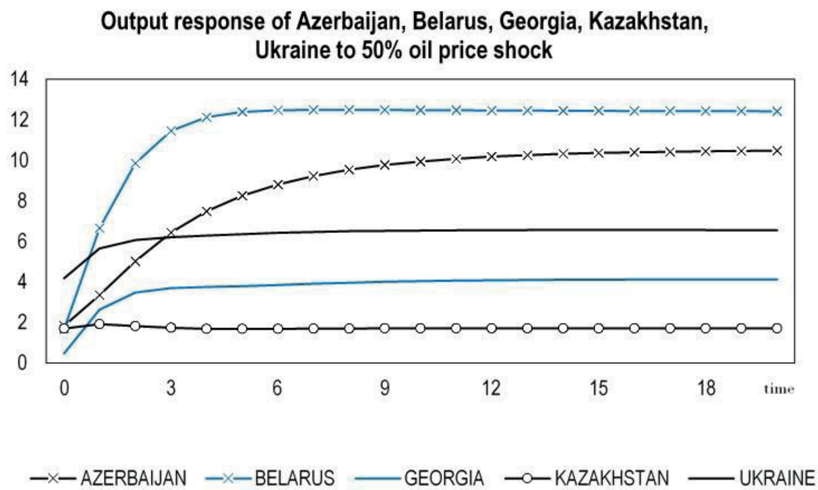
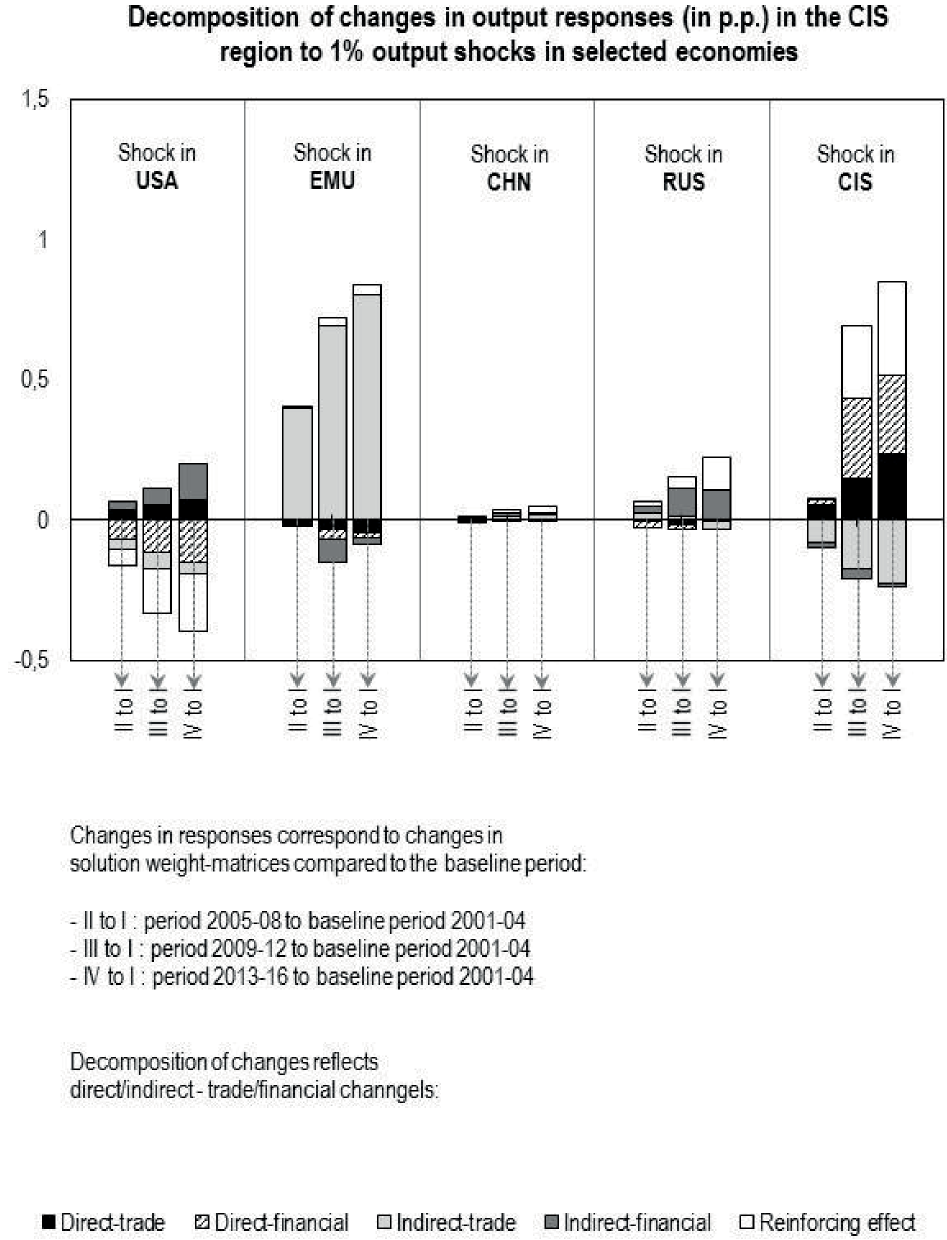


Figure 8. The marginal direct and indirect effect of changing trade and financial linkages on the long-run responses in the aggregated CIS region to 1% output shocks in the US, euro area, China, Russia and CIS. Note: Reinforcing effect refers to the residual.



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ESSAY
III

Chinese Services Gaining Significance in Global Production Chains

Heli Simola

Asian Economic Papers 17:2 (Summer 2018), 50-64.

4 ESSAY 3: CHINESE SERVICES GAINING SIGNIFICANCE IN GLOBAL PRODUCTION CHAINS

Abstract

China has been a key participant in international fragmentation of production during last decades. China has specialized mainly in labor-intensive manufacturing, but is striving to shift towards higher value-added production stages and production. At the same time, during recent decades, services have contributed increasing shares of valued added to products produced through global production chains. For this reason we examine the evolving role of Chinese services in international production chains. Our results suggest that Chinese services account for an increasingly large share of production for the domestic market, and more lately have made increasing contributions to foreign production chains, which suggests that Chinese production is shifting to activities in production chains that are associated with higher value-added.

4.1 Introduction

The increasing international fragmentation of production during past couple of decades has been documented widely in the literature, through work at the aggregate level[50] as well as in projects which have relied on highly disaggregated data[51]. The motives which underpin this fragmentation trend include firm efforts to improve efficiency through deeper specialization as well as natural comparative advantage factors affecting the decision of firms on where to locate each production stage to take advantage of production cost differentials. Further fragmentation has been facilitated by improved information and communication technologies as well as continued reductions in transportation costs. Worldwide liberalization of trade and investment policies has further supported the international fragmentation of production. Moreover, the opening up of many emerging markets like China and Central Eastern European countries for international transactions has provided possibilities for cost savings with lower labor costs.[52]

There is evidence that increasing international fragmentation has been accompanied by a growing importance of services in production. The share of value-added created by services has also grown in manufacturing sectors, prompting the characterization referred to as the "deepening of the smile-curve" or the "servicification of manufacturing". The growing contribution of services to value-added might reflect the increasing complexity of manufacturing products that require more service inputs like R&D and design. It may also be related to increasing geographic dispersion of production chains which leads to increased demand for coordinating and connecting services (like transport and communication), changes in relative prices (manufacturing stages shifted to regions with lower labor costs) and reclassification of activities (outsourcing services previously performed in-house in a manufacturing company, such as marketing). Increasing international fragmentation of services has been supported by advances in coordination and communication technologies which have made it possible to design and run production chains that cover an ever larger geographic footprint.[53]

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[50] Johnson and Noguera (2012b), Backer and Miroudot (2013), Baldwin and Lopez-Gonzalez (2013), Timmer et al. (2014), Choi (2015).

[51] Athukorala (2006), Athukorala (2011), Obashi and Kimura (2017).

[52] Baldwin (2012), OECD (2013), Park et al. (2013).

[53] Baldwin et al. (2015), Ye et al. (2015).

China has been a key player in the development international fragmentation of production chains. Within this development, China initially was focused on labor-intensive and relatively low value-added production stages, such as assembly. More recently, China has sought to shift its production towards higher value-added stages. In line with the concept of a deepening smile curve[54], the production stages currently providing the highest shares of value-added in global production chains tend to be services performed in the beginning and end of the chains, including design and marketing. Therefore we try to examine the role and development of Chinese service inputs in global production chains. We discuss the data and methodologies used in the analysis in section 2, present the results in section 3 and sum up conclusions in section 4.

4.2 Data and methodology

4.2.1 Data

To examine the role of Chinese service inputs in global production chains we use the international input-output tables from the World Input-Output Database (WIOD). It is one of the recently developed databases that provide insights into global production and trade structures. Though new databases differ in some ways, (e.g. by their time and country coverage as well as compilation methodologies[55]), the basic principles are similar. The international input-output tables depict global production structures and divide the total output of a sector in a country to the value-added created in that sector and to the inputs required from other sectors and countries. As a result, these data allow researchers to separate the actual value-added created in the sector itself from the inputs coming from other sectors and countries at different stages of the production chain.

The WIOD data is constructed by combining national statistics on production and trade flows with data on estimated inputs. WIOD provides annual data, and the latest version covers the years from 2000-2014. The data reports information from 43 individual economies (all 28 EU member countries and other large economies of

[54] Baldwin et al. (2015), Ye et al. (2015).

[55] For introduction on and discussion of WIOD and other global input-output tables see e.g. Timmer et al. (2015) and Tukker and Dietzenbacher (2013).

the world) and a rest of the world aggregate. It is divided to 56 sectors based on the ISIC classification system. The data values are expressed in nominal USD.[56]

4.2.2 Measuring international production chain activity

The methodology we use follows closely earlier research and has been applied to earlier versions of the WIOD data, although with a slightly different focus[57]. A value chain or production chain (we use the terms interchangeably) includes all inputs or production stages required for the completion of a final product or output. The sector and "nationality" of the chains are defined based on the location of the last stage of production, from which the products are supplied directly to final consumers either in the domestic or in export market. For this reason, the "nationality" of production chain refers to the location of the final stage production. Due to the absence of ownership data, it is not possible to distinguish between the production chains controlled by domestic or foreign-owned companies. For example, when constructing the information on a value chain for Chinese textiles, we begin with global demand (both domestic and foreign) for Chinese textiles and clothes and trace back to measure all the value-added components from different countries and sectors that are utilized as China fulfils this demand.

