WP/19/214

IMF Working Paper

Macroeconomic Effects of Reforms on Three Diverse Oil Exporters: Russia, Saudi Arabia, and the UK

by Samya Beidas-Strom and Marco Lorusso

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INTERNATIONAL MONETARY FUND

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IMF Working Paper

Institute for Capacity Development

Macroeconomic Effects of Reforms on Three Diverse Oil Exporters: Russia, Saudi Arabia, and the UK

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Authorized for distribution by Valerie Cerra

October 2019

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Abstract

We build and estimate open economy two-bloc DSGE models to study the transmission and impact of shocks in Russia, Saudi Arabia and the United Kingdom. After accounting for country-specific fiscal and monetary sectors, we estimate their key policy and struc-tural parameters. Our findings suggest that not only has output responded differently to shocks due to differing levels of diversification and structural and policy settings, but also the responses to fiscal consolidation differ: Russia would benefit from a smaller state foot-print, while in Saudi Arabia, unless this is accompanied by structural reforms that remove rigidities, output would fall. We also find that lower oil prices need not be bad news given more oil-intensive production structures. However, lower oil prices have hurt these oil pro-ducers as their public finances depend heavily on oil, among other factors. Productivity gains accompanied by ambitious structural reforms, along with fiscal and monetary reforms could support these economies to achieve better outcomes when oil prices fall, including via diversifying exports.

Keywords: DSGE model, Economic diversification, Shocks and commodity exporters, Bayesian estimation, Fiscal policy, Inflation targeting, Managed float, Oil intensity.

JEL classification: C11, E31, E43, E62, F41, Q43.

We thank, without implication: Ryadh Alkhareif, Marco Arena, Nabil Ben Ltaifa, Andrew Berg, Hilde Bjørnland, Tim Callen, Valerie Cerra, Charis Christofides, Hamid Davoodi, Christopher Dunnett, Tim Gould, Mahnaz Hemmati, Ruy Lama, Jingzhou Meng, Anta Ndoye, Valerie Ramey, Ernesto Ramirez Rigo, Francesco Ravazzolo, James Roaf, Barbara Rossi, Slavi Trifonov Slavov, S. Hossein Samiei, Marzie Taheri Sanjani, Susan Yang, Felipe Zanna, and other seminar participants. Preliminary results of this paper were presented at the IMF Spring 2018 Meetings Analytical Corner (entitled: Are Low Oil Prices a Blessing in Disguise?) and the 27th Annual Symposium of the Society for Nonlinear Dynamics and Econometrics, Federal Reserve Bank of Dallas.

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1 Introduction

In the aftermath of the 2014 oil price collapse, oil exporters grappled with lower revenues and weaker growth. While Russia's economy recovered from the 2015-2016 recession, on the back of the authorities' effective policy response and higher oil prices, the medium-term outlook remains muted due to structural bottlenecks and the lingering impact of sanctions. The large footprint of the state, governance and institutional weaknesses, and insufficient infrastructure constitute structural reform priorities. Implementing reforms in these areas, as well as continued fiscal consolidation, would boost productivity and the supply of labour and capital to enhance medium-term growth (IMF, 2018b). The Saudi Arabian economy cushioned the impact of the oil price collapse initially by spending out of its accumulated wealth. It is now recovering, on the back of higher oil prices and has been implementing a wide range of reforms under Vision 2030 (IMF, 2018c).

The challenge for both Russia and Saudi Arabia is to ensure that sound macroeconomic policies continue to be implemented and structural policies that have led to resource misallocation are rebalanced to raise potential output while being mindful of equity considerations. For example, potential output would increase when capital and labour re-allocate from firms/sectors with low marginal products to those with high marginal products (Hsieh and Klenow, 2009). Moreover, the state could cut and/or reorient its spending to support research and development and nimble investments, among others, to induce positive productivity spillovers between the natural resource and non-resource sectors (Bjørnland and Thorsrud, 2016; Mazzucato and Semieniuk, 2018).

This is where our paper comes in. Our estimated DSGE models provide empirical evidence suggesting that in the United Kingdom (UK), and potentially in Russia and Saudi Arabia, the exploitation of natural resources can have substantial productivity spillovers to the other sectors of the economy inducing a sustained increase in medium-term GDP through the reallocation effects of input factors when combined with fiscal and monetary policy reforms.

Our paper sheds light on four central questions. Firstly, what drives output volatility in Russia and Saudi Arabia (relative to the UK, the latter being our benchmark economy)? Secondly, what would be the impact of a smaller state footprint on Russia and Saudi Arabia (benchmarked against the UK), given the structure and policy settings of their economies, and what kind of fiscal consolidation would work best? Thirdly, does the global shift away from fossil fuels necessarily bode ill for Russia and Saudi Arabia? Finally, what can policy makers in Russia and Saudi Arabia learn from the UK experience in early 1990's, following large scale deregulation and a decade of low oil prices, in terms of reforms and their sequencing that would raise productivity growth and diversifying exports?

To answer these four questions, we pose and then test four hypotheses. Firstly, is output volatility largely driven by oil demand and supply shocks in oil exporters? Secondly, does fiscal consolidation necessarily impact core macroeconomic variables adversely? Thirdly, does a global shift away from fossil fuels necessarily result in lower output growth in oil exporters? Fourthly, could fiscal consolidation and oil intensive production structures when combined with positive productivity gains improve the structure and performance of the economies of oil exporters?

We test these hypotheses using the following strategy. Firstly, we collect data and then build and estimate three DSGE models that are attentive to the fiscal and monetary regimes in each of our three economies, as well as to the fact that their economic structure is energy-rich and production of goods is energy-intense, among other structural characteristics. Secondly, we characterize key transmission channels that are at play to study responses to a reduced and rebalanced role of the state, productivity enhancing structural reforms, and other fiscal and monetary policy reforms (benchmarking them to the policies and structural features of the UK's economy). Finally, we run counterfactual analyses (i.e., what if scenarios) to assess the impact of combining and sequencing reforms.

Our paper suggests four main findings. Firstly, although in the short-run, reducing the role of the state through a government current-spending led consolidation typically hurts

the Russian and Saudi Arabian economies through both demand and supply channels, in Russia within a few quarters the effects of the latter largely dominate and result in a better allocation of resources via sustained higher marginal products of factors.[1] This stimulates private investment increasing output growth and employment over the medium-term. In Saudi Arabia, however, wage rigidities and price indexation together with the leading role of government current spending prevent a positive response. Similarly our results also suggest that only in Russia does a decrease in government investment have a positive impact on the economy over the medium-term, whereas in Saudi Arabia a government investment reduction can boost output only if it is accompanied by structural reforms which decrease wage rigidities and price indexation.[2]

Secondly, our results show that oil exporters, in particular Russia, can benefit temporarily from the global shift away from fossil fuels and lower oil prices due to their energy intensive production and consumption, with the lower oil price having similar effects to a positive supply shock that supports output. However, there is a major adverse effect: domestic public finances deteriorate due to lower government oil revenues and this results in a large and negative wealth or income effect.[3] These side effects can be managed through fiscal and monetary policy reforms. For example, the adoption of new tax measures (aimed at increasing and redistributing more equally the tax burden across all agents and sectors in the economy, and shifting it away from the narrow oil revenue collection currently in place) and monetary reforms if the structure of the economy has

[1]Our models assume both productive and unproductive government spending. Specifically, government consumption is considered unproductive, whereas government investment is productive. This is because, as in the standard DSGE literature, government consumption expenditures are thought of as "purchases thrown into the ocean" (see, among others, Ambler and Paquet, 1996 and Ambler et al., 2017). On the other hand, government investment enters directly into the production function of firms producing goods (see, for example, Asimakopoulos et al., 2016).

[2]Naturally, a reduction in the state's presence is not enough. For example, a level playing field with higher standards of governance, rule of law, and judicial institutions are needed to avoid a situation whereby the transition is simply from a high-state concentration to a private sector concentration (i.e., assets in a few private hands) without adequate incentives for profit-maximizing behaviour (i.e., risks to rent-seeking behaviour). The lack of such a level playing field and the materialization of some large risks have likely played a role in the performance of these economies but an analysis of these effects are beyond the scope of this paper.

[3]Indeed, this came to pass in both Russia and Saudi Arabia during the 2014-2015 oil price collapse.

been reformed (that allow the policy rate to focus solely on price stability) can reduce the negative income effect and debt accumulation at times of lower oil prices.

Thirdly, our analysis suggests that increases in productivity growth need to be accompanied by ambitious structural reforms aimed at removing labour market and nominal rigidities in both Russia and Saudi Arabia. This allows for a strong rise in employment as well as a trade balance improvement (including from the response of non-oil exports) inducing durable and large increases in the output of these countries.

Fourthly, in the case of Saudi Arabia, our analysis suggests that when considering reforms sequencing, it will be important to implement ambitious and durable structural reforms so that the economy can benefit from productivity gains – and on this basis consideration can thereafter be given to other reforms.

The rest of this paper is organized as follows. Section 2 gives a summary of how our paper fits in the literature. Section 3 presents basic stylised facts. Section 4 describes the theoretical model, the empirical strategy and the parameters estimation. Section 5 focuses on the main empirical results. Section 6 reports impulse response and counterfactual analyses. Section 7 concludes.

2 Relation to the literature

Our study is related to several branches of the literature. The first branch is the macroeconomic effects of oil price fluctuations. Most of the existing literature has focused on oil importer countries, such as the US prior to its recent oil production and refined oil exports surge.[4] The recent work by Bjørnland et al. (2018) analyses the role of oil price volatility in reducing the US macroeconomic instability and revisits the timing of the Great Moderation and the sources of changes in the volatility of macroeconomic variables.

[4]See, for example, Kim and Loungani (1992), Rotemberg and Woodford (1996), Finn (2000), Backus and Crucini (2000), Barsky and Kilian (2004); Carlstrom and Fuerst (2006), Kilian (2009), Baumeister and Kilian (2016).

There have also been cross-country studies on oil importers in advanced economies. Blanchard and Galí (2007) analyse a set of industrialized economies focusing on the differences between oil price shocks of the 1970's and those prior to 2014. They find the effects of oil price shocks to have changed over time due to: (a) the variation in real wage rigidities; (b) different monetary policies; (c) the decrease in the shares of oil production and consumption. Baumeister et al. (2010) find a smaller effect on Euro Area GDP of oil supply shocks than in the United States, although similar effects in the two areas from oil shocks driven by world activity (i.e., demand shocks).

Recent literature has also focused on oil exporter countries. Bergholt (2014) uses a general equilibrium model to analyse monetary policy for an oil exporter in a small open economy context. Snudden (2016) evaluates alternative forms of fiscal policy rules for both macroeconomic and welfare stabilization in oil-exporting economies, including OPEC oil specialists such as Saudi Arabia. Bergholt et al. (2017) develop and estimate a two-country New Keynesian model to quantify the importance of oil price shocks for Norway.

Only a few studies have analysed the UK macroeconomy and oil shocks. Harrison and Oomen (2010) investigate the effects of permanent energy price shocks for economies with declining stocks of natural resources, such as the UK. Millard (2011) considers a macroeconomic model which studies the effects of many temporary shocks, including energy prices, on inflation as well as how monetary policy can respond to such shocks. However, both these papers implicitly assume that the real oil price is exogenous with respect to macroeconomic fundamentals.[5] Lorusso and Pieroni (2018) assess the impact of different types of oil shocks on the main UK economic fundamentals.

In contrast to the above literature, Husain et al. (2015), IMF (2015), and Sommer et al. (2016), focus on commodity exporters in emerging and developing economies during commodity price swings, including the 2014 oil price collapse. They show how natural

[5]This assumption has been proven to be incorrect (Kilian, 2008; Byrne et al., 2018).

resource exporters faced an exceptionally challenging policy environment although some entered the period of lower oil prices from a position of strength having built up large financial buffers during the years of high oil prices. Along similar lines, our paper focuses on developing countries that are also oil exporters, namely Russia and Saudi Arabia, benchmarked against the UK.

A second branch of literature related to our paper concerns productivity spillovers between the resource-rich sector and the rest of the economy. Most of the previous analyses examining this issue have used structural vector autoregression (SVAR) models[6] or panel data,[7] finding that the effects of mining and petroleum investment on domestic output are small. However, the recent work by Bjørnland and Thorsrud (2016) shows that these studies have disregarded the cross-sectional co-movement of variables within a country. They estimate a Bayesian Dynamic Factor Model (BDFM) for Australia and Norway finding that a booming resource sector has substantial productivity spillovers on non-resource sectors, challenging the traditional literature on Dutch disease (e.g., Corden, 1984).[8] More specifically, in both Australia and Norway, productivity growth in the overall economy increases when the boom in the resource endogenous sector crowds-in productivity spillovers to the non-resource sectors. Moreover, they show that learning-by-doing spillovers between the traded and non-traded sectors strengthen this mechanism.

In this regard, one crucial aspect is the mobility of factors and how their misallocation (induced, for example, by price distortions, such as subsidies) can lead to distortions in the manufacturing sector. In this vein, our estimated DSGE models provide empirical evidence that in the UK (and potentially in Russia and Saudi Arabia) the exploitation of natural resources can have substantial productivity spillovers to the other sectors of the economy, inducing a sustained increase in medium-term GDP under certain assumptions and settings.

[6]See, for example, Hutchison (1994), Bjørnland (1998), Dungey et al. (2014).

[7]See, for instance, Ismail (2010).

[8]In this regard, Bjørnland and Thorsrud (2016) argue that the main limitation of the Dutch disease approach relates to the assumption of exogenous productivity, whereas they endogenize it.

The third branch of literature associated with our paper relates to DSGE models investigating endogenous oil price shocks. A careful analysis in this direction is offered by Bodenstein et al. (2008), and Nakov and Pescatori (2010). These two papers develop DSGE models with an endogenous real oil price, albeit without a global economic framework (i.e., without having a bloc to account for trade with the rest of the world). Moreover, Nakov and Pescatori (2010) ignore the many sources of possible shocks that affect oil price fluctuations. Our theoretical framework is in line with Bodenstein et al. (2011) and Bodenstein et al. (2012) in that it assumes an endogenous determination of the real oil price and employs modelling for the rest of the world economy data in a new Keynesian framework. From a theoretical point of view, our paper presents two main contributions with respect to these two papers. Firstly, we assume that domestic households and firms face several taxes that affect their respective behaviours. Secondly, we set up country-specific detailed fiscal sectors which include several policy rules for these (distortive) taxes.

3 Stylized facts

We start our analysis by providing three stylized facts that shed light on some of the key structural differences between the three economies under study.

Firstly, we focus on the level of diversification, by examining goods' exports as an indicator of diversification. Figure 1 reports the percentage shares of current gross exports disaggregated by product type for Russia, Saudi Arabia and the UK during 1995-2014. As expected, the UK goods' exports (bottom panel) are the most diversified among the three countries. On the other extreme, Saudi Arabian exports (middle panel) are dominated by oil and gas and, hence Saudi Arabia is the least diversified of the three economies.[9]

[9]Saudi Arabian goods' exports were almost exclusively driven by oil and gas. Indeed, during 2014 the share of exported oil and gas over total exports was 84%. Vision 2030 aims to diversify the economy and its exports.

Finally, Russia has an intermediate level of diversification (top panel), although the share of non-energy goods exports has been declining.[10] Therefore, we conclude that the size of the resource sector relative to the rest of the economy is very different in our three countries.

The second stylized fact relates to the transformation and smaller state footprint of the UK economy in the late 1980's and the shift in the exchange rate regime in the early 1990's, as there are strong parallels for both Russia and Saudi Arabia own transformations and state sizes. The smaller state footprint in the UK was achieved through a combination of tax cuts accompanied by reductions in public expenditures (Lawson, 1992).[11] This transformation coincided with the post-Gulf War fall in oil prices to a new low of about US$20 for the rest of the decade (Hamilton, 2009) and led to lower oil-related fiscal royalties and corporate taxes from oil companies, putting pressure on the UK's fiscal position. In addition, inflation had reached 9.5% in 1990, and so interest rates were raised (to 15%) and given the ERM (European Exchange Rate Mechanism) sterling depreciation was prevented.[12] A deep recession ensued and the stronger pound (due to the pegging of the ERM) made labour-intensive industries less competitive.

Financial markets picked up on the inconsistency in the UK's monetary policy and the weakening state of its economy and put pressure on the currency. After spending over £3 billion to defend the parity, the UK withdrew from the ERM (in 1992) and sterling depreciated sharply.[13] It seems it was just what manufacturing needed, coupled with low

[10] In 2014, oil and gas exports accounted for 69% of total exports.

[11] In the early 1980's and 1990's, much of the UK's industry was in the hands of the state, and industry was relatively heavy and oil intense. Bolick (1995) argues that during this period the greatest period of deregulation and transformation in modern British history took place, mainly through privatization of most of the national industries and deregulation of the utilities. However, this transformation and smaller state footprint resulted in rising unemployment in the 1980's, social unrest, and large regional disparities in the UK's value added that persist even today (Beidas-Strom, 2017).

[12] While seemingly unbelievable today, during the 1980s, discussions on Sterling's ERM entry, there were concerns that the currency could breach even the other permissible parity bands ($-/+$ 6 percent) as it was a "petrocurrency" (Connolly, 1995). Others have since used the term Petro-Pound in their analysis (Kelly, 2016).

[13] At around this period the far east, especially China, was opening and labour-intensive industries (e.g., mass clothing production) migrated from the UK and other countries to China.

oil prices, lower interest rates and of course productivity gains from a more competitive and deregulated economy with a smaller state footprint (Lamont, 1999), fueling a double-digit boom in UK manufacturing (Figure 2). Technology diffusion into manufacturing was partly aided by cheap oil and innovation, supported by UK and EU subsidies, and reforms that supported intellectual property rights.[14]

The UK's transformation has a direct corollary to needed transformations in the current Russian and Saudi Arabian economies. We have shown that the Russian and Saudi Arabian economies are less diverse than the UK's (Figure 1). However, what would happen if there was less direct government intervention in some sectors of the economy (IMF, 2012; IMF, 2018b), a weaker exchange rate, lower interest rates and oil prices, along with technology spillovers that lift output productivity; could these economies transform themselves? We will dissect this question and test it in Section 6.

The third stylized fact relates to the size and shape of fiscal and monetary policies in operation. Specifically, while fixed exchange rate regimes and large fiscal budgets (i.e., state dominance) may have desirable advantages in the short- and medium-term, they adversely impact resource allocation, competition, and the ability to withstand shocks in the long-run (IMF, 2012).[15] Table 1 reports the shares of government spending (on consumption and investment) in the economy for the three countries.

[14]During the late 1980's and mid-1990's, there was an increase in technology transfer, and licensing and patent activity. Technologies to detect cracks in the legs of North Sea oil platforms using innovative plastics were starting to diffuse into manufacturing via the introduction of polymers (made from cheap oil and gas). Examples include hospital mattresses, medical appliances, bio-tech and optical computers, electronics, and transport sectors, magnetic taping for credit cards, technology to capture pollutants such as sulphuric acid from UK power generation. Nevertheless, there was a much stronger under-current shaping the UK economy, with the onset of *Cool Britannia* in late 1997 onwards, and the creation of NESTA and other reforms that supported technology diffusion into the creative industries and services more broadly (and the UK became much less-oil intense in its production).

[15]The IMF's G20 2012 Los Cabos Summit Report (IMF, 2012) suggests that there are critical shortcomings in the business and investment environment in Russia; a reduction in implicit subsidies to energy or other factors is needed in Saudi Arabia; an improvement in governance, reduction in rent seeking and state dominance (including by deepening reform of state-owned enterprises) are needed in Russia; and continued reforms to address labour market shortcomings or ensure new labour reforms are designed or implemented in a market-friendly manner to avoid distortions and preserve competitiveness are needed in Saudi Arabia. In Russia, commitments appear focused on the labour market and unemployment, but improving the ailing investment climate is missing. For upside growth momentum product and labour market reforms to boost productivity are suggested for both Russia and Saudi Arabia.

In Russia, for the period 1996-2014, we estimate the average share of government consumption and investment to be 25% of GDP, although this is likely to be significantly underestimated.[16] Russia has the largest average government consumption expenditure among our three economies at 22% of GDP. During the same period, Saudi Arabia's state footprint (proxied in this paper as the average share of government spending on consumption and investment) corresponds to 26% of GDP, showing an increasing trend in both government consumption and investment over the sample period.[17] Finally, the state share is much lower and with no trend in the UK, at 21%, following the large deregulation of the 1980's-1990's and post crisis austerity.

The shape of the state's involvement among the three countries could not be more different. By and large the UK state has become a welfare state, taking care of basic education, health, the elderly and disadvantaged, seizing direct involvement in the economy, while regulating competition (unlike Russia and Saudi Arabia).[18] This change in the shape of the UK state and deregulation is widely considered to have played a key role in boosting productivity in the 1990's.[19]

Turning to tax policy, Table 2 reports the main tax rates of the three countries during 1995-2014. Recent developments in UK taxation have been in line with those of other advanced economies. In general, the tax system has redistributed significantly from the rich to the poor (Adam et al., 2010).

In Russia, the "Tax Code", introduced in 1999-2001, replaced numerous and diverse legal acts governing taxation and optimized the structure of taxes. Further improvement was introduced in 2008-2009, affecting income tax and social taxes and charges.

[16] IMF (2018b) reports that the Russian state's share in GDP is around 30-35% of GDP, having increased in the banking and oil and gas sectors during the last few years. Sectors where the state's share is high (e.g., oil and gas extraction, natural monopolies, among other) are more concentrated than others, but concentration is large even in sectors where the state's share is low. While this data is not yet readily available, it corroborates the findings reported in IMF (2012)) on the size of the state and the need for reforms.

[17] Clearly, also a lower bound given the larger size of the public sector.

[18] See, for example, IMF (2012).

[19] More recently, shortages in public infrastructure and housing investment spending appear evident in the UK, and the size of the state is toward the smaller end of OECD economies (Beidas-Strom, 2017).

From the point of view of intake during 1995-2014, the most important taxes are: taxes on the extraction of mineral resources, individual income tax, corporate profit tax and value added tax.[20] These taxes altogether account for nearly 80% of tax revenues of the "Consolidated Budget" (Pogorletskiy and Bashkirova, 2015).

In Saudi Arabia the development of the tax system has been largely shaped by the size of oil revenues available to the government. Up until the 2014 oil price collapse, abundant oil revenues (albeit with considerable volatility) led the government to favour promoting direct investment and attracting expatriate labour. Moreover, as of end 2014, personal income tax was absent and corporate taxes were reduced substantially during the 2000's to promote foreign direct investment (FDI). In the aftermath of the 2014 oil price collapse, attention has shifted to the development of the non-oil tax revenue system, but this period is not covered in our paper.

In terms of monetary policy, in the UK, following the ERM crisis of 1992, the Bank of England's Monetary Policy Committee (MPC) was given operational independence in May 1997 (Lamont, 1999; HM Treasury, 2013). This institutional arrangement helped improve credibility and accountability in the context of a floating exchange rate regime with inflation targeting.

The Central Bank of Russia (CBR) introduced an exchange rate corridor system in 1995. However, the government debt crisis of 1998 triggered a shift to a managed floating exchange rate regime. The exchange rate continued to be tightly managed through 2002-2005. In 2005, a dual-currency basket was implemented, again to smooth the volatility of the rouble's exchange rate vis-à-vis other major currencies (Figure 3, top panel). Further exchange rate flexibility continued, with intervention volumes steadily decreasing and a fully floating regime being introduced in the wake of the 2014 oil price collapse and adoption of headline inflation targeting (Figure 3, top panel).[21] These interventions

[20] Fuel excises revenues have been prevalent in Russia since 1994, albeit small averaging less than 0.5% of GDP during 1998-2014, and rising gradually in recent years. This data was not included in our study.

[21] For more details, see CBR (2013).

(before the floating system came into place at end 2014 and early 2015) are reflected in our modelling and estimation of the monetary authority's reaction function (Section 4.1.2).