In particular, we decompose the global input-output matrix to country-sector value chains. Using notation, we denote the output vector of sector *i* in country *j* by Qij, the coefficient matrix of intermediate inputs in sector *i* of country *j* by B and the final demand vector of the products produced in sector *i* of country *j* by C. This yields the following expression for output:

$$Q = (I - B)^{-1}C \qquad (1)$$

where I is the identity matrix and $(I - B)^{-1}$ is the so called Leontief inverse. Since we want to concentrate on actual value-added, we need to multiply Q by a diagonal matrix F that contains the ratios of value-added to gross output of all countries and industries in its diagonal. Now we can calculate further the value-added production

56 Comprehensive information and discussion on the construction of the data and underlying data sources is provided by Timmer et al. (2015) and Timmer et al. (2016).

57 Applications on WIOD data include Timmer et al. 2014, Los et al. (2015), Timmer et al. (2015). Discussion on methodologies for distinguishing value-added from gross exports is provided also e.g. in Johnson and Noguera (2012a) and Koopman et al. (2014).

K of sector *i* in country *j* that is needed to supply final demand C for the products produced in sector *i* of country *j*, via the following equation:

$$K = F(I - B)^{-1}C \quad (2)$$

To disentangle all the value-added components needed in the country-sector chains we insert for C the global (including both domestic and foreign) demand for the final products of that particular chain, e.g. the global demand for textiles and clothes produced in China. Then we can calculate the value added production K for Chinese textiles and clothes that contains all the value added components needed from different sectors in different countries (China itself and foreign countries) for fulfilling the global demand for Chinese textiles and clothes.

Using this decomposition methodology we get 2,408 individual production chains (56 sectors for 43 economies since we exclude the chains located in the rest of the world -aggregate) for every year in the sample. We decompose the chains into their domestic and foreign value-added links. We also examine the characteristics of value chains by aggregate sectors and compare the development of production chains that culminate with production in China with production chains which anchor final production in other countries. To provide a measure of international fragmentation of production chains we use the share of foreign value-added in the chains, which corresponds relatively closely to the backward participation index used earlier in the literature[58]. We concentrate only on manufacturing and business services both as the sector of outputs as well as inputs, as we are primarily interested in the phenomenon of complex production fragmentation (as opposed to the exchange of raw materials).

4.2.3 Constant market share analysis of value-added production and exports of China

We extend the analysis to the development of total value-added production and exports of China in order to get a more comprehensive view regarding the development and role of Chinese services. As the final demand for the products

[58] E.g. OECD (2013) defines the backward participation index as the share of FVA in gross exports, whereas Wang et al. (2017a, 2017b) consider as the backward participation index the share of GVC activities in the production of a country. There exists a variety of other indicators related to measuring the fragmentation of production chains, like forward participation index and the length of chains, but for our purposes backward participation aspect is the most relevant.

supplied by sector *i* in country *j* we now insert in equation (2) the sum of demand in all individual sectors of a country (for domestic demand this is country *j* itself and for foreign demand another country in the sample). Then we can calculate the value added components needed from all sectors and countries for fulfilling the demand of this particular country, e.g. demand for Chinese textiles and clothes in Japan. Summing over all the individual countries and sectors gives the total value added production of the country. Excluding the production that is supplied for domestic demand results in value-added exports.

To examine the role of services in Chinese production and exports more closely, we use a constant market share (CMS) analysis. The CMS approach essentially turns to an accounting framework to decompose variation in a country's market share into a component related to structure effects and a second component, or "pure" market share effect, that is interpreted as a competitiveness effect. This approach has been applied by several researchers studying gross exports, but also to value-added exports in a slightly modified form[59]. To our knowledge this approach has never been applied to the data we are using.

In a CMS setting, the structure effect can be further decomposed into market and product effects. If a country is specialized in supplying markets or products whose demand grows faster (slower) than the total demand, then its market share increases (decreases) are attributed to a structure effect. It is impossible to completely separate the structural market and product effects, so the structure effect also contains a residual interaction effect. Following the elimination of the structural effects related to a country's market and product specialization, the residual is interpreted as the competitiveness effect.

4.2.4 Data and methodological issues

The results of the analysis should be interpreted with caution as there are several caveats related both to the data and to the methodology. First, statistical data on services is relatively scarce and in many cases it is imprecisely measured in the underlying national statistics, which leads to imprecisions also in the international input-output tables that are constructed from these data. Second, since the data are

59 Our analysis mainly follows the European Central Bank (ECB) (2005) and is briefly presented in the Appendix. Other recent applications of the method to gross exports include e.g. Husted and Nishioka (2013), Cheptea et al. (2014), Pandiella (2015). Related analysis with comparison of gross and value-added exports is provided e.g. in Benkovskis and Wörz (2015).

reported in nominal USD, changes in prices and exchange rates may mechanically affect the calculations. We try to alleviate the price problem by using the approach taken by other researchers who use the CMS technique, and exclude commodity sectors from the analysis. For the purpose of our project the exchange rate effect should be limited in any case in the first years of our data sample since China's exchange rate was fixed to the USD. However, since mid-2005 China's currency has strengthened continuously against the USD up to the beginning of 2014. If the share of trade denominated in USD is smaller in Chinese exports than in world exports, then a depreciation of the USD will mechanically lead to an increase in Chinese market share.

Third, compilation of the data is based on the assumption that the production processes are identical and independent of the final use of the output. This may be unrealistic, especially in the case of China, where production structure for exports and domestic use can be very different, due to the relatively heavy use of imported inputs in the production of products for export[60]. Thus, the share of domestic value-added in Chinese exports may be overestimated. Finally, while we are interested in gaining a fuller understanding of the development of China's service sector activities, the high level of data aggregation in the data set prevents us from studying service sectors at a finer level.

4.3 The Role of Chinese services in global production chains

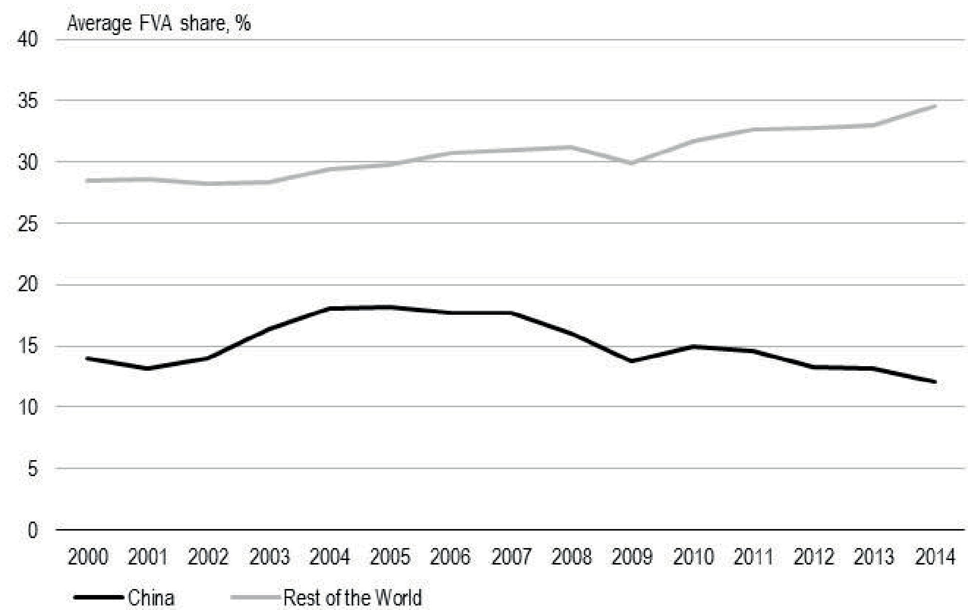
4.3.1 Chinese production chains rely increasingly on domestic services

One of the implications of wider international fragmentation of production is that production chains located in one country have raised their sourcing of inputs from other countries. This is reflected by the increasing share of foreign value-added (FVA) in the output assembled in complex production chains. Consistent with previous results, we find that the average share of FVA increased almost continuously for most countries through the sample period, 2000–2014, although

[60] Evidence on this is provided e.g. by Dean et al. (2011), Koopman et al. (2012), Koopman and Wei (2014) and Xing (2014). Discussion on the limitations of the WIOD data is provided in Timmer et al. (2015).

the trend paused in 2009 and stabilized at the end of the sample.[61] This evolving time pattern for FVA shares is evident for most countries and sectors in the sample, although the levels of FVA differ considerably across countries and sectors. China is a notable exception, however. As Figure 9 shows, in the case of Chinese production chains international fragmentation increased in the first years of the 2000s, before the trend reversed.

Figure 9. The average share of foreign value-added in the manufacturing production chains of China and other countries of the sample (rest of the world), % (simple average across countries and sectors)



Source: Author's calculations based on WIOD data.

The average share of FVA calculated for all countries in the sample excluding China and across all manufacturing sectors was 28 percent in 2000 and increased to 35 percent by 201462. In business services the average FVA share has also increased

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[61]Timmer et al. (2016) and Wang et al. (2017b) conclude that the total global international fragmentation of production has even slightly declined after 2011 applying a slightly different methodology.

[62] We use simple averages across countries and sectors in all calculations in order to take into account the heterogeneity between countries and sectors. The results are somewhat different if weighted averages are reported instead, as a few countries and sectors would strongly dominate the

though at a slower rate, attaining only 19 percent by 2014. In Chinese manufacturing, the share of FVA was 14 percent in 2000, rose to its peak levels at around 18 percent in the middle of the decade and then gradually declined to 12 percent by 2014. In addition to FVA share reversal, China's production chains differed from the manufacturing chains of the average of other countries in their lower FVA share. China's FVA share is, however, at a similar level than in most other largest economies of the world. Moreover, these comparisons should be viewed with some caution, since it is possible that the share of FVA in Chinese production might be somewhat underestimated in the data. Notably, in the case of Chinese business service chains, the share of FVA is still much higher than it is for production chains that end in other countries, although it has declined during past decade.

The differential trends in the development of Chinese production chains appear to be primarily driven by the increasing role of Chinese service activities. This trend is illustrated in Table 36, which shows that the average share contribution of business services (the total of domestic and foreign) in production chains has increased in all countries. In China this development has taken place mostly in the later part of the sample, while other countries experienced this change in the earlier years, and have stabilized in the latter sample years.

The notable difference between China and the rest of the world seen in Table 36 is, however, that the increase in the contribution of services to Chinese production chain activity has mainly stemmed from the increased utilization of domestic business services. This contrasts with chains located in the other countries in the sample that have relied much more heavily on foreign-source business services.

This contrast between Chinese and other production chains might partly reflect the observation that Chinese production chains have experienced growth in the length of the domestic part of the production chain, while the lengthening of chains in other countries has been based on wider international dispersion[63]. Nonetheless, while the contribution of services to Chinese production chains has grown at a more rapid rate than it has for other countries, it is still the case that the share of services in Chinese production chains is smaller on average than it is for the other countries in the sample.

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development. For our calculations, we define world as the other countries in the sample aside from China. When we refer to China our analysis is based on information from mainland China only.

[63] Wang et al. (2017a) define production length of a production chain as the average number of production stages between the primary inputs in a country/sector to final products in another country/sector.

Table 36. Average shares of domestic and foreign value-added by aggregate sector in manufacturing and business service value chains in China and rest of the world, % (excluding inputs from primary and other sectors)

Manufacturing value chains (average)							
China				**Rest of the World**			
	2000	2007	2014		2000	2007	2014
DVA manufacturing	62.8	60.7	59.3	DVA manufacturing	51.9	48.9	48.2
DVA bus. services	23.2	21.6	28.5	DVA bus. services	20.4	20.8	19.4
FVA manufacturing	8.4	9.8	6.1	FVA manufacturing	14.9	15.5	16.1
FVA bus. services	5.6	8.0	6.0	FVA bus. services	12.8	14.7	16.2
	100	100	100		100	100	100
Business service value chains (average)							
China				**Rest of the World**			
	2000	2007	2014		2000	2007	2014
DVA manufacturing	14.8	11.5	11.3	DVA manufacturing	4.1	3.3	2.9
DVA bus. services	77.1	79.3	83.1	DVA bus. services	83.9	84.0	83.3
FVA manufacturing	4.7	4.6	2.5	FVA manufacturing	4.2	4.0	4.3
FVA bus. services	3.4	4.6	3.1	FVA bus. services	7.9	8.6	9.5
	100	100	100		100	100	100

Source: Author's calculations based on WIOD data.

Note: DVA = domestic value-added; FVA = foreign value-added.

4.3.2 Small but increasing contributions of Chinese services to foreign production chains

Since we observe that Chinese production chains are relying increasingly on Chinese service sector inputs, we explore a related question, examining if this development is also apparent in other countries. In other words, we seek to determine whether Chinese services have also become an increasingly important part of production chains anchored in other countries. To tackle this question, we calculate the backward participation indices for all the other countries in the sample with respect to Chinese value-added.

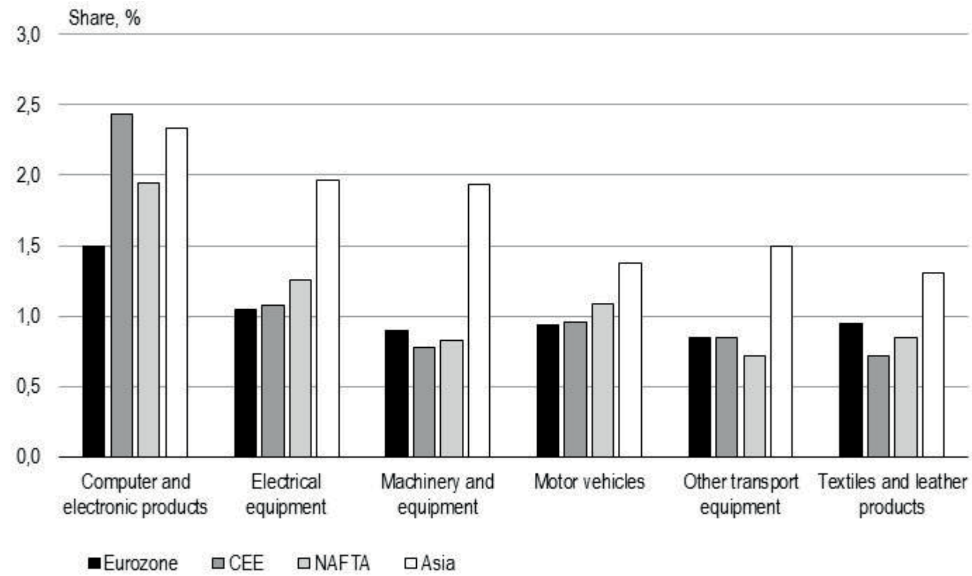
Unsurprisingly, the general trend is that the share of total Chinese value-added included in the production chains of other countries has risen considerably during the sample years, 2000-14. The average share of Chinese value-added in manufacturing chains of other countries increased from 0.4 percent in 2000 to 2.5

percent in 2014, while the corresponding shares for business service chains were 0.2 percent in 2000 and 0.8 percent in 2014. However, the largest part of this increase was attributable to the rising importance of Chinese manufacturing inputs. The average share of Chinese business service inputs in foreign manufacturing production chains increased from 0.1 percent to 0.8 percent and in foreign business service production chains from 0.1 percent to 0.3 percent over the 2000-14 interval. In general, the shares of Chinese business services are highest in the production chains of Asian countries, which is an intuitive outcome, based on the abundant evidence on dense regional production networks in Asia[64]. In most manufacturing chains, the average share of Chinese business services in Asian countries is twice as high as it is for production chains that end in other regions.

The notable industry exception is, however, computers and electronics. As Figure 10 shows, in these chains the average share of Chinese service inputs is actually the highest for chains in Central and Eastern European countries, reaching nearly 5 percent for chains tied to computer and electronics production in Hungary and the Czech Republic. In the case of business service production chains, the share of Chinese service inputs is substantially lower than it is for manufacturing chains and there is less variation in the Chinese share across production chains located in different regions. At the sector level, the Chinese service inputs embodied in foreign production chains are most commonly wholesale trade and financial service sectors.

[64] See for example, Athukorala (2011), Obashi and Kimura (2016).

Figure 10. Share of Chinese service sector inputs in manufacturing production chains of other countries in 2014, % (simple average over countries)



Source: Author's calculations based on WIOD data.

Note: CEE refers to 11 central Eastern European EU-member countries. Asia includes India, Indonesia, Japan, Republic of Korea, and Taiwan.

In comparison with other large economies of the world, China has been catching up rapidly as an input provider to international production chains. By 2014, the average share of Chinese value-added in the manufacturing chains of other countries in the sample reached roughly the same level of value-added as that of Japan. While the shares of Germany and the U.S. were higher yet, at 6 and 5 percent respectively, the differential levels may be particular to the data sample, which is dominated by European countries and lacks most Asian countries, which would be more likely to source inputs from China due to geographic proximity.

The picture is very similar if we focus solely on value chain business service inputs. In many sectors the average share of Chinese business services has reached levels that are comparable to the share of Japanese business services in the production chains of the countries included in the sample. However, the composition of Japanese and Chinese business service provision differs since scientific services make up a larger portion of Japan's service inputs than is the case for China.

4.3.3 Services supporting increasingly Chinese competitiveness

Through the use of a constant market share analysis we are able to examine the evolution of Chinese services in more detail. We compare the growth of China's value added production and exports to that of the rest of the world and first decompose the changes in China's global market shares into the components that are driven by structural or competitiveness effects. Then we examine the competitiveness effect in more detail as we study the underlying sector and market contributions to the competitiveness effect.

As illustrated in Table 37, applying the analysis on China's value-added production shows that China has gained share in global production primarily through the market structure and competitiveness effects. While the product structure effect has been negative in most years, its small magnitude implies that Chinese value-added production has not specialized in sectors which were characterized by particularly rapid or slow growth. However, this question deserves further consideration in the future if more disaggregate data become available, since the small effects may also arise due to the coarse aggregate level at which the data are reported. The market structure effect is positive for all years, since Chinese demand has grown faster than the demand in other countries and because the share of the domestic market is practically always higher in a country's own production relative to the contributions originating in other countries. The strong growth of the domestic market was the main driver during the first part of the time period under consideration, while the competitiveness effect was small or even negative in some of the years.

Table 37. Constant market share analysis for Chinese value-added production

	Total effect	Structure effect	Competitiveness effect	Competitiveness effect by sectors / markets			
				Manufacturing	Services	Domestic	Foreign
2001-2005	7.5	9.1	-1.6	0.1	-1.8	-6.0	4.4
2006-2010	17.1	8.7	8.3	4.5	3.8	4.3	4.1
2011-2014	11.6	4.7	6.9	2.9	4.0	5.1	1.8

Source: Author's calculations based on WIOD data.

Since 2005, in contrast with previous trends, the competitiveness effect took over as the primary factor driving China's growing share in global production. Taking a closer look at the sector-level contributions to the competitiveness effect, Table 37 shows that the contributions of service sectors have increased gradually and in the latest years of the sample have surpassed those provided by manufacturing industries. From the market contributions to the competitiveness effect we find that in the first years China actually lost competitiveness in its domestic markets whereas in later years it has in contrast gained strongly market shares domestically. This is in line with our findings in the previous section that the share of domestic value-added in Chinese production has increased, and furthermore to a large extent due to domestic services.

Our other earlier finding in the previous section that Chinese service sector inputs have gained much less footing in foreign production chains than domestically can be further illustrated by applying the constant market share analysis only on Chinese value-added exports. In Chinese value added exports, the competitiveness effect accounts for practically all of China's market share gains in export markets, whereas both product and market structure effects are small. Thus Chinese exports are not concentrated on particularly fast growing markets or sectors.

But unlike in production, in Chinese exports the majority of the competitiveness gains stems from the manufacturing sectors. The contribution of the service sectors to the competitiveness effect becomes sizable only in the latter part of the time period under consideration. This is also in line with earlier literature examining the evolution of smile curves of Chinese exports which finds that in foreign markets China has grabbed so far more value by increasing its production volume in low value-added manufacturing stages instead of shifting on the smile curve to higher value-added functions like pre- and post-manufacturing services[65].

4.4 Conclusion

Our examination of global value chains reveals the increasingly important role played by Chinese business services. The increase to date has mainly occurred as domestic service inputs have replaced foreign service inputs in Chinese production chains. Rapid growth in China's domestic demand in general and lately in consumption demand in particular has naturally been an important driver for increased output of domestic services such as trade, but the development may also reflect further fragmentation of Chinese production domestically (e.g. outsourcing of accounting

[65] Ye et al. (2015)

or marketing services) as well as an increased demand for Chinese services as multinational corporations turn to local service providers in China.