In Saudi Arabia, monetary policy is carried out by the Saudi Arabian Monetary Authority (SAMA) as an agent of the Government (Al-Jasser and Banafe, 1999). Limitations to monetary policy, are due to the openness of the economy, with the riyal firmly pegged to the US dollar since 1986 (Alkhareif et al., 2017). From the bottom panel of Figure 3, we observe that, between mid-1990's and 2001, the real effective exchange rate appreciated sharply with the US dollar anchor, and in the absence of nominal adjustment, non-oil exports have lost competitiveness (Fasano and Iqbal, 2003). From 2001 until the GFC, the pegged regime facilitated international trade, investment and financial development (IMF, 2011). On other hand, given the fixed exchange rate, the steady increase in government spending put pressure on domestic inflation (IMF, 2011). Following the oil price collapse, pressure in forward foreign exchange markets built up, which quickly abated owing to the elevated level of foreign exchange reserves at SAMA's disposal (IMF, 2014).

In summary, the UK, Russia and Saudi Arabia have very different fiscal and monetary policies in place as of end 2014. Hence, our theoretical modelling, presented in the next section, aims to allow these differences to show up in the estimation.

4 DSGE modelling, data, empirical strategy and estimation

4.1 Modelling

In this section, we focus on our theoretical framework that is in line with Bodenstein et al. (2012). We consider three different models with two symmetric blocs to account for each country's trade pattern with the rest of the world economy: (i) the UK and the

rest of the world (RoW); (*ii*) Russia and RoW; (*iii*) Saudi Arabia and RoW. In what follows, for simplicity, we provide a general description of the UK model only, as the representative economy, while showing key differences for Saudi Arabia and Russia.[22]

Each model consists of a domestic and a foreign economy encompassing international trade in the oil and non-oil good markets.[23] As in Bodenstein et al. (2012), we assume that asset markets are complete at the country level, but incomplete internationally. In each bloc, the representative household maximizes its lifetime utility function by choosing purchases of consumption and investment goods, capital stock and next period's holdings of both domestic and foreign government bonds given its period-by-period budget constraint.

Moreover, we assume that the domestic fiscal authority absorbs part of the gross income of the representative household (by taxing it) to finance its expenditure, although this is clearly not the case in Saudi Arabia as it will be shown in the estimation section. We consider the following set of distortive taxes: (*i*) a consumption tax levied on consumption purchases (i.e., VAT), (*ii*) tax levied on labour income (i.e., income tax), (*iii*) a dividends tax (i.e., corporation tax), (*iv*) an additional pay-roll tax rate levied on representative household labour income (i.e., social security tax paid by households), (*v*) a tax on the oil endowment (i.e., petroleum revenue tax). Unlike the UK economy, the Russian tax system does not include a national contribution paid by households, whereas Saudi Arabia does not have labour income taxes. In all three models, the domestic representative household has monopoly power over wages that implies sticky nominal wages à la Calvo (1983). The labour market is much more complex in Saudi Arabia than presented here, but data to model this complexity are not available.[24]

[22]The full derivation of the model is shown in the online Appendix A.

[23]In line with the set-up of Backus and Crucini (2000).

[24]It can be characterized by three-tiers: low-skilled expatriates (largely from South Asia and the Middle East); low and high-skilled Saudi Arabia nationals; and high skilled expatriates (largely from the OECD and some Middle Eastern countries). The latter two tiers exhibit strong downward wage rigidity and thus set high reservation wages. However, the former is fully flexible and adjusts with real economy developments (IMF, 2018a). Sufficiently long quarterly data series of these wage variables are not available and hence are not modeled.

In each model, for both blocs, there are firms producing investment goods that operate under perfect competition. In particular, domestic and foreign investment goods are combined in order to obtain final investment goods. Similarly, final consumption goods are produced under perfect competition. The representative firm producing final consumption goods uses a nested constant elasticity of substitution production function. In particular, domestic and foreign intermediate consumption goods are combined in order to obtain non-oil consumption goods. Accordingly, final consumption goods are produced combining non-oil and oil consumption goods. For the UK economy, there is a tax on oil used for consumption goods (i.e., fuel duty). The tax on oil consumption is *de facto* absent in both Russia and Saudi Arabia for our period of study (i.e., until end 2014).[25] In all three models, each bloc produces a single final production good and a continuum of intermediate production goods. The production function for a typical intermediate production good firm is assumed to be a nested constant elasticity of substitution with four inputs: private capital, public capital, labour and oil.[26] In particular, labour, private and public capital are combined in order to obtain total value added.[27] In turn, the intermediate production good is produced combining the value-added input with the oil input. Moreover, as before, there is a domestic payroll tax rate levied on wage payments.[28] Intermediate production firms also set prices according to the Calvo (1983) model. An additional assumption concerning nominal rigidities is that we allow for partial indexation of both wages and prices to past inflation rates.

Finally, each model encompasses a rich stochastic structure. Indeed, we consider sixteen shocks driving the economy.[29]

[25] Our understanding is that, while there are now some excise taxes on fuel in Russia and Saudi Arabia, these are small and, thus, are considered absent for our period of estimation.

[26] See Section 1.1.11 of online Appendix A.

[27] As in Leeper et al. (2010b), we assume implementation delays for building up public capital.

[28] This is a social security tax paid by firms.

[29] More specifically, these shocks affect domestic and foreign productivity, domestic and foreign oil production, domestic and foreign oil intensities, domestic and foreign consumption preferences, domestic and foreign import preferences, a domestic investment specific technology, domestic price mark-up, domestic wage mark-up, domestic inflation target, domestic government consumption and investment expenditures.

4.1.1 Fiscal authority

For the benchmark model, the domestic fiscal authority's period-by-period budget constraint has the following form:

$$P^g_{1,t}G^d_{1,t} + P^{kg}_{1,t}I^{gd}_{1,t} + B_{1,t} = \tau^c_{1,t}P^c_{1,t}C_{1,t} + \left(\tau^l_{1,t} + \tau^{wh}_{1,t} + \tau^{wf}_{1,t}\right) W_{1,t}L_{1,t} + \tau^d_{1,t}D_{1,t} + \tau^{oc}_{1,t}P^o_{1,t}O^c_{1,t} + \tau^{yo}_{1,t}P^o_{1,t}Y^o_{1,t} + \left(R^b_{1,t}\right)^{-1} B_{1,t+1} \tag{1}$$

where $P^g_{1,t}$ indicates the price of government consumption goods, $G^d_{1,t}$ is government spending on consumption goods, $P^{kg}_{1,t}$ is the price of government investment goods, $I^{gd}_{1,t}$ denotes government spending on investment goods, $B_{1,t}$ is government debt and $R^b_{1,t}$ represents the gross nominal return on domestic government bonds. Moreover, $P^c_{1,t}C_{1,t}$ is government revenue from the consumption of private goods, $W_{1,t}L_{1,t}$ is labour income of households, $D_{1,t}$ represents the firms dividends, $P^o_{1,t}O^c_{1,t}$ denotes government revenues from the consumption of oil goods and $P^o_{1,t}Y^o_{1,t}$ is government revenues derived from oil production. In addition, $\tau^c_{1,t}$, $\tau^l_{1,t}$, $\tau^{wh}_{1,t}$, $\tau^{wf}_{1,t}$, $\tau^d_{1,t}$, τ^{oc}_t and τ^{yo}_t are VAT, income, households and firms social security, corporation, fuel duty and petroleum revenue taxes, respectively. We assume the following log-linearized expressions for the fiscal policy rules concerning the distortive taxes:

$$\hat{\tau}^c_{1,t} = \psi^{cc}_1 \hat{c}_{1,t} \tag{2}$$

$$\hat{\tau}^l_{1,t} = \psi^{ly}_1 \hat{y}^d_{1,t} + \psi^{lb}_1 \hat{b}_{1,t-4} \tag{3}$$

$$\hat{\tau}^{wh}_{1,t} = \psi^{whb}_1 \hat{b}_{1,t-4} \tag{4}$$

$$\hat{\tau}^{oc}_{1,t} = \psi^{ococ}_1 \hat{o}^c_{1,t} \tag{5}$$

$$\hat{\tau}^{wf}_{1,t} = \psi^{wfb}_1 \hat{b}_{1,t-4} \tag{6}$$

$$\hat{\tau}^d_{1,t} = \psi^{dd}_1 \hat{d}_{1,t} \tag{7}$$

$$\hat{\tau}^{yo}_{1,t} = \psi^{yopo}_1 \left[\frac{\hat{P}^o}{\hat{P}^{GDP}}\right]_{1,t} \tag{8}$$

where the small letters with the hats denote log-deviations of the variables from their respective steady states. Moreover, in line with Leeper et al. (2010a), we assume that

the coefficients linking taxes to the variables described below have positive values (i.e. $\psi_1^x \geq 0$ for $x = cc, ly, lb, wb, ococ, dd, yopo$).

The fiscal rule (2) implies that the consumption tax depends on total final consumption. In particular, the parameter ψ_1^{cc} indicates the response of the consumption tax rate to changes in the level of consumption, i.e., its elasticity.[30] As in Leeper et al. (2010a), the fiscal rule for the labour income tax, equation (3), allows for a response to the cyclical position of the economy and to changes in the level of government debt. Accordingly, the coefficients ψ_1^{ly} and ψ_1^{lb} denote the responses of the labour income tax rate to changes in each economy's GDP and government debt, respectively. More specifically, we assume that the labour income tax immediately responds to changes in domestic output, whereas it responds with a delay of one year to variations in government debt.[31]

The fiscal rules (4) and (5) imply that the social security tax paid by households and firms depends only on variations in the level of government debt. Thus, the parameter ψ_1^{wb} represents the response of the social security tax rate to the one-year lagged government debt.[32] As shown in equation (6), the fiscal rule for the corporation tax allows for a response to changes in domestic dividends. In particular, ψ_1^{dd} indicates the response of the corporation tax rate to changes in dividends of firms.[33] The fiscal rule (7) implies that the fuel duty tax depends on oil demand in the domestic country. More specifically, ψ_1^{ococ} denotes the response of the fuel duty tax rate to current changes in domestic oil demand.[34] Finally, as we can note from equation (8), the petroleum revenue tax varies according to the domestic oil price at time t. In particular, ψ_1^{yopo} represents the response

[30] This formulation is consistent with the definition of the consumption tax rate (see the online Appendix C).

[31] This choice is motivated by the fact that the estimated correlation between the UK income tax rate and the one year lagged government debt is higher than the correlation between the IT rate and the government debt both at time t.

[32] This decision is related to the fact that the correlation between the social security tax rate and the one year lagged government debt is higher than the contemporaneous correlation between the social security rate and the government debt.

[33] This assumption is in line with the definition of the corporation tax rate (see the online Appendix C).