The share of Chinese service inputs has increased also in foreign production chains. Nonetheless, despite the rapid increase in the use of Chinese services, the average share of Chinese business services is still quite low in comparison with some countries including Germany and the United States, though the Chinese share is now close to that of Japan. The largest shares of Chinese service inputs are found in the machinery and equipment manufacturing sectors, and are particularly notable in the computer manufacturing production chains for certain Central Eastern European countries. This probably reflects the operations of both foreign and Chinese multinational companies, and it points to China's increasingly global reach as its inputs are integrated not just regionally, but within geographically dispersed international production chains. Interpretation of intra-firm service flows is, unfortunately, very difficult, in particular since a large portion of Chinese service inputs to foreign production chains consists of financial services.

Finally, our constant market share analysis further reveals the increasing role of services as a factor underpinning Chinese competitiveness, in the domestic market especially, but also in exports in recent years. As a result, for recent years the contribution of services to China's export competitiveness has risen to a level of influence that is commensurate with the influence observed in the manufacturing sectors. Despite the inherent uncertainty related to the quality and interpretation of service sector data we believe our results provide signs of Chinese production shifting towards higher value-added production stages, particularly in domestic, but also in foreign production chains.

APPENDIX. CONSTANT MARKET SHARE ANALYSIS

Constant market share analysis is used to analyze the factors that contribute to the differences between one country's export performance as compared with its competitors. The comparison typically compares the country's outcomes relative to an aggregate which comprises all other countries. The following brief description is based on ECB (2005).

The total effect refers to the growth difference between China's total exports and the exports of the world aggregate. It can be decomposed into two main effects as follows:

$$g^{CN} - g^{W} = \left[\sum_i \sum_j \left(\theta_{ij}^{CN} - \theta_{ij}^{W}\right)\right] + \left[\sum_i \sum_j \theta_{ij}^{CN}\left(g_{ij}^{CN} - g_{ij}^{W}\right)\right]. \qquad \text{(A1)}$$

In this equation g refers to percentage change in exports in period t and θ represents the share of industry i exports to destination country j in total exports of China and the rest of the world in period t-1. The superscript CN stands for China while the superscript W refers to the world (excluding China). The subscripts i and j refer to industry sector and country destination market, respectively.

The first term in square brackets in (A1) measures the overall structure effect which can be further decomposed into three components – a product effect (A2), a market effect (A3) and a mixed structure effect (A4). These components are defined as follows:

$$\sum_i (\theta_i^{CN} - \theta_i^{W})\, g_i^{W} \qquad \text{(A2)}$$

$$\sum_j \left(\theta_j^{CN} - \theta_j^{W}\right) g_j^{W} \qquad \text{(A3)}$$

$$\sum_i \sum_j \left[\left(\theta_{ij}^{CN} - \theta_{ij}^{W}\right) - (\theta_i^{CN} - \theta_i^{W})\frac{\theta_{ij}^{W}}{\theta_i^{W}} - \left(\theta_j^{CN} - \theta_j^{W}\right)\frac{\theta_{ij}^{W}}{\theta_j^{W}}\right] g_{ij}^{W} \qquad \text{(A4)}$$

The product and market effects compare China's specialization in individual sectors and in particular markets with industry and country concentrations of the rest of the world. The product and market effects will be positive if China is more specialized than the rest of the world on fast-growing sectors and markets. The mixed structure effect is a residual which has no straight-forward interpretation. By construction, this residual reflects the interaction of product and market effects.

The second term in square brackets in (A1) is called the competitiveness or "pure" market share effect. This term reflects the sum of China's market share gains that are driven by factors other than the structure effect.

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ESSAY
IV

Evaluating International Impacts of China-specific Shocks in an Input-Output Framework

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5 ESSAY 4: EVALUATING INTERNATIONAL IMPACTS OF CHINA-SPECIFIC SHOCKS IN AN INPUT-OUTPUT FRAMEWORK

Abstract

The slowing in China's massive economy has wide implications. China plays an essential role in international production chains, so disturbances can spill over to other economies in the global production network. We evaluate the international transmission and impact of various China-specific shocks with an input-output framework applied to the World Input-Output Database (WIOD). We consider shocks to Chinese final demand at the aggregate level, bilateral import tariffs between the US and China and sector-specific shocks to Chinese final demand and supply. Our results suggest that aggregate level shocks, as well as certain sector-specific shocks originating in China, may have large impacts elsewhere. Transmission of shocks through the global production network, however, is mitigated by the relatively low import-intensity of Chinese production.

Keywords: Chinese economy, shock transmission, input-output, international production network

JEL codes: C67, F14, F43

5.1 Introduction

Four decades of spectacular growth have made China one of world's largest economies. Growth has been supported by heavy investment and integration in the global economy (Dieppe et al., 2018), factors that have helped the Chinese economy develop in qualitative terms shifting gradually from low-value-added, labor-intensive production to more complicated, higher-value tasks. China is a significant node in the global production network and an important trading partner for many countries (Baldwin & Lopez-Gonzalez, 2015; Timmer et al., 2016; Simola, 2018).

The loss of steam in the Chinese economy in recent years partly reflects a natural, desirable economic rebalancing from heavily investment-led growth to a consumption-oriented paradigm. While the slowdown in growth has been gradual, the risks of economic weakness and a hard landing loom – especially given China's massive indebtedness (Dieppe et al., 2018). China is aiming at large and much-needed structural reforms such as liberalization of its financial sector (Lin, 2019; Wagner, 2018). Such comprehensive reforms are difficult to realize for any country and may add uncertainty to the future development of the Chinese economy. Moreover, the growing role of China in world trade can exacerbate economic tensions as seen in the current US-China trade dispute (Liu & Woo, 2018).

Since shocks to the Chinese economy are likely to have repercussions regionally and globally, we evaluate the impact of various shocks originating in China on the global production network, on individual countries and on sectors. Our analysis utilizes an input-output framework that accounts for international production linkages and extends to the disaggregated sectoral level. First, we examine the effects of aggregate-level demand shocks originating in China on other countries and across sectors. Next, we analyze the effects of bilateral import tariffs that could be imposed in the context of the current trade disputes between the US and China. Finally, we examine the transmission of sector-specific shocks to Chinese final demand and production.

This work relates to the recent strand of literature that examines the propagation of sub-aggregate level shocks to the aggregate level. Defying the traditional view that idiosyncratic shocks average out at the aggregate level, a number of recent studies find that sector-specific (and even firm-specific) shocks can result in fluctuations in national aggregates due to network structure of production (Gabaix, 2011; Acemoglu et al., 2012; Acemoglu et al., 2016). In the international context, the role of production networks has been shown to be important from the viewpoint of trade policy magnifying the impacts of trade barriers and having indirect effects on third countries (Miroudot et al., 2013; Caliendo & Parro, 2015; Johnson & Noguera, 2017) and affecting the transmission of exchange rate movements (Bems & Johnson 2017). There is also a vast body of literature dealing with the effect of international production chains on the differences between gross and value-added trade (Johnson & Noguera, 2012; Koopman et al., 2014; Los et al., 2015).

There are several China-specific studies that evaluate the consequences of a shock on growth at the aggregate level with various methodologies. In a GVAR setting, a 1 % shock to Chinese output is typically estimated to have an impact of 0–0.6 % for the output of other countries in the short and medium term (Cesa-Bianchi et al., 2012; Korhonen & Feldkircher, 2012; Dreger & Zhang, 2014; Faryna & Simola, 2018). Dreger & Zhang (2014) find slightly smaller effects than in the GVAR setting utilizing the structural NiGEM model to evaluate the effects of Chinese fiscal stimulus on other countries. Ahuja & Nabar (2012), using a FAVAR model to evaluate the spillovers from Chinese investment slowdown, show that a 1 percentage point slowdown in Chinese investment is associated with a reduction of global growth of just under one-tenth of a percentage point. The estimates of Furceri et al. (2017), which are based on single-equation panel framework, range from 0.1-0.2 % in the short term (depending on the region) up to 0.7 % in the medium term. Dieppe et al. (2018) present estimates calculated with several models, including the ECB's semi-structural global model and the IMF's global DSGE model. Their estimates suggest that a 0.7 percentage-point drop in Chinese GDP growth (with some rebalancing of demand from investment to consumption) translates to a drop in GDP growth in other countries of 0–0.5 percentage points in the medium term (and possibly more for oil exporting countries). These studies generally agree that the international impact of Chinese shocks has increased significantly in recent decades.

An input-output framework is utilized by Ma et al. (2016) for assessing the consequences of rebalancing of the Chinese economy for domestic production and international trade. They find that shift from investment to consumption in Chinese demand is likely to negatively affect the exports from most economies to China. Hardest hit countries are East Asian technology exporters such as Taiwan and South Korea and raw material exporters such as Saudi Arabia and Chile. Methodologically, the most important study for this work is Vandenbussche et al. (2019), which examines the effects of tariff increases resulting from Brexit in the input-output framework. Bems and al. (2010) have also used input-output framework for analyzing the transmission of various demand shocks during the global financial crisis. Huidrom et al. (2019), Vandenbussche et al. (2017) and Ali-Yrkkö & Kuusi (2017) apply input-output analysis to examine the effects of recent US import tariffs, illustrating their impacts through production chains on third countries not directly targeted by tariffs.

The recent interest in the impacts of import tariffs in the context of the US trade policy, and trade disputes between the US and China in particular, has engendered several studies estimating the effects of various "trade war" scenarios. These suggest that punitive bilateral tariffs between the US and China could lead directly to losses of more than 1 % of GDP in the short term in particular for China (IMF 2019) and up to 0.3–0.6 % of GDP for both the US and China (Bellora & Fontagne, 2019; Caceres et al., 2019; Charbonneau & Landry, 2018; Felbermayr & Steiniger, 2019; IMF 2019). The Chinese sectors hit hardest are Chinese manufacturing, particularly electronics and machinery, while the biggest losers in the US are agriculture, food production and manufacturing of transport equipment (Bellora & Fontagne, 2019; Felbermayr & Steininger, 2019; Freund et al., 2018). The effect on several third countries (e.g. Canada, Mexico and Japan) is estimated to vary between -0.1 % and 0.3 % of GDP (Bellora & Fontagne 2019, Caceres et al. 2019, Charbonneau & Landry 2018). The magnitude of the effects obviously depends in part also on the details of the scenarios evaluated, as there is some variation in the scenarios considered in different studies.