[34] Our assumption is consistent with the definition of the fuel duty tax rate (see the online Appendix C). Note that total retail sales of automotive fuel are included in domestic oil demand.

of the petroleum revenue tax rate to variations in the real oil price.[35]

Next, we focus on the main differences from the benchmark UK model, as they pertain to each of the Russian and Saudi Arabian economies, unless already noted. The government budget constraint for the Russian economy does not include the social contributions tax paid by households nor the oil consumption tax:

$$P_{1,t}^{g}G_{1,t}^{d} + P_{1,t}^{kg}I_{1,t}^{gd} + B_{1,t} = \tau_{1,t}^{c}P_{1,t}^{c}C_{1,t} + \left(\tau_{1,t}^{l} + \tau_{1,t}^{wf}\right)W_{1,t}L_{1,t} + \tau_{1,t}^{d}D_{1,t} + \tau_{1,t}^{yo}P_{1,t}^{o}Y_{1,t}^{o} + \left(R_{1,t}^{b}\right)^{-1}B_{1,t+1} \tag{9}$$

Therefore, we have the following Russian fiscal rules:[36]

$$\hat{\tau}_{1,t}^{c} = \psi_{1}^{cc}\hat{c}_{1,t} \tag{10}$$

$$\hat{\tau}_{1,t}^{l} = \psi_{1}^{ly}\hat{y}_{1,t}^{d} + \psi_{1}^{lb}\hat{b}_{1,t-4} \tag{11}$$

$$\hat{\tau}_{1,t}^{wf} = \psi_{1}^{wfb}\hat{b}_{1,t-4} \tag{12}$$

$$\hat{\tau}_{1,t}^{d} = \psi_{1}^{dd}\hat{d}_{1,t} \tag{13}$$

$$\hat{\tau}_{1,t}^{yo} = \psi_{1}^{yopo}\left[\frac{\hat{P}^{o}}{\hat{P}^{GDP}}\right]_{1,t} \tag{14}$$

In the Saudi Arabian economy model, the domestic government budget constraint is given by:

$$P_{1,t}^{g}G_{1,t}^{d} + P_{1,t}^{kg}I_{1,t}^{gd} + B_{1,t} = \tau_{1,t}^{c}P_{1,t}^{c}C_{1,t} + \left(\tau_{1,t}^{wh} + \tau_{1,t}^{wf}\right)W_{1,t}L_{1,t} + \tau_{1,t}^{d}D_{1,t} + \tau_{1,t}^{yo}P_{1,t}^{o}Y_{1,t}^{o} + \left(R_{1,t}^{b}\right)^{-1}B_{1,t+1} \tag{15}$$

We note that labour income tax and oil consumption tax are absent in this economy, as was the case prior to end 2014. Accordingly, we have the following Saudi Arabian fiscal

[35] Our choice is motivated by the definition of the petroleum revenue tax rate (see the online Appendix C): the revenues from crude oil sales crucially depend on the *de facto* oil price, unlike the *de jure* fixed oil price in the budgets of Russia or Saudi Arabia.

[36] As in the UK model, for both the Russian and Saudi Arabian economy models, our assumed fiscal rules are based on economic intuition and the estimated correlations between several tax rates and their relative macroeconomic aggregates.

rules:

$$\hat{\tau}^{c}_{1,t} = \psi^{cc}_{1}\hat{c}_{1,t} \tag{16}$$

$$\hat{\tau}^{wh}_{1,t} = \psi^{whb}_{1}\hat{b}_{1,t-4} \tag{17}$$

$$\hat{\tau}^{wf}_{1,t} = \psi^{wfb}_{1}\hat{b}_{1,t-4} \tag{18}$$

$$\hat{\tau}^{d}_{1,t} = \psi^{dd}_{1}\hat{d}_{1,t} \tag{19}$$

$$\hat{\tau}^{yo}_{1,t} = \psi^{yopo}_{1}\left[\frac{\hat{P}^{o}}{\hat{P}^{GDP}}\right]_{1,t} \tag{20}$$

4.1.2 Monetary authority

We assume that in each model the central bank sets the nominal interest rate according to a monetary policy reaction function. In an inflation targeting regime, as in the UK case, we have the following relation:

$$i_{1,t} = \bar{\imath}_1 + \gamma^{i}_{1}\left(i_{1,t-1} - \bar{\imath}_1\right) + \tag{21}$$
$$\left(1-\gamma^{i}_{1}\right)\left[\left(\pi^{core}_{1,t} - \bar{\pi}^{core}_{1}\right) + \gamma^{\pi^{core}}_{1}\left(\pi^{core}_{1,t} - \bar{\pi}^{core}_{1} - \bar{\pi}^{core}_{1,t}\right) + \gamma^{y}_{1}y^{gap}_{1,t}\right]$$

This is a modified version of the so-called Taylor (1993) rule in which the central bank responds to the change in the past quarter nominal interest rate, core inflation[37] and the output gap (defined as the difference between actual and potential output). We denote the steady state values of the nominal interest rate and core inflation by $\bar{i}_1$ and $\bar{\pi}^{core}_{1}$, respectively. The parameter γ^{i}_{1} allows for interest rate smoothing, whereas γ^{y}_{1} and $\gamma^{\pi^{core}}_{1}$ indicate the reaction of the interest rate to the output gap and core inflation, respectively. In the Russian and Saudi Arabian models, we assume that the nominal interest rate is set to target the level of the relative exchange rate, as was the case prior to end 2014 in Russia and remains so for Saudi Arabia today, and to much lesser extent headline

[37] In our model, current core inflation depends on expected future inflation. See equations A(115) and A(177) in the online Appendix A.

inflation.[38] Therefore, we have the following monetary policy function:

$$i_{1,t} = \bar{i}_1 + \gamma_1^i \left(i_{1,t-1} - \bar{i}_1\right) + \left(1 - \gamma_1^i\right) \begin{bmatrix} \left(\pi_{1,t}^{head} - \bar{\pi}_1^{head}\right) + \\ \gamma_1^{\pi^{head}} \left(\pi_{1,t}^{head} - \bar{\pi}_1^{head} - \bar{\pi}_{1,t}^{head}\right) + \\ \gamma_1^y y_{1,t}^{gap} + \gamma_1^e \left(rer_{1,t} - rer_{1,t-1}\right) \end{bmatrix} \tag{22}$$

Where γ_1^e indicates the reaction of interest rate to relative exchange rate fluctuations and $\gamma_1^{\pi^{head}}$ denotes the reaction of the interest rate to headline inflation.

4.2 Data, estimation strategy and parameter estimation

4.2.1 Data

The three models are estimated at quarterly frequency over a sample from 1996:Q1 to 2014:Q4.[39] The length of the sample is governed by data availability for Saudi Arabia and Russia.[40] In each model, we use sixteen data series given the sixteen shocks introduced in the theoretical models. These are: domestic and foreign real GDP,[41] domestic and foreign crude oil production, real oil price, domestic real effective exchange rate, domestic private consumption expenditure, domestic private gross fixed capital formation, domestic oil imports,[42] domestic non-oil goods imports, domestic non-oil goods exports, domestic core inflation,[43] domestic wage inflation,[44] domestic nominal interest rate, domestic government debt and domestic government investment.[45]

[38] See Benes et al. (2015) for further details on other functional forms for managed floating regimes that allow for foreign exchange intervention to lean against the wind during episodes of exchange rate volatility.

[39] We use the period 1995:Q1-1995:Q4 as a pre-sample.

[40] The aim is to keep a homogenous sample across all three countries to compare estimated results.

[41] See the online Appendix B for how we obtained foreign real GDP using Loretan (2005) method applied to the main trading partners of the UK, Russia and Saudi Arabia.

[42] Instead of domestic oil imports, for Russia and Saudi Arabia we use domestic oil demand.

[43] Rather than domestic core inflation, for Russia and Saudi Arabia we use domestic headline inflation.

[44] See the online Appendix B for details on how we extended the short wage inflation data series for Russia and Saudi Arabia using the well-known Denton (1971) method of proportional benchmarking of frequency time series disaggregation.

[45] The data sources and the construction of all observed variables, including those where only annual data is available and how these were transformed into quarterly frequency using the Denton method (Di Fonzo and Marini, 2012), are reported in the online Appendix B.

4.2.2 Model parameters

In each model, we split the parameters into three different sets. The first set corresponds to values of a few parameters that are kept fixed in line with the literature or judgement/assumptions. The second set is constructed from the observed data. Finally, the third set of parameters is estimated with Bayesian methods.[46]

4.2.3 Fixed and calibrated parameters according to actual data

The parameters of the first group can be viewed as strict priors for the three models (Table 3). For the UK model, these values are set in line with the literature on advanced economies (e.g., Millard, 2011; Smets and Wouters, 2007; Bodenstein et al., 2012). However, for Russia and Saudi Arabia there are no antecedents, to the best of our knowledge. Hence, we rely on judgement and the findings of models estimated for other emerging and developing economies (e.g., Beidas-Strom and Poghosyan, 2011).

The first parameter of importance is the steady state of labour supply, which is higher in Russia and UK, relative to Saudi Arabia, proxied from data on hours worked. Accordingly, on average, the assumption is that Saudi Arabian households supply less labour and, thus, consume more leisure.[47] As we will describe below, this has important consequences for the marginal product of labour and aggregate wages. The second important difference relates to the parameter on bond intermediation costs. We assume that both Russia and Saudi Arabia face higher borrowing costs in international capital markets relative to the UK (Beidas-Strom and Poghosyan, 2011).[48] As we will show below, this also has relevant implications in terms of consumption smoothing. Thirdly, the UK has

[46] All estimates were made using Dynare (http://www.dynare.org/).

[47] As described in footnote 24, the labour market is segmented in Saudi Arabia, with low-skilled expatriate workers supplying the most hours worked.

[48] Following Turnovsky (1985) and Bodenstein et al. (2011), ϕ_1^b indicates the presence of an intermediation cost paid by households in the home country for purchases of foreign bonds. Therefore, it can be seen as a financial constraint related to domestic households. While Saudi Arabia's sovereign rating CDS and credit rating have been stable and in the upper quarter of investment grade spectrum, Waked (2016) shows that households and firms in this country face higher financial constraints compared to the UK, and World Bank (2018) suggests the same is also true in Russia.

the highest elasticity of substitution between capital and labour, implying a higher mobility of production factors across sectors. Lastly, the rate of depreciation of government capital and government implementation delays are assumed to be higher in Russia and Saudi Arabia than the UK (Berg et al., 2013; Berg et al., 2016), implying that realised government investment in Russia and Saudi Arabia occurs at a slower pace, adding to the capital stock more slowly than in the UK.[49]

The second set of parameters captures other data-driven salient structural and fiscal policy characteristics, and the results presented next are one of the contributions of our paper.[50] Focusing first on structural parameters of each economy (Table 4, top panel), we observe that Russia and Saudi Arabia are more capital intensive than the UK. Interestingly, this holds for both private and public capital. Turning to the weight of oil in production and consumption, both Saudi Arabia and Russia are more oil intense than the UK. Moreover, Saudi Arabia relies the most on imports of investment goods and, perhaps surprisingly, has a similar weight of imports in consumption as the UK. As expected, Russia and Saudi Arabia are more important oil producers than the UK, with world shares of oil production almost four times higher than the UK. Regarding fiscal sector parameters (Table 4, bottom panel), we set the steady state of public expenditures and tax rates according to their average values for the period 1995-2014.[51]

4.2.4 Endogenous parameters' priors and posteriors estimation

The endogenous parameters of the three models are estimated using Bayesian techniques. Table 5 shows the means and standard deviations of the prior distributions together with the means as well as the 5 and 95 percentiles of the posterior distributions obtained using

[49]Following Leeper et al. (2010b), we estimate our models assuming a fixed period of delay in realised government investment. More specifically, we assume that, in Russia and Saudi Arabia, such delay is two times longer than in the UK. For more details refer to online Appendix A.

[50]The parameters of the foreign blocs are constructed using the Loretan (2005) technique. See the online Appendices A and D for the derivation of composite parameters of the three models and their estimated values.

[51]The online Appendix C describes in detail the time series used to obtain the several tax rates for the UK, Russia and Saudi Arabia.

the Metropolis-Hastings algorithm.[52]

For the UK, priors are in line with those reported in the literature for advanced economies (Fuhrer, 2000; Millard, 2011; Smets and Wouters, 2007; Del Negro and Schorfheide, 2008; Leeper et al., 2010a). For Russia and Saudi Arabia, there have been no estimated DSGE models yet, hence this is another contribution of our paper and, as mentioned above, we rely on other emerging and developing economy estimates (e.g., Berg et al., 2013; Berg et al., 2016; Beidas-Strom and Poghosyan, 2011).

Following Pfeifer (2014), to estimate the three models, we detrend each variable using the HP filter with a smoothing parameter equal to 1,600, while we demean inflation rates and nominal interest rates.[53] As mentioned, the models are estimated with Bayesian methods. For the UK and Russian models, the acceptance rates correspond to 31%, whereas that of the Saudi Arabian model is 37%. To test the stability of the sample, we use the convergence diagnostic of Brooks and Gelman (1998) that compares the between and within moments of multiple chains for the three models.[54]

Regarding the identification of parameters in the three models, in the online Appendix G, we show that for most of the parameters, the prior probability density functions are wide, and the posterior distributions are different from the priors. Moreover, we conducted the test proposed by Iskrev (2010), which essentially checks the identification strength and sensitivity component of the parameters based on the Fischer information matrix and the moment information matrix normalized by either the parameter at the prior mean or by the standard deviation at the prior mean.[55] The results of this test for the three models show that the derivative of the vector of predicted autocovariogram of observables with respect to the vector of estimated parameters has full rank when we

[52] In the online Appendix F we report the figures for the priors and posteriors distributions for parameters of the three models.

[53] As noted by Leeper et al. (2010a), incorporating common stochastic trends into a model with fiscal policy is non-trivial since several fiscal variables appear to have their own trends which require adjustments.

[54] All diagnostic tests are shown in the online Appendix F.

[55] We report the results of this test in the online Appendix G. Further graphs about collinearity and identification pattern are available upon request.

evaluate it at the posterior mean estimate. This implies that the parameters of the three models are all identifiable in the neighbourhood of our estimates.

Focusing on structural parameters, for the UK we assume a higher value for the prior mean of the consumption habit coefficient than in Del Negro and Schorfheide (2008), to capture the UK's unbalanced growth path led by consumption (IMF, 2012). On the other hand, we assume that Saudi Arabia and (to a lesser extent) Russia have lower prior mean values compared to the UK, given their higher borrowing costs and assumption that there is a higher fraction of liquidity constrained households and, hence, consumption smoothing is more difficult relative to UK households. Our estimated results suggest that the posterior estimates for the three countries are well identified and show that Russia, perhaps surprisingly, has the highest value of consumption habit and this higher real rigidity could potentially dampen the response of private consumption in Russia to reforms (relative to Saudi Arabia and the UK), as will be shown in Section 6. For all three economies, we assume that investment adjustment costs are the same as in Del Negro and Schorfheide (2008). Although our posterior estimates exhibit large values for this real rigidity, the UK has the highest adjustment costs in investment, suggesting a potentially lower response of private investment to reforms (relative to Saudi Arabia and Russia), as will be shown in Section 6.

For the UK economy, the prior of the parameter determining the labour supply elasticity is in line with Bodenstein et al. (2012) but, for both Russia and Saudi Arabia, we assumed higher prior mean values for this parameter. Our assumption implies that Russian and Saudi Arabian households are lower-skilled in terms of labour and therefore their labour supply is relatively elastic. The estimated posteriors for these parameters are weakly identified and confirm that, in both Russia and Saudi Arabia, labour supply is more elastic than in the UK (in Section 6.4 we will show that, in Russia and Saudi Arabia, changes in hours worked are less persistent in response to shocks affecting the economy). In general, our posterior means are much higher than the ones found by previous literature (Harrison and Oomen, 2010; Millard, 2011). Indeed, our theoretical framework

implies additional channels that affect real wages relative to the standard small open economy models.[56]

In terms of nominal rigidities, for the UK, the priors of Calvo probabilities for wages and prices as well as indexation parameters for both wages and prices are in line with the ranges of values found by Del Negro and Schorfheide (2008). For both Russia and Saudi Arabia, we assume slightly higher prior means for Calvo price and wage probabilities than the UK. We also assume that the prior value for wage indexation is lower in Russia and Saudi Arabia than the UK, whereas the opposite assumption is made for the price indexation parameter.

Focusing on the estimated results, we observe much larger values for Calvo wage probabilities in Russia and Saudi Arabia than in the UK. This suggests that in Russia and Saudi Arabia, on average, wages are less likely to be renegotiated between quarters than in the UK. On the other hand, the estimated posteriors for Calvo price probabilities are similar in the three countries. Moreover, the estimated posteriors show similar values for wage indexation parameters in the three oil exporters. However, we find that prices are, on average, much more indexed in Russia and Saudi Arabia than in the UK. The latter could be due to the prevalence of administrated prices in the consumer price inflation basket in Russia and Saudi Arabia during the sample period and will have a bearing on the results shown in Section 6.

Turning to the price elasticity of oil demand, for the UK its prior mean value is broadly in line with empirical studies that have estimated this elasticity for the US economy,[57] and we assume that the same is true in Russia and Saudi Arabia absent any specific estimates. However, the posterior estimation does not support this view, with oil demand in Russia and Saudi Arabia doubly more price elastic than the UK (and suggesting that in the UK oil demand is relatively inelastic and, given a change in the oil price, the change in the

[56] As mentioned earlier, these models miss the variation stemming from the endogenous oil price and its impact on wages.

[57] See for example Kilian and Murphy (2014) and Bodenstein et al. (2012).

quantity of oil demanded by firms and households in Saudi Arabia and Russia is larger than that in the UK). These higher elasticities in Saudi and Russia have a bearing on tax incidence and imply that introducing an explicit oil consumption tax will not distort economic activity (as will be shown in Section 6). Moreover, for the UK, the prior mean for the elasticity of substitution between domestic and foreign non-oil goods is slightly higher than the estimated value of Hooper et al. (2000), while for Russia and Saudi Arabia they are lower, especially for Saudi Arabia whose consumption is as import-intensive as the UK (as shown in the top panel of Table 4).[58]

Turning to policy parameters, on the monetary side, for all the three countries, our assumed priors for the weight of inflation in the Taylor rules have higher means values than those for the output gaps.[59] In addition, the UK parameter for policy rate smoothing has a slightly higher prior mean value than the one of Smets and Wouters (2007). In contrast, for Russia and Saudi Arabia, we assume lower values for this parameter (relative to the UK), reflecting their central banks' ability to alter interest rates more frequently (due to imperfect asset substitution and more rigid exchange rate regimes). Moreover, for both Russia and Saudi Arabia, we assume the same priors for the response of the policy rate to exchange rate fluctuations given that both economies' monetary policy during our sample period was aimed at maintaining exchange rate stability, whether the level or its volatility (as shown in Figure 3).[60]

Our estimated results suggest that the UK policy rate is highly responsive to core inflation. Moreover, we find that, in Russia, the nominal interest rate is more responsive to headline inflation than in Saudi Arabia. On the other hand, our posterior estimates show a higher responsiveness of the policy rate to output changes in Russia, relative to Saudi Arabia and the UK. This is indicative of the multiplicity of monetary policy

[58] These estimated posteriors also confirm our rejection of the first hypothesis and our first stylized fact, as will be shown in Section 5.

[59] As we have shown in Section 4.1.2, the UK policy rate responds to core inflation whereas Russia and Saudi nominal interest rate respond to headline inflation.

[60] As shown in Section 4.1, this term in not modeled in the UK's monetary policy function, given its pure floating exchange rate regime during the sample period.

objectives in Russia prior to its adoption of inflation targeting (unlike the single objective of inflation targeting in the UK and that of exchange rate fixity in Saudi Arabia). In addition, the posterior means of the interest rate smoothing parameters imply that the nominal interest rate exhibits strong autocorrelation in the UK and Russia. In Section 6, we will demonstrate how these differences in the Taylor rules influence the responses of the three economies to exogenous shocks.

Continuing on policy parameters, in general, for all the three countries, the priors for the fiscal parameters concerning the distortive taxes are chosen to be fairly diffused and cover a large range of parameter values.[61] For the UK, the highest prior means correspond to the response of VAT to total consumption, the response of the labour income tax to output,[62] and the response of the fuel duty tax to oil demand, while the response of the social security tax to lagged government debt and that of the petroleum revenue tax to oil prices have low prior means. For both Russia and Saudi Arabia, we assume that the priors for all fiscal parameters have the same distribution with a mean of 0.90.[63]

Our estimated results show that, in the UK and Russia, there is a much stronger response of VAT to private consumption relative to Saudi Arabia, the latter having a general consumption tax with low intake (IMF, 2018c). Moreover, Russia and the UK show a similar procyclical response of labour income tax to domestic output, as would be expected, while this tax is absent in Saudi Arabia in our sample period. However, in Russia, the labour income tax responds more strongly to debt than in the UK, possibly reflective of the higher sovereign credit rating of the UK sovereign during the sample period.[64]

Interestingly, the response of households' social security tax to debt is stronger in

[61] In general, these assumed prior means are consistent with the estimated correlations between several rates and their relative taxable incomes as noted earlier.

[62] Note that our assumed prior mean value for this parameter is slightly higher than the one by Leeper et al. (2010a) for the US economy.

[63] The only exception is the response of the social security tax paid by households to lagged government debt.

[64] This rating was AAA until 2016.

Saudi Arabia than in the UK, and similarly, the responses of firms' social security taxes to debt in Russia and Saudi Arabia are higher than in the UK. These two results on social security tax possibly reflect funded precautionary savings typical of emerging market oil exporters (Bems and de Carvalho Filho, 2011). Our results also indicate that in Russia and Saudi Arabia corporate tax rates respond more strongly to variations in firms' dividends relative to the UK. As expected, we also observe a much stronger response of petroleum revenue taxes to oil price changes in Russia and Saudi Arabia compared to the UK, reflecting the relatively narrow tax base and its oil dependence. As will be shown in Section 6, these different posterior estimates of fiscal policy parameters induce contrasting responses among our three economies.

Finally, we estimated all the parameters of the shock processes.[65] Given our paper's four central questions, we focus on the estimates of the persistence of three shocks: government consumption, government investment and productivity.[66] The estimated results exhibit a larger persistence of productivity shocks in Saudi Arabia and UK compared to Russia. On the other hand, in Russia, both government consumption and investment shocks are more persistent than in Saudi Arabia and the UK.[67]

5 Estimated output volatility and diversification

In this section, we analyse the main drivers of output volatility in Russia, Saudi Arabia and the UK. Such analysis allows us to assess the level of diversification of these three economies indirectly, through the differing responses to past estimated shocks. In particular, we focus on the historical decomposition of output volatility for each of our three oil exporters for the period post the GFC.[68] Figure 4 shows the volatility of output (red

[65] We assumed Beta distributions for all the autoregressive coefficients and inverse Gamma distributions for standard errors of all exogenous shocks (see the online Appendix E, Tables A1 and A2).

[66] As we will see in Section 6, these persistences play an important role in terms of transmission mechanisms of the relative shocks.

[67] See Tables A1 and A2, in the online Appendix E for more details.

[68] In the online Appendix H, we report the historical decompositions for the full sample.

lines), and the main drivers of this volatility (coloured bars). The bottom panel shows the historical decomposition of the UK's output. We observe that the UK is a well-diversified economy not least since oil shocks are considerably less important and, as expected, when oil shocks occur, they broadly have a negative effect, since North Sea oil production has been falling since 2010.[69] Domestic productivity shocks are the key drivers of output volatility in the UK, as are foreign demand shocks, which have put downward pressure on GDP post GFC.

Figure 4's top panel shows the historical decomposition of Russian GDP. Prior to the oil price collapse and the Crimean War of 2014, output was slowing due to weak domestic and foreign confidence, reflected in low FDI (IMF, 2018b), with oil supply and demand attenuating. From 2014:Q1 onwards, sanctions and the oil price collapse led to a depreciation in the terms of trade (i.e., the real effective exchange rate) and, with preparations to shift monetary policy to inflation targeting, interest rates were hiked to cool spiking inflation, temporarily putting downward pressure on GDP.

Figure 4's central panel suggests that GDP in Saudi Arabia started contracting in 2012:Q4, led by negative domestic productivity (i.e., supply-related) shocks, with oil demand and supply attenuating. These roles reversed in 2014:Q3, and weak foreign demand pushed the economy back into recession.

As we can observe from Figure 4, the main drivers of output volatility in Saudi Arabia are oil shocks as well as domestic productivity shocks.[70] Russia's output is influenced by a larger variety of shocks than Saudi Arabia.[71] Clearly, the UK is the country that is affected by the greatest number of shocks. To sum up, the results shown in Figure 4 confirm the first stylized fact described above (Section 3) and effectively show different levels of shocks diversification among the three oil exporters.

[69] See, for example, statistics from IEA (2013) and Scottish Government (2017).

[70] Saudi Arabia acts as the lead spare capacity oil producer in OPEC, often adjusting its domestic oil supply to support orderly adjustment and pricing in the global oil market at times of stress.

[71] These are mainly oil, foreign productivity, domestic and foreign demand shocks.