This work also relates to the literature on sub-aggregate level supply shocks. Much of the discussion in this area concerns the short-term impacts of natural disasters or other abrupt disturbances. The input-output framework has been relatively popular in this type of study (Santos & Haimes, 2004; Hallegatte, 2008; Rose & Wei, 2013). The demand-driven nature of the input-output approach poses particular limitations on the analysis of supply shocks, but its transparency and relative incomplexity in combination with detailed sector-level interlinkages are considered as its main advantages in comparison to CGE models (Galbusera & Giannopoulos, 2018). In the context of China, Wu et al. (2012) examine the nation-wide effects of the 2008 Wenchuan earthquake. MacKenzie et al. (2012) analyze the effects of Japanese Tohoku earthquake and tsunami nationally and internationally, comparing the effects of hypothetical shocks to car production chains in several countries, including China. Recently, the input-output framework has also been combined with network analysis for estimating effects of supply shocks (Acemoglu et al., 2015; Lee, 2019). Previous literature on the international impact of Chinese supply shocks focuses on the effects of Chinese imports on local labor markets, especially in the US (Autor et al., 2013; Acemoglu et al., 2016; Feenstra & Sasahara, 2018).

This work contributes to several branches. First, our results for sector-specific shocks in China support the view that sub-aggregate-level idiosyncratic shocks in one country (at least in a globally important economy like China) may have important repercussions for international fluctuations. Second, on the more practical side, we provide for the first time quantitative estimates on the effect of various China-specific shocks in the common framework of input-output analysis. We also give more detailed sector-level analysis than most other studies. Moreover, we examine the international effects of supply shocks originating in China, which, to our best knowledge, are rarely addressed in the previous literature. Finally, our results suggest that despite its simplicity, the input-output framework produces estimates of the impacts of various shocks that are relatively close to the results achieved by more complex approaches. They provide valuable complementary insights, in particular, for evaluating short-term effects and sector-level analysis.

The rest of the paper is constructed as follows. In section 2, we discuss the theoretical framework providing micro-level foundations for the input-output framework and relating it to the traditional gravity model of international trade. Section 3 presents the data and methodology used in calculating the effects of various China-related shocks. In section 4, we give the results of our analysis and compare our estimates to those from the previous literature. Section 5 concludes.

5.2 Theoretical framework

In this section, we present the theoretical framework underpinning our analysis. Utilizing a gravity-type approach as in Anderson and van Vincoop (2003), we augment it with trade in value added as in Noguera (2012) and multisector production as introduced in Vandenbussche et al. (2019), which we follow in deriving the model. Markets are assumed to be competitive and technology constant. The model is based on the Armington assumption, resulting in imperfect substitutability between goods produced in different countries. Regarding notation, superscripts are used to denote the country and sector of origin and subscripts the country and sector of destination. Upper-case letters refer to real quantities; lower-case letters to nominal terms.

5.2.1 Model setup

Starting from the consumer side, a representative household in country *k* maximizes its utility of the following form:

$$U_k = \prod_{s=1}^{S} [F_k^s]^{\alpha_k^s}, \tag{1}$$

which is a Cobb-Douglas combination of final goods from all sectors and α^s_k the corresponding share in total expenditure. The sector-specific final good is a CES aggregate of the varieties produced in different countries:

$$F_k^s = \left[\sum_{i=1}^{n} \left(F_k^{is}\right)^{\frac{\sigma_s - 1}{\sigma_s}}\right]^{\frac{\sigma_s}{\sigma_s - 1}}, \tag{2}$$

where $\sigma_s > 1$ is the elasticity of substitution (for final goods) between varieties from different countries in sector *s*.

In the production side, output of sector z in country k is given by a Cobb-Douglas production function:

$$Y^{kz} = (L_{kz})^{1-\beta^{kz}} (X_{kz})^{\beta^{kz}}, \tag{3}$$

where L_{kz} is labor used in the production of sector *z* in country *k*, X_{kz} is a composite of intermediate inputs and β^{kz} is the corresponding share in the total sales of country *k*'s sector *z*. The composite of intermediate inputs X_{kz} is:

$$X_{kz} = \prod_{s=1}^{S} [X_{kz}^s]^{\gamma_{kz}^s}, \tag{4}$$

implying that X_{kz} is a Cobb-Douglas combination of intermediate inputs from all sectors and γ^s_{kz} is the corresponding share in the total expenditure on inputs. Similarly, as on the consumption side, the sector-specific intermediate good X^s_{kz} is a CES aggregate of the varieties produced in different countries:

$$X_{kz}^s = \left[\sum_{i=1}^{N} \left(X_{kz}^{is}\right)^{\frac{\rho_s - 1}{\rho_s}}\right]^{\frac{\rho_s}{\rho_s - 1}}, \tag{5}$$

where $\varrho_s > 1$ is the elasticity of substitution (for intermediate goods) between varieties from different countries in sector *s*.

We assume iceberg-type trade barriers, implying that for delivering one unit of its output to country *j*, the sector *z* in country *k* needs to produce $\tau^{kz}{}_j > 1$ units. Therefore, the price of one unit of output of sector *z* in country *k* equals $p^{kz}{}_j = \tau^{kz}{}_j p^{kz}$.

Households in country k maximize their utility as expressed in equation (1) with respect to their income, which consists of the wage w_{kz} they receive from supplying labor L_{kz}:

$$I_k = \sum_{z=1}^{S} w_{kz} L_{kz} \,. \tag{6}$$

Firms maximize their profits taking factor and goods prices as given. Solving the maximization problems gives us the following nominal demands (i.e. multiplied by corresponding prices and denoted by lower-case symbols) for final and intermediate goods:

$$x_{kz}^{is} \equiv p_k^{is} X_{kz}^{is} = \tau_k^{is} p^{is} X_{kz}^{is} = \left(\frac{\tau_k^{is} p^{is}}{P_k^s}\right)^{1-\sigma_s} \gamma_{kz}^s \beta^{kz} y^{kz} \tag{7}$$

$$f_k^{is} \equiv p_k^{is} F_k^{is} = \tau_k^{is} p^{is} F_k^{is} = \left(\frac{\tau_k^{is} p^{is}}{P_k^s}\right)^{1-\sigma_s} \alpha_k^s \sum_{z=1}^{S} (1 - \beta^{kz})\, y^{kz} \,, \tag{8}$$

where the CES price index in country *k* of goods from sector *s* equals:

$$P_k^s = \left[\sum_{i=1}^{N} \left(p_k^{is}\right)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}} . \tag{9}$$

We have assumed for simplicity that $\sigma_s = \varrho_s$, implying that the price of a good produced in sector *s* is the same whether it is sold for final consumption or as an intermediate input. The result is identical price indices for final and intermediate goods.

5.2.2 Market clearing

In this section, we derive gravity equations for the exports of final and intermediate goods at the sector level following Vandenbussche et al. (2019).

We define the nominal gross exports from sector *z* of country *k* to country *j* as:

$$e_j^{kz} \equiv f_j^{kz} + \sum_{s=1}^{S} x_{js}^{kz} \;, \tag{10}$$

with the first term depicting exports for final consumption and the second term exports for intermediate inputs for all sectors *s*. Market clearing requires:

$$y^{kz} = \sum_{j=1}^{N} e_j^{kz}. \tag{11}$$

Next, we denote world nominal output by y^w and define the share of sector *z* of country k in world output as $\Theta^{kz} = y^{kz}/y^w$. Substituting the nominal demands for final and intermediate goods from (7) and (8) to the export equation (10) allows us to solve for prices p_is. Inserting these into the price index in (9) and the resulting expression for the price index back to the demand equations (7) and (8) gives the following equations for bilateral exports of intermediate inputs and final goods:

$$x_{js}^{kz} = \frac{y^{kz}\gamma_{js}^{z}\beta^{js}y^{js}}{y^{w}}\left(\frac{\tau_j^{kz}}{\Pi^{kz}P_j^{z}}\right)^{1-\sigma_s} \tag{12}$$

$$f_j^{kz} = \frac{y^{kz}\alpha_j^{z}\sum_{s=1}^{S}(1-\beta^{js})y^{js}}{y^{w}}\left(\frac{\tau_j^{kz}}{\Pi^{kz}P_j^{z}}\right)^{1-\sigma_s} \tag{13}$$

with the multilateral resistance terms given by:

$$P_j^z = \left[\sum_{i=1}^{N} \theta^{kz}\left(\frac{\tau_j^{kz}}{\Pi^{kz}}\right)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}} \text{and}$$

$$\Pi^{kz} = \left[\sum_{j=1}^{N} \varphi_j^z\left(\frac{\tau_j^{kz}}{P_j^{z}}\right)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}},$$

where

$$\varphi_j^z = \sum_{s=1}^{S} \theta^{js}\left[\gamma_{js}^{z}\beta^{js} + \alpha_j^{z}(1-\beta^{js})\right]$$

depicts the importance of goods from sector *z* for producers and consumers in country *j*, taking into account the dependence of producers on intermediate inputs from sector *z* in country *j* and the final demand for sector *z* goods in country *j*.

As we can see from equations (12) and (13), exports from sector *z* in country *k* to country *j* depend on the relative sizes of the countries (y^{kz}/y^w and y^{js}/y^w), the bilateral trade costs ($\tau^{kz}{}_j$) and outward and inward multilateral resistance terms (Π^{kz}

and P^z_j). The outward and inward multilateral resistance terms depict the overall trade costs of the countries. Π^{kz} concerns the export costs of sector *z* in country *k* to all countries and P^z_j correspondingly the import costs in country *j* from all countries. Indeed, in addition to bilateral trade costs, the relative trade costs (bilateral costs relative to multilateral costs) are also important in determining trade flows between two countries. In addition, exports of final goods depend on the share of sector *z* in final consumption (α^z_j) and the exports of intermediate goods on the share of intermediate inputs in production (β_{js}) and on the share of sector z inputs in the total expenditure on inputs (γ^z_{js}).

5.2.3 Input-output linkages

To highlight the input-output linkages, we first divide both sides of the intermediate goods export equation (12) by y^{js}:

$$\frac{x^{kz}_{js}}{y^{js}} \equiv a^{kz}_{js} = \frac{y^{kz}\gamma^z_{js}\beta^{js}}{y^w}\left(\frac{\tau^{kz}_j}{\Pi^{kz}P^z_j}\right)^{1-\sigma_s}. \qquad (14)$$

Equation (14) shows the value of inputs from sector *z* of country *k* needed to produce a dollar's worth of output in sector *s* of country *j*, i.e. the technical coefficient a^{kz}_{js}.