6 Reforms and their macroeconomic effects

In the following sections, we present our simulated impulse response analysis conducted while setting the values of the estimated parameters equal to their mean estimates of the posterior distributions. However, to simplify the analysis and the comparison of the effects on our three oil exporters, we assume the same standard deviations for the chosen shocks.[72]

6.1 First reform: fiscal consolidation via public spending cuts

Next, we test our second hypothesis on the adverse impacts of fiscal consolidation. As of end 2014, fiscal consolidation was necessary in both Russia and Saudi Arabia despite its well-established adverse impacts on output.[73] Accordingly, the first question we answer is: could both Russia and Saudi Arabia make their states leaner through spending-led fiscal consolidation to promote a better allocation of resources broadly emulating the UK experience described in the second stylized fact above (Section 3), and achieving larger increases in GDP and employment over the medium-term, without hurting output too much in the short-term? To answer this question, we generate impulse response functions (IRFs) to assess the impact of a reduction in government spending. More specifically, we assume a 10% decrease in government consumption and investment in each oil exporter. Figures 5 and 6 show the simulated IRFs of the main macroeconomic aggregates.

Figures 5 shows that the Russian economy has the most persistent government consumption shock (as we mentioned in Section 4.2.4). On the other hand, this shock has the lowest persistence in the UK, implying that the overall effects will be short in their time duration.

[72] In the online Appendix I, we report the correspondent IRFs with a one-standard deviation of estimated shocks as well as the simulated impulse responses for the UK economy.

[73] IMF (2012) sheds light on the need for reducing the footprint of the state in both Russia and Saudi Arabia. For a detailed analysis see both the Russian Federation and Saudi Arabia's respective IMF Article IV staff reports over the past few years, including (IMF, 2018b; IMF, 2018c).

Focusing on Russia and Saudi Arabia, in the short-term (six to seven quarters), a fall in government consumption spending results in a lower actual output.[74] However, over the medium-term, actual output recovers fully, while potential output rises much more. The larger impact on Saudi Arabian potential output reflects large labour market rigidities (relative of the other two economies). In both Saudi Arabia and Russia, public debt falls, and in Russia, the trade balance improves on the back of higher fiscal savings. Following the negative shock to domestic government consumption spending, domestic goods are relatively less expensive than foreign goods,[75] inducing a real exchange rate depreciation.[76] These last two effects are weaker and negligible in Saudi Arabia.

Focusing on the Russian economy, we analyse the transmission channels of this shock. Figure 5 shows that the supply side of the economy plays a key role in boosting actual output. Marginal products of labour and oil increase substantially boosting manufacturing and services. The marginal product of government capital falls reflecting the time-to-build feature[77] but after ten quarters it turns positive and constantly increases. Hours worked start to increase two years after the shock occurs and, hence, labour supply increases. Moreover, the shock causes a stronger shift in labour demand compared to labour supply causing an increase in wage rates. This supply side channel is reinforced from the demand side: lower government spending induces higher private consumption and investment due to the reduction of the tax burden in present value terms. As a result, domestic absorption ticks up and lifts output over the medium-term.

In contrast, in Saudi Arabia, the marginal product of labour, hours worked, and wages increase only marginally due to labour market rigidities.[78] Similarly, the increases in

[74] A reduction in government consumption implies a decrease in the wage bill and other spending (such as subsidies). The tax side of fiscal consolidation is examined in Section 6.4.

[75] In our model, we define the real exchange rate as the price of the foreign consumption basket over the price of the domestic consumption basket in a common currency.

[76] Higher national saving induces an increase in the supply of domestic currency to be invested abroad. Such higher supply causes the real exchange rate to fall, that is domestic currency becomes less valuable.

[77] This may also be related to side effects from lower maintenance spending.

[78] For example, a distortionary high reservation wage curtails skilled employment in the private sector in Saudi Arabia as a result of generous public wage bill (IMF, 2018c). See footnotes 24 and 47.

marginal products of oil and government capital are negligible. Moreover, the increases in both private consumption and investment are less pronounced since government spending leads private sector activity. As a result, the increase in domestic absorption is less evident than in Russia and, hence, over the medium-term, Saudi Arabia's actual output improves less than in Russia.

These findings suggest that, particularly in Russia, there are important rewards from a cut in government consumption over the medium-term. As we will show in Section 6.4, in Saudi Arabia, actual output gains can only be realised if the cut is supported by structural reforms, that remove rigidities in the economy, and further fiscal policy reforms.

Next, we simulate a reduction in government investment (Figure 6). Our IRFs show that the government investment shock in Russia is only slightly more persistent than in Saudi Arabia (as mentioned in Section 4.2.4). The UK economy has a much lower estimated persistence for this shock and, as a consequence, the responses of all economic fundamentals to this shock are short-lived.

Focusing on Russia and Saudi Arabia, we observe that, as expected, in the short-run (between the first and tenth quarters), both economies experience a fall in actual output. Thereafter, only Russia experiences positive gains in both actual and potential output, while in Saudi Arabia actual output falls permanently albeit slightly (indicative of the strong complementarity between private and public investment). Interestingly, in the latter, potential output recovers several quarters after the shock occurs, confirming the presence of strong labour market as well as wage rigidities.

Why are the impacts of this shock so different between Saudi Arabia and Russia? To understand these results better, we turn next to the channels that have induced them.

Focusing on Russia, the supply side is the most important channel explaining the output increase. Marginal products of all factors rise steadily over the medium-term, albeit with some negative effects on private capital and oil in the first ten quarters. The marginal product of labour has a consistent positive response to the shock. Moreover,

the contribution to higher domestic absorption from increased private consumption and investment is particularly pronounced over the medium-term (with the short-term more sluggish due to consumption habit and investment adjustment costs, see Section 4.2.4). Hours worked increase given the higher labour supply. Since the shift in labour demand is larger than that of labour supply, aggregate wage increases. As expected, public debt falls in response to the shock. Moreover, the domestic fiscal contraction causes an improvement in the domestic trade balance and depreciates the domestic currency.

Turning to Saudi Arabia, the response of marginal products of labour and government capital are more muted than the responses in Russia, whereas the marginal product of private capital falls in the short-run and the marginal product of oil drops in the long-run. Hours worked decrease initially although wages remain stable (due to wage rigidities as discussed in Section 4.2.4). On the demand side, after a few quarters, there is a strong fall in private investment inducing a decrease in domestic absorption. Once again, these responses confirm, not only the leading role of government investment spending in Saudi Arabia, but also the strong rigidities and, hence, the inability of the private sector to respond as the public sector retrenches (unlike Russia). As a result, over the medium-term, actual output falls. Like Russia, government debt falls, the trade balance improves, and the real exchange rate depreciates.

These empirical results suggest that, in Russia, reforms that decrease government investment have a positive impact on the economy over the medium-term, indicative of crowding-out effects in Russia. For these to have a positive impact also in the short-term would require reforms that reduce real rigidities. In Saudi Arabia, the results are more ambiguous. Although potential output benefits from the reduction in public investment, actual output does not. As we will show in Section 6.4, in this country, structural reforms (similar to those underway in Vision 2030) aimed to lower nominal rigidities are needed to achieve gains in actual output.

6.2 Second reform: capitalising on oil intensive production and consumption goods

In recent years, many economies reduced their dependence on oil in both consumption and production (e.g., IEA, 2013; Baumeister and Peersman, 2013; Edelstein and Kilian, 2009; Herrera and Pesavento, 2009; Blanchard and Galí, 2007; Ramey and Vine, 2011). One would expect this shift away from fossil fuels (due to environmental concerns and households and firms' preferences) to have an overall negative impact on the wealth and income oil exporters as the softer demand exerts downward pressure on global oil prices, resulting in lower fiscal revenues. At the same time, Russia and Saudi Arabia are two oil exporting economies that are oil intensive in their consumption and production goods, and thus lower prices, inducing lower input costs for firms, could have similar effects to a positive supply shock. We, therefore, simulate a 1% shift away from oil by the RoW in each model (Figure 7).[79]

The estimated persistence of the foreign oil intensity shock is much stronger in Russia and UK models. This implies a strong fall in oil demand of the rest of the world (RoW) and a large drop in the real oil price in these two countries. As a consequence, we observe a large increase in oil demand in Russia and the UK. This is because households and firms in these countries benefit from the cheaper oil input. The increased use of the oil input in reaction to the lower oil price pushes down the marginal product of oil but exerts an upward pressure on the marginal products of the other input factors.[80] The increase in the current and future marginal product of private capital causes private investment to increase, mainly in Russia and the UK.

On the demand side, the response of private consumption shows different patterns in the three countries. In Saudi Arabia and Russia consumption increases, albeit with a lag

[79]Evidently, this is not a reform per se, but we are interested in understanding the consequences of lower oil prices on the production and consumption structures of these economies.

[80]Differently from Saudi Arabia and the UK, in Russia the marginal product of labour decreases after fifteen quarters the shock occurs. This drop is explained by the fall in hours worked.

in Russia given the higher estimated real rigidity on consumption. On the other hand, in the UK we observe a fall throughout all quarters. Domestic absorption increases putting pressure on domestic prices and, thus, inducing an appreciation in the real exchange rate, mainly in Russia and the UK.

In response to the shock, we observe an increase in the GDP, in particular in Russia and the UK. On the other hand, the fall in the oil price reduces government oil revenues. As a result, government debt expands. This last effect is more pronounced in Russia and Saudi Arabia because their fiscal sectors heavily rely on oil revenues.

Turning to the external sector, in Russia and, to lesser extent, in Saudi Arabia, the overall balance falls due to lower oil exports given lower global oil demand. In the UK, in the short-run, the increase in the non-oil trade balance offsets the fall in the oil balance and, therefore, the overall balance is almost unchanged. In Russia and the UK, the exchange rate appreciates because the improvement in the RoW oil intensity implies that foreign goods are relatively cheaper than domestic goods and due to the boom in domestic absorptions of these countries.

Therefore, we have tested our third hypothesis and found that the gradual global shift away from fossil fuels can induce output gains in Russia and, to a lesser extent, in Saudi Arabia but lower oil prices mean lower oil revenues and have negative effects on the public finances of these two countries. In Section 6.4, we are going to show that further monetary and policy reforms, in both countries, can attenuate this side effect.

6.3 Third reform: actions to enhance productivity

In this section, we simulate IRFs to test our fourth hypothesis to answer this question: what would happen if Russia and Saudi Arabia were able to lift output productivity? As mentioned in Section 2, during the 1990's, in the UK there were productivity gains

from technological spillovers across sectors.[81] In this vein, we simulate a small aggregate productivity gain of 1%. Figure 8 shows that the persistence of the shock in Saudi Arabia and the UK is higher than in Russia (as we mentioned in Section 4.2.4). In all the three countries, a 1% improvement in productivity results in an increase of both actual and potential output[82] whereas government debt decreases.

Focusing on the transmission channels of the shock, the increase in GDP is primarily driven by more productive inputs and by the positive response of domestic absorption. The response of hours worked to this shock differs among countries. While, in Russia and Saudi Arabia, hours worked fall on impact, in the UK hours worked increase. However, in all the countries, the aggregate wage tends to increase in the long-run. As expected, in all the three countries, the real exchange depreciates because the positive productivity shock induces a fall in the price of domestic goods with respect to imported goods. The trade balance improves on impact but, surprisingly, in Russia and Saudi Arabia, it turns negative in the medium-term. Considering the high level of trade openness implied by the large value of the estimated trade elasticity in these countries[83] and, assuming that their volume of imports remains almost unchanged in the medium term, more expensive goods in the RoW imply that the value of imports increases more than the value of exports in these oil exporters. Accordingly, in the medium-run their total trade balance turns negative.

Overall, our results suggest that, in both Russia and Saudi Arabia and (even the UK), productivity gains that induce technological improvements do induce durable and large gains in both actual and potential output. In the next section, we are going to show that, with the reduction of nominal rigidities (achieved via ambitious structural reforms), output, in both Russia and Saudi Arabia, rises significantly more.

[81] Berry and Hay (2016) argue that "the public good at the heart of the UK government's industrial policy is essentially about productivity... and after the 2008 crisis, [calls for] a new industrial policy like that of the mid 1990's has been a recurring theme in Britain."

[82] Over seven years, the cumulative increase in GDP corresponds to 7.5% in Russia and 9.5% in Saudi Arabia

[83] This implies a relevant degree of substitutability between domestic and foreign goods.