Inserting the technical coefficients to the market clearing condition given by equation (10) we get:

$$y^{kz} = \sum_{j=1}^{N}\left(\sum_{s=1}^{S} x^{kz}_{js} + f^{kz}_j\right) = \sum_{j=1}^{N}\sum_{s=1}^{S} a^{kz}_{js}\, y^{js} + \sum_{j=1}^{N} f^{kz}_j$$

and summarizing for all countries and sectors:

$$\boldsymbol{Y} = \boldsymbol{AY} + \sum_{j=1}^{N}\boldsymbol{f_j}\,, \qquad (15)$$

where

$$\boldsymbol{Y} = \begin{bmatrix} y^{1,1} \\ \vdots \\ y^{N,S} \end{bmatrix}; \qquad \boldsymbol{A} = \begin{bmatrix} a^{1,1}_{1,1} & \cdots & a^{1,1}_{N,S} \\ \vdots & \ddots & \vdots \\ a^{N,S}_{1,1} & \cdots & a^{N,S}_{N,S} \end{bmatrix}; \qquad \boldsymbol{f_j} = \begin{bmatrix} f^{1,1}_j \\ \vdots \\ f^{N,S}_j \end{bmatrix}$$

with fj the (S*N) x 1 vector of country *j*'s final demands and A the (S*N) x (S*N) global input-output matrix at country-sector level.

We can re-write equation (15) in the form:

$$(\boldsymbol{I}-\boldsymbol{A})\boldsymbol{Y}=\textstyle\sum_{j=1}^{N}\boldsymbol{f_j}\ , \tag{16}$$

where I is a (S*N) x (S*N) identity matrix. If the matrix (I-A) can be inverted, nominal output is given by:

$$\boldsymbol{Y}=(\boldsymbol{I}-\boldsymbol{A})^{-1}\textstyle\sum_{j=1}^{N}\boldsymbol{f_j}=\boldsymbol{L}\sum_{j=1}^{N}\boldsymbol{f_j}\ , \tag{17}$$

where L is the Leontief inverse matrix. Its elements give the dollar value of goods of sector *z* of country k needed to fulfill one dollar's worth of final demand in sector *s* of country *i*.

Combining to this the export equation of final goods from (13) gives the nominal output of sector *z* in country *k* in the form:

$$\begin{aligned}y^{kz}&=\sum_{i=1}^{N}\sum_{s=1}^{S}L_{is}^{kz}\sum_{j=1}^{N}f_j^{is}\\&=\textstyle\sum_{i=1}^{N}\sum_{s=1}^{S}L_{is}^{kz}\sum_{j=1}^{N}\left(\frac{y^{is}\alpha_j^s\sum_{r=1}^{S}(1-\beta^{jr})y^{jr}}{y^w}\left(\frac{\tau_j^{is}}{\Pi^{is}P_j^s}\right)^{1-\sigma_s}\right)\end{aligned} \tag{18}$$

We still want to get from this gross output the value-added production. Following Vandenbussche et al. (2019), we assume that the value-added share in the sector *z* of country *k* is the share of labor in the production. According to production function (3), the labor share is $(1-\beta^{kz})$. Thus, the value added created in sector *z* of country *k* is:

$$va^{kz}=v^{kz}\textstyle\sum_{i=1}^{N}\sum_{s=1}^{S}L_{is}^{kz}\sum_{j=1}^{N}f_j^{is}, \tag{19}$$

where $v=(1-\beta^{kz})$ is the value-added-to-output ratio.

5.3 Data and methodology

For the empirical application, we utilize the World Input-Output Database (WIOD), like previously done by Vandenbussche et al. (2019), Huidrom et al. (2019) and Bems & Johnson (2017). WIOD is a publicly available outcome of a project commissioned by the European Commission. WIOD tables are constructed by combining and harmonizing national accounts data from various countries with detailed customs and balance of payments statistics and augmented with estimated inputs for gaps as discussed in Timmer et al. (2015) and Timmer et al. (2016). The resulting global input-output tables present the distribution of global supply and use by countries and sectors.

The latest version of WIOD global input-output tables covers 43 countries and a rest-of-the-world bloc. The countries range from the 28 members of the European Union to other major economies of the world, including emerging economies such as China. The input-output tables are further divided into 53 sectors according to the International Standard Industrial Classification revision 4 (ISIC Rev. 4) and presented in accordance with System of National Accounts standard SNA 2008. WIOD provides a comparable annual series of global input-output tables for 2000–2014. Values are expressed in current US dollars.

5.3.1 Demand and supply shocks

We start from a shock to final demand in China which effects can be calculated by inserting expression (17) to equation (19) and differentiating it with respect to final demand as shown e.g. by Miller & Blair (2009). If the final demand in China changes, then the change in value added in sector *z* of country *k* is given by:

$$dva^{kz} = v^{kz} L \, d \, f_{CN}. \qquad (20)$$

From equation (20) we see that the change in value added production in sector *z* in country *k* (dva) can be solved by multiplying the change in the final demand vector f (denoted f_{CN} as only elements depicting Chinese demand across sectors change) by the Leontief inverse matrix (L) which elements depict the value of output needed from sector z in country k for fulfilling the final demand. Therefore the calculation takes into account the direct effect from the change in demand for final goods as well as the indirect effect arising from the change in need for intermediate inputs in the production of final goods.

Finally, we still have to multiply the effect on gross output by the vector containing the value-added-to-output ratios to find out the change in value added production. In the case of aggregate final demand shocks, all elements depicting Chinese final demand change. In the case of sector-specific final demand shocks we change only one element depicting Chinese final demand at a time.

We next consider a supply shock. Since the input-output framework is essentially a demand-led model of the economy with exogenous demand defining the production side,[66] the possibilities for examining supply shocks are rather specific. We thus consider as a supply shock an exogenous disturbance that leads to a change in the output of sector s in China that is transmitted to supplier sectors through production network linkages by reducing demand for intermediate inputs. For this, we define matrix $L^* = L(\tilde{L})^{-1}$, where $\tilde{L}$is a diagonal matrix created from the on-diagonal elements of L. This means that we extract from the basic Leontief inverse matrix L the direct effect that is related to final demand and are left with only the indirect effect related to demand for intermediate inputs. Thus an element in column *j* of matrix L* shows how much output from sector *i* is needed to produce one unit of output in sector *j*. Following Miller and Blair (2009), if the output of sector s in China changes, the change in the value added of sector *z* in country k is given by:

$$dva^{kz} = v^{kz} L^* \, d \, x_{CNs} \,. \qquad (21)$$

Following equation (21) we can solve the change in the value added production of sector z in country k by multiplying the change in the output sector (denoted x_{CNs} as only the element depicting the output in Chinese sector s changes) by the adjusted Leontief inverse matrix L*. Thus the calculation now concerns only the demand for intermediate inputs and not for final demand as we are focusing on the supply perspective.

To examine the implications of demand and supply shocks, we use the latest WIOD table available, i.e. 2014. Despite the lag of several years, the data should be quite relevant as economic structures change relatively slowly. After removing missing values, we get a 2289 x 2289 matrix that depicts the global production network structure. With this basis for our analysis, it is relatively straightforward to calculate the effects of various demand and supply shocks on different countries and industries according to equations (20) and (21).

[66] There exists a supply-driven version of the input-output framework, but it has been criticized for highly unrealistic features e.g. by Oosterhaven & Bouwmeister (2016). Many studies in this field rely on an "input-output inoperability model," but as argued by Dietzenbacher & Miller (2015) and Oosterhaven & Bouwmeister (2016), it is essentially a transformation of the standard input-output model.

5.3.2 Trade cost shocks

We also consider a shock on bilateral trade costs τ. Following Vandenbussche et al. (2019), we calculate the change in the value-added production of sector *z* in country *k* resulting from a change in the trade costs from equation (19) after substituting (18). Differentiating the value added equation with respect to the bilateral trade costs τ we obtain:

$$dva^{kz} = -v^{kz}\sum_{i=1}^{N}\sum_{s=1}^{S}(\sigma_s - 1)\, L_{is}^{kz}\sum_{j=1}^{N}\left[\frac{d\tau_j^{is}}{\tau_j^{is}} - \frac{d\Pi^{is}}{\Pi^{is}} - \frac{dP_j^s}{P_j^s}\right]\left[f_j^{is} + \sum_{r=1}^{S} x_{jr}^{is}\right]$$
$$= -v^{kz}\sum_{i=1}^{N}\sum_{s=1}^{S}(\sigma_s - 1)\, L_{is}^{kz}\sum_{j=1}^{N}\frac{d\tau_j^{is}}{\tau_j^{is}} e_j^{is} + v^{kz}\sum_{i=1}^{N}\sum_{s=1}^{S}(\sigma_s - 1)\, L_{is}^{kz}\sum_{j=1}^{N}\left[\frac{d\Pi^{is}}{\Pi^{is}} + \frac{dP_j^s}{P_j^s}\right] e_j^{is}, \qquad (22)$$

where the first term is the direct effect caused by the change in the bilateral trade costs and the second term is the indirect effect that results from the change in relative trade costs as measured the multilateral resistance terms.

As we can see from the first part of the equation (22), an increase in the bilateral trade costs is expected to have a negative effect on the value added production of sector *z* in country *k*, which is the trade destruction effect. The size of the effect depends on the increase in trade costs, the trade elasticity parameter σ_s and on the global production structure as depicted by the Leontief inverse matrix. The indirect effect or the trade diversion effect tends to concern longer term adjustment. Because we are focusing on short-term effects, however, we follow Vandenbussche et al. (2019) and take only the first term as a proxy for the effects of trade cost changes.[67]

As a case study for empirical application of trade cost shocks, we take the tariffs imposed in context of the ongoing trade dispute between the US and China. First, we examine the effect of tariffs imposed by the US on imports from China. We use 25 % import tariffs across all sectors as we cannot separate individual products in our framework. This choice is supported by the fact that tariffs are currently already imposed on a majority of US imports from China. This scenario also facilitates comparison of our results with previous research. Additionally, we calculate a second scenario augmented with potential symmetric Chinese retaliation.

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[67] As noted by Vandenbussche et al. (2019), the trade diversion effects of tariffs are usually found to be relatively small compared to the trade destruction effects.

For the value-added flow data, we again use the WIOD 2014 table as for the demand and supply shocks. The US and Chinese tariff levels preceding the trade disputes are taken from WTO data. We use the aggregate MFN applied tariffs for product groups, since the WIOD contains sector-level data. The US tariffs range from 0.6 % for wood and paper to 11.7 % for clothing. The Chinese tariffs range from 4.1 % for wood and paper to 16 % for clothing. For the trade elasticity, we choose a conservative estimate of 2 following Vandenbussche et al. (2017) and Ali-Yrkkö & Kuusi (2017). This is because our data is on a relatively aggregate level and there is typically large variation in the elasticity estimates across products and countries (Caliendo & Parro, 2015; Imbs & Mejean, 2017). Even with this moderate elasticity estimate, the imposition of tariffs reduces demand notably both in the US and China. Obviously, the decline would be even larger with higher trade elasticity.