6.4 Counterfactual analysis: further structural and policy reforms

Next, we provide a counterfactual analysis to further shed light on the transmission channels of the shocks analysed in the previous section.[84] This analysis also allows us to identify other reforms that could be undertaken, particularly in Russia and Saudi Arabia, to enhance their diversification and lift their GDPs. We start by considering some additional structural, fiscal (i.e., tax) and monetary (i.e., exchange rate) policy reforms that could be developed in combination with the spending-led fiscal consolidation mentioned earlier.

In the first experiment, we answer the following question: what if the mean values of fiscal and monetary policy parameters of Saudi Arabia and Russia were aligned to those of the UK benchmark, while the means of all structural parameters are kept as estimated and there is a 10% reduction in current government spending, would the results shown in Figure 5 change?

In both Russia and Saudi Arabia, this implies the introduction of the same broad-based tax system (capitalising on the higher price elasticity of oil demand, for example, and thus the introduction of a fuel tax similar to the UK) with identical rates, and the adoption of the same monetary policy rule (i.e., identical Taylor rule with a floating exchange rate regime) as in the UK.[85] Figure 9 shows the simulated IRFs of key macroeconomic variables comparing the benchmark case (black line), i.e., without fiscal and monetary policy reforms, with the counterfactual case (blue line), i.e., with the introduction of fiscal and monetary policy reforms.

Although, in Russia, we do not observe large improvements following the introduc-

[84] Our strategy is in line with Galí et al. (2007). More specifically, these authors compare the dynamic responses of some key variables in their baseline model to those generated by alternative calibrations that can be interpreted as structural and policy reforms.

[85] In this experiment, we assume that Russia introduces a social security tax paid by households and a tax on oil consumption, while Saudi Arabia introduces an income tax and a tax on oil consumption. Both countries adopt a Taylor rule targeting inflation, giving a higher weight to inflation than output changes as well as the nominal interest rate not being dependent on the exchange rate.

tion of fiscal and monetary reforms (perhaps as the data already reflect the shift to a floating exchange rate regime and fiscal elasticities are smaller), in Saudi Arabia there are considerable benefits from these measures. In particular, the new tax system induces a more balanced redistribution of the tax burden across consumers and investors in the economy (via the introduction of taxes on fuel consumed of households but more importantly by firms and labour income taxes), leading to a positive response of actual GDP to the cut in government spending. Such an expansion in actual output is due to a substantial increase in investment-led domestic absorption as well as to the improved marginal products all factors (except labour). Moreover, we note that the introduction of labour income tax induces an increase in hours worked.[86] Turning to monetary policy, the flexible exchange rate depreciates much less than the pegged one and this, in turn, induces a smaller adjustment in the trade balance, although the non-oil trade balance is left unchanged. In other words, the move to a floating exchange rate does not induce an improvement in the trade balance (including no change to non-oil exports); indeed the improvement is largely the result of the fiscal policy reforms.[87]

Therefore, our findings indicate that, in Saudi Arabia, a reduction in government consumption together with new tax measures (aimed at increasing and redistributing more equally the tax burden across all agents and sectors in the economy) is central to achieving the large medium-terms gains reported in this experiment and reversing the adverse impact of fiscal consolidation on the economy.

Our second experiment answers the following question: what if structural reforms were undertaken in combination with the 10% reduction in government investment in both Russia and Saudi Arabia that we showed earlier?

The impulse response analysis aligns the structural parameters of Russia and Saudi Arabia to the UK benchmark, but keeps fiscal and monetary policy settings as they are

[86]The mechanism is as follows: given a certain level of net wages, an increase in the labour tax induces an increase in hours worked by households since consumption smoothing necessitates and thus implies a similar level of disposable income.

[87]See online Appendix J to corroborate these results.

in the estimated model.[88] Figure 10 shows the responses of the main Russian and Saudi Arabian macroeconomic aggregates, once again, with the benchmark case shown in black (without the introduction of structural reforms) and the counterfactual case shown in blue (with the introduction of structural reforms).

Focusing on Russia, the adoption of structural reforms has ambiguous effects. In the short-run, the economy benefits from these measures, but in the long-term the performance of all macroeconomic aggregates deteriorates. This could be explained as follows: Russia's public know how is impressive, indeed state of the art in some sectors. However, there is arguably too much direct state involvement in the production of goods and services, including monopolistic behaviour, and yet still large infrastructural needs (e.g., roads, airports, ports).[89] Accordingly, reorienting and pruning public investment rather than cutting it would be necessary to ensure the impact of structural reforms is durable in the long-term.

On the other hand, a change in the structural parameters of the Saudi Arabian economy leads to the enhancement of its economic fundamentals. Comparing the benchmark results with those obtained from introducing structural reforms, it becomes evident that the Saudi Arabian economy benefits from the reduction of labour market rigidities and price indexation. Therefore, in the counterfactual case (in contrast to the benchmark results) actual GDP does not fall in response to a cut in government investment. Such a fall is avoided due to improvements in both the demand and supply sides of the economy. On the demand side, domestic absorption increases on impact and remains positive in the long-run (unlike the benchmark case where it drops one year after the shock). On the supply side, the marginal products of both private capital and oil do not fall in response to the shock (unlike the benchmark case). In terms of trade, the balance increases

[88] In this experiment we assume that, in both Russia and Saudi Arabia, the following parameters have the same values as in the UK: government capital depreciation rate, government investment implementation delay, labour steady state, elasticity of substitution between capital and labour, consumption habit persistence, private investment adjustment cost, labour supply elasticity, Calvo prices and wages probabilities, degree of indexation of both prices and wages.

[89] See, for example, IMF (2018b).

less than in the benchmark case whereas the real exchange rate depreciates for a longer period.

In general, these results confirm that the impressive public investment laid in Saudi Arabia now could be pruned if combined with structural reforms that invigorate the labour market and reduce nominal rigidities. Such reforms help innovative technology processes to diffuse into the economy and create incentives for a much larger role for the private sector, which has so far played a more limited approach and been heavily reliant on government spending.

The last experiment answers the following question: what if structural reforms (like those envisaged in Saudi Arabia's Vision 2030) are combined with productivity gains? Thus, we next focus on a positive productivity shock assuming both economies structural parameters are as those values as the UK's, whereas the policy parameters are set at their original estimated values. Figure 11 shows the results of this experiment, once again with the IRFs of the benchmark case in black (without structural reforms) and the counterfactual in blue (with structural reforms) in the presence of 1% increase in productivity.

As shown, the adoption of structural reforms leads to a stronger increase in actual output compared to the benchmark case in both economies. In Saudi Arabia, the gain is due to a stronger rise in the marginal product of labour, as a result of the structural reforms and productivity gains, and a larger expansion in domestic absorption, both investment and consumption given higher wages. The reforms lower real domestic prices relative to foreign ones and the trade balance (including non-oil exports) improves appreciably. In Russia, the higher increase in actual GDP is linked to the external sector, since the trade balance improves sharply owing to the stronger productivity being reflected in (the flexible) exchange rate dynamics.

These findings show that both Russia and Saudi Arabia could experience durable and large gains in actual output if wage rigidities as well as price indexation were reduced. This would allow their product markets to function properly, with ample technology

diffusion, assuming confidence, stability and free movement of trade as well as financial flows. In addition, in the case of Saudi Arabia, it suggests that structural reforms are a necessary pre-requisite when it comes to sequencing reforms.

7 Conclusion

In this paper we have shed light on the shape and diversification levels of three oil exporters: Russia, Saudi Arabia and the UK. We have reviewed the UK's economic transformation from an oil exporter with a strong state footprint and we have employed this experience to benchmark the structural and policy settings of Russia and Saudi Arabia, estimating pertinent parameters of the latter two economies for the first time. We then used these estimates to examine the impact of spending-led fiscal consolidation and lower oil prices induced by the global shift away from fossil fuels. Thereafter, we carried out counterfactual analyses to ascertain options for reforms and their sequencing.

We have four major findings. Firstly, as expected, fiscal consolidation adversely impacts the Russian and Saudi Arabian economy in the short-run. However, in the medium term, a better allocation of resources via sustained higher marginal products of factors of production increases output and employment in Russia. In Saudi Arabia, gains can only be achieved if the reduction in government spending is simultaneously accompanied by tax reforms aimed at a more balanced distribution of the tax burden across agents and sectors and structural reforms which decrease nominal rigidities. Secondly, since both Russia and Saudi Arabia have oil intensive domestic production and consumption structures, lower oil prices represent a positive supply shock and can induce an increase in output, if these oil economies are diversified, as is the case in Russia. However, lower oil prices decrease government oil revenues negatively affecting public finances in both Russia and Saudi Arabia. Thirdly, our analysis suggests that increases in productivity growth need to be accompanied by ambitious structural reforms aimed at removing labour market and nominal rigidities in both Russia and Saudi Arabia. This allows for

a strong rise in employment as well as a trade balance improvement inducing a much larger increase in the output of these countries. Fourthly, in the case of Saudi Arabia, our analysis suggests that when considering reforms sequencing, it will be important to implement ambitious and durable structural reforms, so that the private sector can benefit from productivity gains and the economy can diversify and on this basis consideration can thereafter be given to other reforms.

In Saudi Arabia, the reform momentum under Vision 2030 is strong and covers a wide range of measures (e.g., tax and subsidy reforms, raising female labour participation and other labour market and employment reforms, measures to remove other obstacles to private sector growth and non-exports, including domestic capital market development). The Vision Realization Programs are rolling out these reforms. In Russia, the liberalization of the exchange rate and implementation of inflation targeting in early 2015 have served the country well in the face of the oil price shock and other reforms appear to be moving ahead. In both countries, these reforms will surely have a durable impact on the economy over the medium term, however their effects are outside of the sample period covered in our analysis. Having said that, if these reforms are implemented, our analysis suggests that this would be an important step to further diversify their economic structures and realise these economies full potential.