5.4 Results

We present the results on the effects of shocks originating in China in this section.[68] The results should be viewed as depicting the transmission of shocks through the trade channel only, as we cannot take wider effects e.g. on financial markets into account in our framework. Moreover, our framework is focused on the short-term effects before the economies have adjusted to the shocks. We start from the aggregate level and examine first two scenarios of shocks to China's final demand. We then consider trade cost shocks in the form of import tariffs imposed bilaterally by the US and China again under two scenarios. Finally, we move to the sector level to examine sector-specific demand and supply shocks.

5.4.1 Chinese aggregate demand shocks

The main use of input-output analysis is to explicate shocks to final demand. To facilitate comparison with results from previous literature, we calibrate the aggregate shocks to China's final demand to a magnitude where they correspond to a 1 % negative shock to China's GDP. First, we consider a simple 1 % shock to China's GDP keeping the structure of final demand unchanged (i.e. final demand for all sectors declines by the same amount in relative terms). The effect is slightly negative

[68] In this section, "China" is synonymous with mainland China.

for all countries, leading to a negative shock of 0.03 % to the combined global GDP (excluding China itself). As Table 38 shows, the largest effects are recorded for Taiwan and Korea (0.12 % and 0.08 %, respectively). The smallest, 0.01 %, are experienced by some countries in Southern Europe. At the sector level, Taiwanese and Korean manufacturing of electronics and Australian mining are among the hardest hit industries.

In the second scenario, we also consider rebalancing from investment to private consumption. We again assume a shock that corresponds to a 1 % negative shock to Chinese GDP, but further assume it changes the structure of final demand so that the share of private consumption in final demand increases by 5 percentage points and the share of fixed investment declines correspondingly. Since the change between the shares is large, demand in some consumer sectors actually rises (although the shock is negative at the aggregate level). Admittedly, the change in the structure of final demand is quite strong for short-term horizon, but it illustrates more clearly the significance of rebalancing for effects on other countries.

Table 38. Effects of Chinese aggregate final demand shock in selected economies, % of GDP.

	Negative shock: 1% of GDP	**Negative shock: 1 % of GDP with shift in final demand structure**
Korea	-0.08	-0.32
Australia	-0.05	-0.15
Germany	-0.03	-0.12
Japan	-0.03	-0.11
EU-28	-0.02	-0.05
US	-0.01	-0.02
Brazil	-0.02	0.01
Global (excl. China)	-0.03	-0.07

Source: Author's calculations based on WIOD.

Indeed, the effects on other economies are stronger in the rebalancing scenario and there is much more variation across countries. The global effect is now -0.07 % of GDP, with the effects for individual economies ranging from -0.49 % to a slightly positive effect of 0.01 %. With rebalancing, the economies hardest hit are Taiwan and Korea (-0.49 % and -0.32 %, respectively), whereas the effect is slightly positive for Brazil and Ireland. The positive effects experienced by Brazil and Ireland reflect the higher consumer demand, particularly foodstuffs, as these countries are relatively more specialized in exporting consumer goods or raw materials for consumer sectors. Indeed, Brazilian agriculture and Irish food industry join Scandinavian medicine industries as sectors experiencing the largest positive effects. At the negative end, we again find Taiwanese and Korean electronics manufacturing and Australian mining and metals.

As noted in section 1, the estimates from the previous literature typically put the effect of a 1 % negative shock to Chinese GDP between 0 and -0.6 % of GDP in the short to medium term for other countries (Korhonen & Feldkircher, 2014; Dreger & Zhang, 2014; Furceri et al., 2017; Dieppe et al., 2018).69 Thus, our results are quite close to previous estimates achieved with various methodologies. When assuming no changes in the demand structure, our results suggest only small effects that are closer to the lower end of previous estimates. This could reflect the fact that our framework only accounts for trade volume effects. Additional effects can occur, however, through commodity price movements and financial markets. China is a top global consumer of several commodities as pointed out by Gauvin and Rebillard (2018). China is still much less integrated globally in financial than goods markets, but there is evidence of additional effects propagating through financial markets (Dieppe et al., 2018).

When restructuring of final demand is also assumed, our estimates become much higher than in the baseline case. This reflects the stronger import intensity of Chinese investment than private consumption as observed by e.g. Ahuja & Nabar (2012). It also comports with the results obtained by Bems et al. (2010) on the differential effects of demand changes by aggregate sector.

5.4.2 US-China bilateral tariff shocks

For tariff shocks, we assume the US imposes a 25 % import tariff on all Chinese goods in our first scenario and augment our second scenario with a corresponding Chinese retaliation on all US goods. In line with the previous literature, the largest effect in both scenarios falls on China, amounting to a drop of 1.02 % in GDP (Table 39). Surprisingly, the impact on the US is much smaller – a drop of just 0.12 % of GDP even with retaliation measures in place. One possible explanation is the higher initial level of Chinese import tariffs. Thus, the price increase caused by the tariff hikes and the following decrease in demand is relatively smaller for China than the

[69] Estimates are rarely explicitly defined in the previous literature as resulting from a demand shock. In the GVAR framework identification between demand and supply shocks is often quite difficult.

US. The indirectly caused impacts for other countries are small in most cases, which is in line with the findings of Charbonneau & Landry (2018), Caceres et al. (2019) and Ali-Yrkkö & Kuusi (2017). However, the drop in Korea is larger (-0.17 % of GDP). Our results also suggest that the negative effect for third countries is mainly caused by the tariffs posed by the US on Chinese products, whereas the additional effect from Chinese retaliation measures is much smaller. This could reflect the higher share of foreign value added in Chinese exports to the US than in the US exports to China.

Table 39. Effects of 25 % bilateral import tariffs between the U.S. and China in selected economies, % of GDP.

	25 % tariff on US goods imports from China	25 % tariff on US-China bilateral goods imports
China	-1.02	-1.02
US	-0.01	-0.12
Korea	-0.16	-0.17
Australia	-0.07	-0.07
Japan	-0.04	-0.04
Germany	-0.03	-0.03
Mexico	-0.01	-0.03
EU-28	-0.02	-0.02
Global (incl. China and the US)	-0.17	-0.20

Source: Author's calculations based on WIOD.

Compared to earlier results, our estimates are quite similar to IMF (2019) where the setup is closest to ours. According to IMF (2019), the short-term effect from the bilateral tariffs is -0.2 % of GDP for the US, -1.3 % of GDP for China and -0.2 % of GDP for world total. Compared to other previous literature, our estimate is somewhat higher for China and a bit lower for the US.70 Charbonneau & Landry (2018) estimate the effects at -0.33 % for China and -0.25 % for the US; Ballora & Fontagne (2019) at -0.39 % and -0.28 %; Felbermeyr & Steininger at -0.25 % and -0.14 %; and Freund et al. (2018) at -0.3 % and 0 %. The previous literature, however, mostly focuses on long-term effects that realize after the global economy has adjusted to the shocks. For the other countries, there is great variation in the

[70] The scenarios vary somewhat across studies, but we have tried to use the estimates with background assumptions closest to ours.

estimated effects, ranging from -0.11 % to 0.2 % (Charbonneau & Landry, 2018; Ballora & Fontagne, 2019). Most of our estimates fall within this range.[71] Moreover, the positive impact for some countries found in previous studies is due to substitution effects taking place in longer term that cannot be accounted for in our framework.

In sector terms, Chinese manufacturing of miscellaneous products (e.g. furniture and toys), electronics and textiles (-6.79 %, -5.03 % and -2.66 % of the sector value added respectively) are among the hardest-hit industries. Taiwanese electronics manufacturing is also among the sectors hardest hit. From the US side, the largest negative effects concern manufacturing of other transport equipment and manufacturing of machinery. The sector-level results are qualitatively well in line with previous results, and for the most affected sectors also quantitatively quite similar (Caceres et al., 2019; Charbonneau & Landry, 2018; Freund et al., 2018). The main difference is that all effects are negative in our results as the redistributive effects in our framework would need to be evaluated with additional exogenous assumptions. With the longer time horizons in the previous literature, we see some sectors may gain from e.g. increased protection or improved price competitiveness relative to countries subject to tariffs.

5.4.3 Chinese sector-specific demand shocks

We now examine the transmission of sector-specific shocks in China's final demand. We assume a 10 % negative shock to Chinese final demand in each manufacturing sector. We focus on manufacturing sector shocks since the vast majority of final demand in services is fulfilled from domestic sources in China as in other countries (Simola, 2018). The effect accounts for direct loss of production resulting from falling final demand and the indirect loss of production caused by the drop in demand for inputs in the Chinese and foreign sectors supplying goods for China's final demand.

While aggregate-level effects are very small for shocks in most sectors, they are significant for certain sectors (Table 40). In global terms, the largest effects come from a shock in Chinese final demand of machinery, electronics and motor vehicles. For shocks to the final demand in these sectors, the total effect on other countries than China is -0.02 % of their combined value added. The average effect varies by

[71] No estimates for Taiwan are reported in the previous literature.

regions between 0 % and -0.03 % of GDP with the most negative impacts recorded again for shocks from manufacturing of machinery, motor vehicles, electronics and food products. For individual economies, the highest negative effects result from shocks in manufacturing of electronics for Taiwan and Korea (0.23 % and 0.17 % of GDP), manufacturing of machinery for Taiwan and Korea (0.12 % and 0.07 % of GDP) and manufacturing of motor vehicles for Slovakia and Germany (0.09 % and 0.06 % of GDP).

Table 40. Effects of a 10 % negative shock to Chinese final demand in selected sectors and economies, % of GDP.

	Food	Electronics	Machinery	Motor vehicles
Taiwan	-0.02	-0.23	-0.07	-0.12
Korea	-0.02	-0.17	-0.07	-0.05
Australia	-0.04	-0.01	-0.02	-0.02
Germany	-0.01	-0.02	-0.05	-0.06
US	-0.01	-0.01	-0.01	-0.01
Global (excl. China)	-0.01	-0.02	-0.02	-0.02

Source: Author's calculations based on WIOD.

Drilling down on our sector-level findings, we identify the individual sectors hardest hit by sector-specific Chinese demand shocks (Table 41). Taiwan and Korea again top the list with a shock in Chinese final demand of electrical equipment leading to a -2.28 % effect on the value-added production of Taiwanese electrical equipment manufacturing, a shock in Chinese final demand of machinery to a -1.87 % effect on Taiwanese machinery manufacturing and a shock in Chinese demand of electronics to a -1.48 % effect on Korean electronics manufacturing. Certain European industries also experience significant effects from Chinese final demand disturbances, including shocks to Chinese motor vehicle demand (-1.07 % on Slovakian motor vehicle manufacturing, as well as -0.82 % on the British and -0.67 % on the German car sectors) and shocks to Chinese demand for pharmaceutical products (-1.15 % on Norwegian pharmaceutical makers, as well as -0.59 % on the Danish and -0.58 % on the Swedish pharma sectors).

Table 41. Largest individual effects of sector-specific shocks to Chinese final demand, % of sector value added.

Chinese final demand sector	Affected production sector	Impact, % of sector value added
Electronic equipment	Taiwanese electronic equipment mfg.	-2.28
Machinery	Taiwanese machinery mfg.	-1,87
Computers and electronics	Korean electronics mfg.	-1.48
Computers and electronics	Taiwanese electronics mfg.	-1.24
Pharmaceutical products	Norwegian pharmaceuticals mfg.	-1.15
Motor vehicles	Slovakian motor vehicle mfg.	-1.07
Computers and electronics	Japanese electronics mfg.	-0.91
Motor vehicles	British motor vehicle mfg.	-0.82
Machinery	Korean machinery mfg.	-0.81
Pharmaceutical products	Taiwanese pharmaceuticals	-0.81
Machinery	German machinery mfg.	-0.76
Machinery	Japanese machinery mfg.	-0.73

Source: Author's calculations based on WIOD.

5.4.4 Chinese sector-specific supply shocks

Now we perform a similar exercise as in the previous section, but focus on sector-specific supply shocks instead of shocks to final demand. A supply shock here is an exogenous change in the output of a Chinese sector. In the basic input-output framework, the effect of a supply shock reflects demand changes experienced by the other sectors providing inputs to the sector hit by the shock. Therefore, the effect is partly the same as in the previous section. It again accounts for the inputs needed in the production for domestic final demand, but instead of the production for Chinese final demand it includes the inputs needed in Chinese production for exports. We again consider a 10 % negative shock to each manufacturing sector.

The results for sector-specific supply shocks are quite similar to those for final demand shocks (Table 42). For shocks originating in most sectors, the aggregate effects are quite small, but again with some exceptions. Indeed, some of the effects on other countries are actually even larger than in the case of final demand shocks, reflecting the fact that sectors oriented more towards exports in Chinese production tend to be more import-intensive. In global terms (excluding China itself), the largest effect of 0.04 % of combined value added comes from the manufacturing of electronics. The effect of a shock in manufacturing of basic metals is of similar magnitude. The average effect varies by sectors between 0 and -0.05 % of GDP with the most negative impacts recorded for shocks from manufacturing of electronics and basic metals. In regional terms, the highest negative effects result from shocks in manufacturing of electronics for Taiwan and Korea (0.54 % and 0.23 % of GDP), manufacturing of basic metals for Australia and Russia (0.16 % and 0.09 %)[72] and manufacturing of electronic equipment for Taiwan and Korea (0.14 % and 0.08 % of GDP).

Table 42. Effects of a 10 % negative shock on Chinese output in selected sectors and economies, % of GDP.

	Food	Basic metals	Electronics	Electrical equipment
Taiwan	-0.03	-0.08	-0.54	-0.14
Korea	-0.02	-0.06	-0.23	-0.08
Australia	-0.04	-0.16	-0.06	-0.06
Germany	-0.01	-0.02	-0.02	-0.02
US	-0.01	-0.01	-0.01	-0.01
Global (excl. China)	-0.01	-0.04	-0.04	-0.02

Source: Author's calculations based on WIOD.

At the individual sector level, there are similarities and differences compared to the shocks on final demand. Manufacturing of electronics is again – unsurprisingly – the source sector of shocks that results in strongest individual effects (Table 43). Moreover, the hardest-hit sectors again feature a handful of Taiwanese industries73. Indeed, the largest individual effects are recorded for shocks in Chinese manufacturing of electronics to Taiwanese electronics manufacturing (-2.78 % of the sector's value added) and for shocks in Chinese manufacturing of textiles for Taiwanese manufacturing of textiles (-1.67 %). On the supply-shock side, manufacturing of textiles, chemicals and basic metals as sources of shocks create higher individual effects. Unlike with demand shocks, the most affected sectors include several Australian industries.

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[72] The figure for Russia is probably too small due to the lack of data or the fact that the data are outdated (Timmer et al., 2016).

[73] Some of the most affected sectors might seem slightly surprising, as e.g. the relatively strong effect of a shock in Chinese manufacturing of electronics to Taiwanese manufacturing of chemicals, but manufacturing of electronics is actually globally among the top customer sectors of the chemical industry according to Oxford Economics (2019).

Table 43. Largest individual effects of sector-specific shocks to Chinese supply, % of sector value added.

Chinese sector	Affected sector	Impact, % of sector value added
Electronics	Taiwanese electronics mfg.	-2.78
Textiles	Taiwanese textiles mfg.	-1.67
Electronics	Korean electronics mfg.	-1.57
Chemicals	Taiwanese chemicals mfg.	-1.37
Basic metals	Australian mining & quarrying	-1.24
Electronics	Japanese electronics mfg.	-0.90
Basic metals	Australian basic metal production	-0.83
Electronics	Taiwanese non-metallic mineral production	-0.80
Chemicals	Korean chemicals mfg.	-0.74
Foodstuffs	Brazilian crop and animal production	-0.66
Electronics	Taiwanese chemicals mfg.	-0.62
Chemicals	Australian mining & quarrying	-0.61

Source: Author's calculations based on WIOD.

In general, the effects of sector-specific shocks to both Chinese final demand and supply seem to be relatively moderate in most cases. As the previous literature lacks similar estimates, we are unable to compare the magnitude of our estimates to the previous literature. The relatively moderate magnitude of the effects could reflect the fact that the Chinese final demand is still quite heavily oriented towards domestic goods. The import intensity of Chinese production chains, which rely mainly on domestic inputs, has actually decreased in recent years as noted in Timmer et al. (2016) and Simola (2018).

There are, however, a few exceptions where international spillovers are not negligible. Moreover, such shocks would probably induce additional effects from commodity prices and financial markets that are not accounted for in our framework. Our results are in line with the earlier findings of e.g. Acemoglu and al. (2015) and Lee (2019) that idiosyncratic sub-aggregate level shocks may have important effects on the aggregate level through network-based propagation.

5.5 Conclusions

We have examined the international propagation and impact of various shocks originating in the Chinese economy on other economies using an input-output framework applied to recently compiled world input-output data. Our motivation was two-fold. First, our goal was to estimate the magnitude of the effects of the shocks in the relatively simple input-output framework and then compare those results to estimates achieved with more complex methodologies. Second, we wanted to examine more closely the transmission of idiosyncratic sector-specific shocks in the international production network to evaluate their importance at the aggregate level. The possibility for sector-level examination is the major advantage of the input-output framework. We are not aware of a similar analysis in the previous literature.

This study starts by considering the effects of an aggregate-level negative shock to Chinese final demand alone and then combined with a shift in the structure of final demand from investment to private consumption. We find that a negative shock of 1 % of Chinese GDP results in an effect of -0.12–0 % of GDP for other countries. With the demand structure change, the effect is in the range of -0.49–0.01%. Our estimates are close to the typical range of 0 % to -0.6% reached in the previous literature. Several of our estimates fall at the lower end of this range, probably due to the fact that our framework is considers the trade channel only and not the commodity price and financial market channels that may also contribute additional effects. Our estimates for the demand rebalancing scenario are larger and more heterogeneous due to the higher import intensity of Chinese investment than consumption demand, as well as increased demand in certain consumer sectors due to the shift in the demand structure.

We next examined the effects of negative trade cost shocks with respect to the current US-China trade dispute. In the first scenario, we assume a 25 % tariff on all US goods imports from China. In the second scenario, we add corresponding retaliation measures by China on imports from the US. Our results for the second scenario suggest a negative impact of -1.02 % of GDP for China and a mere -0.12 % of GDP for the US, whereas the earlier estimates are in the range of 0.3–0.4 % for China's loss of GDP and a loss of between 0-0.3 % of GDP for the US. In sector terms, our results are quite well in line with the previous literature for the hardest hit sectors. In the Chinese side, they are manufacturing of miscellaneous products, electronics and textiles, while the largest losses for the US are experienced in transport equipment manufacturing and machinery. Our framework cannot, however, account for the longer term redistributive effects that lead to gains in some sectors in estimates presented in the previous literature.

Finally, focusing on the sector level, we examine the international effects of sector-specific demand and supply shocks originating in China. We find that, in general, the international impact of Chinese sector-specific shocks is relatively modest at the aggregate level for both shocks to final demand and supply. This reflects the fact that Chinese final demand (and increasingly production) mainly rely on domestic supply. There are, however, a few exceptions with larger effects. A 10 % negative shock to Chinese final demand of electronics results in an effect of -0.17 % of GDP for Korea and a corresponding shock to Chinese output of basic metals in an effect of -0.16 % for Australia. At the sector level, the effects are obviously also larger in other affected countries. Several Taiwanese and Korean industries suffer both in the case of demand and supply shocks. Manufacturing of medical products in Scandinavia and motor vehicle manufacturing in Slovakia are among the hardest hit sectors in the case of demand shocks and in the case of supply shocks Australian mining and Brazilian agriculture. Moreover, such shocks would probably also induce additional effects from commodity prices and financial markets that cannot be accounted for in our framework.

To conclude, our results suggest that most estimates calculated with a simple input-output framework are relatively close to those received from more elaborate models. The main advantages of the input-output framework are its simplicity and the fact that it permits examination of sector-level effects and network propagation of shocks more closely than in most other models, thus providing valuable complementary insights. In quantitative terms, our results show that shocks originating in China – even sector-specific shocks – can have important effects also for other countries through transmission in international production networks. These effects seem to be limited, despite China's emergence as one of the largest economies in the world. China still relies largely on domestic supply both for final demand and intermediate inputs. The effects can, however, be amplified through commodity price and financial market channels that cannot be accounted for in our framework. Thus, our results also provide support to the view that idiosyncratic shocks do not always average out at the aggregate level.

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