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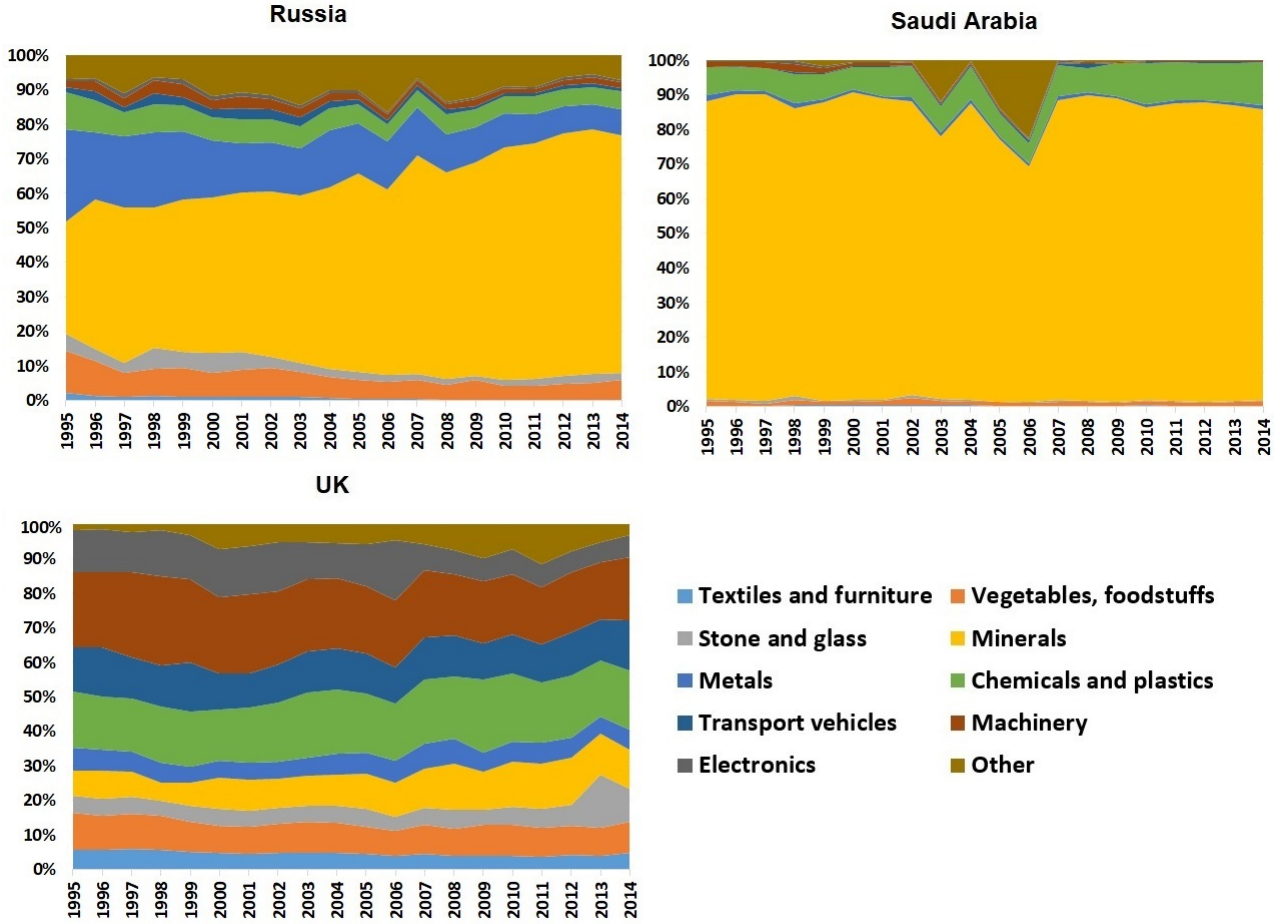
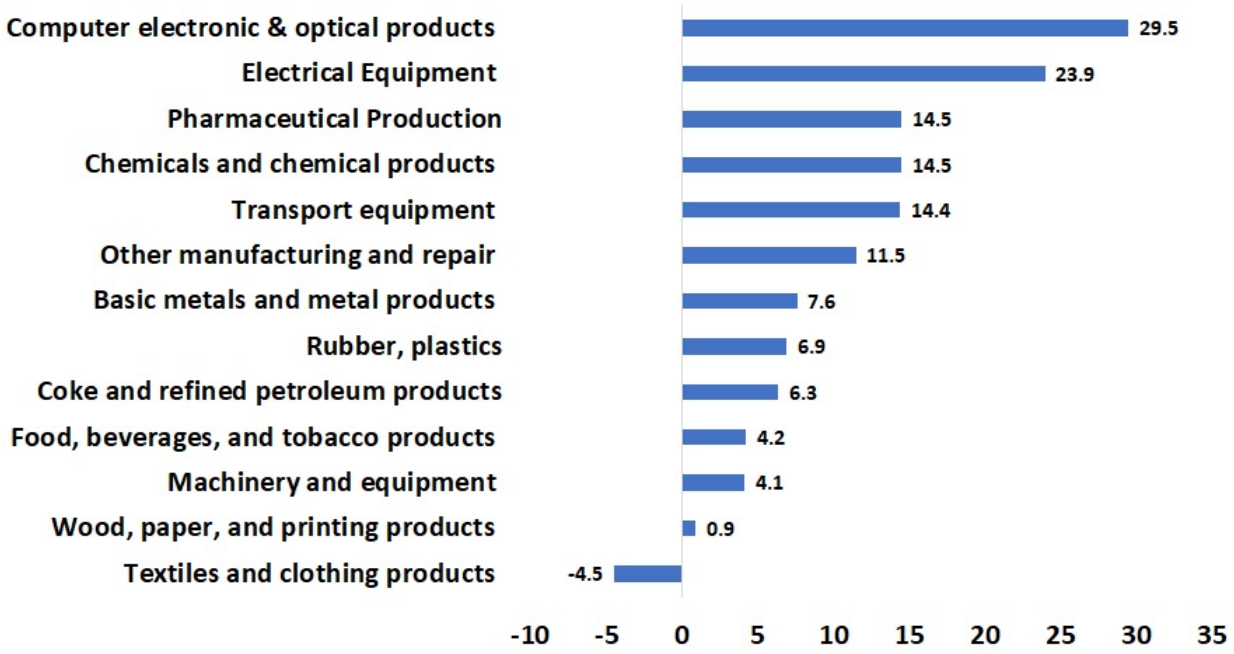
9 Figures

Figure 1: Good exports by type



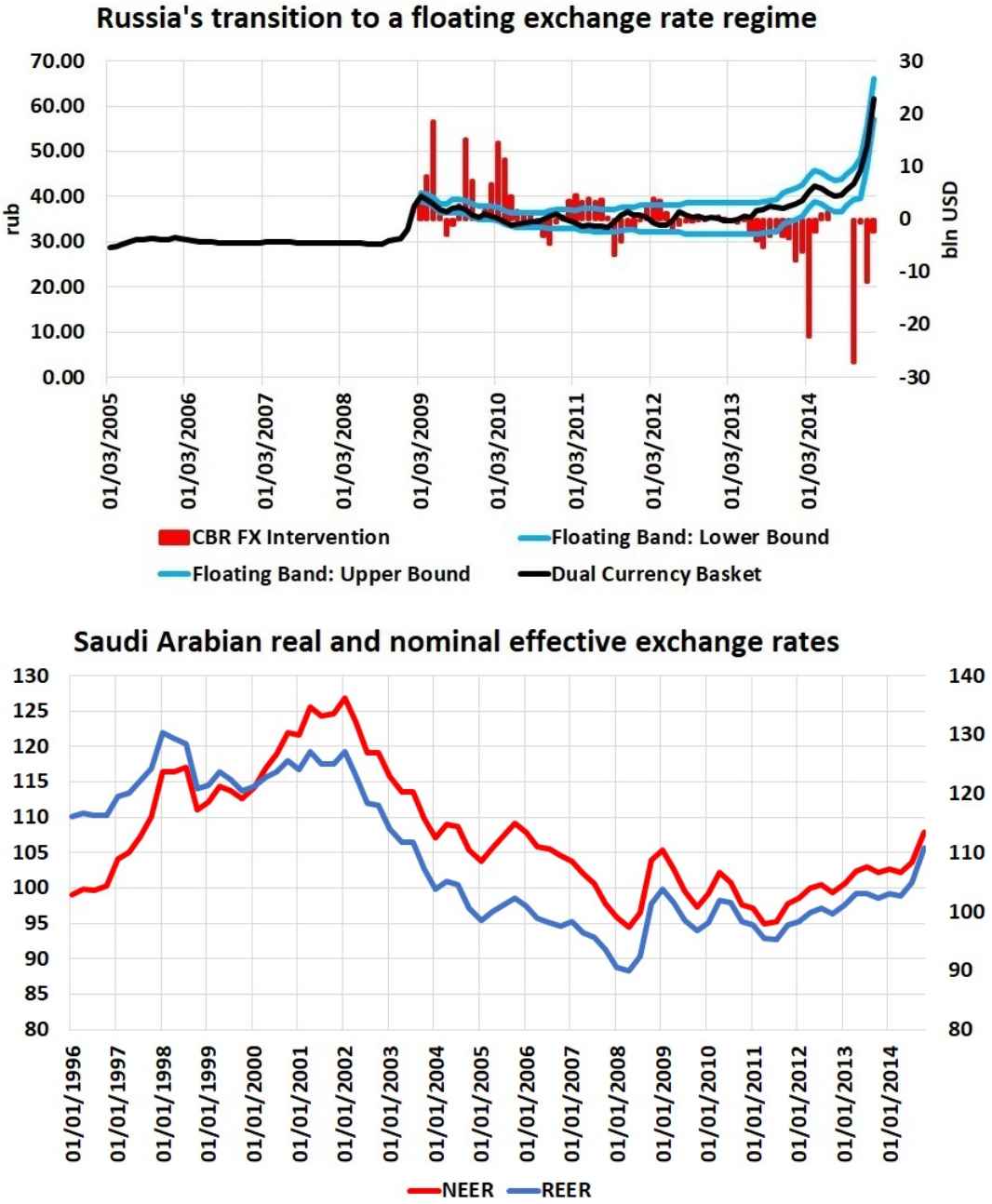
Source: United Nations Comtrade database and authors' estimates.

Figure 2: Percentage cumulative growth by UK manufacturing sectors, 1993-1997



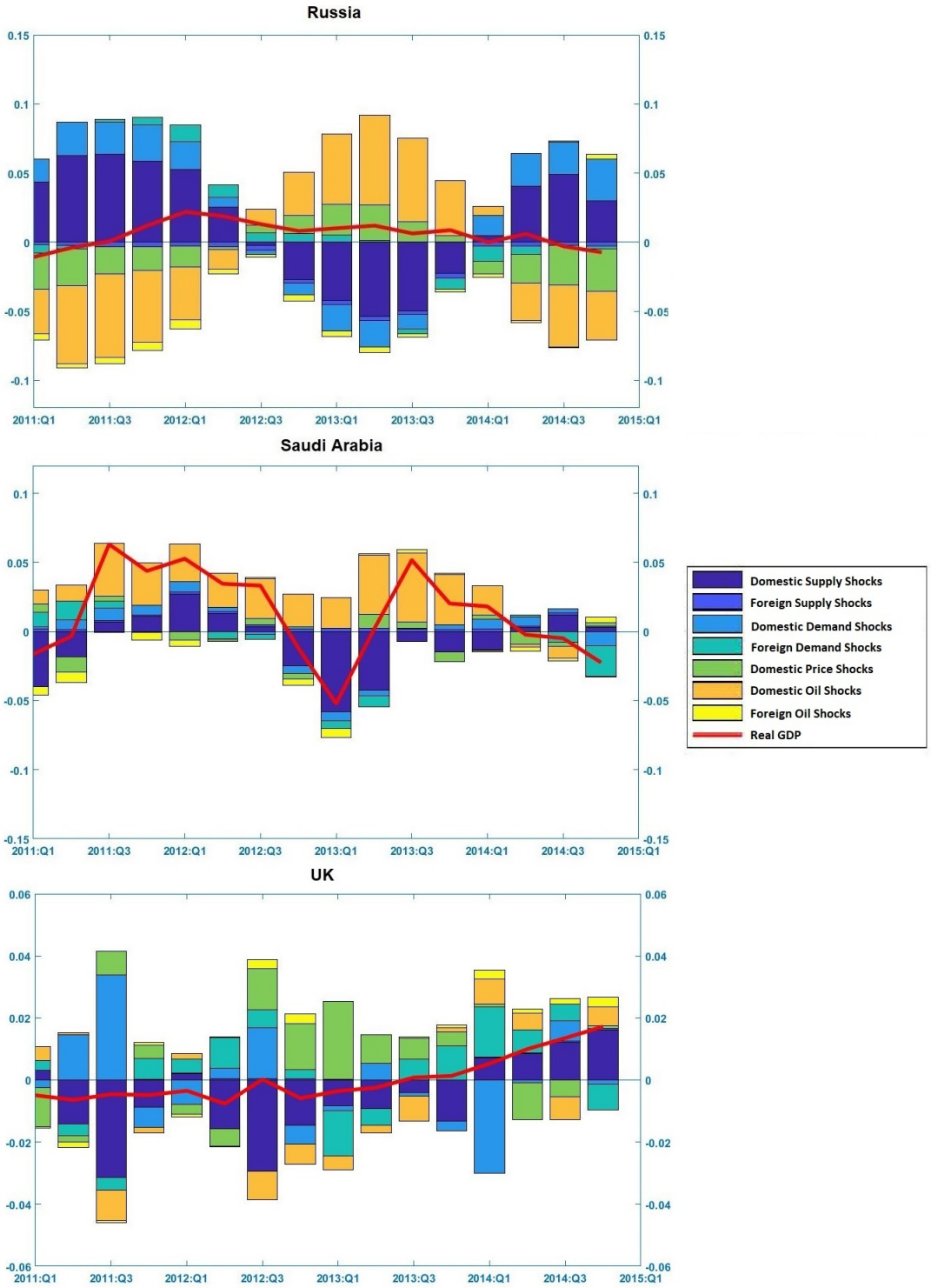
Sources: UK ONS and authors' estimates.

Figure 3: Recent developments in Russia and Saudi Arabia's exchange rates



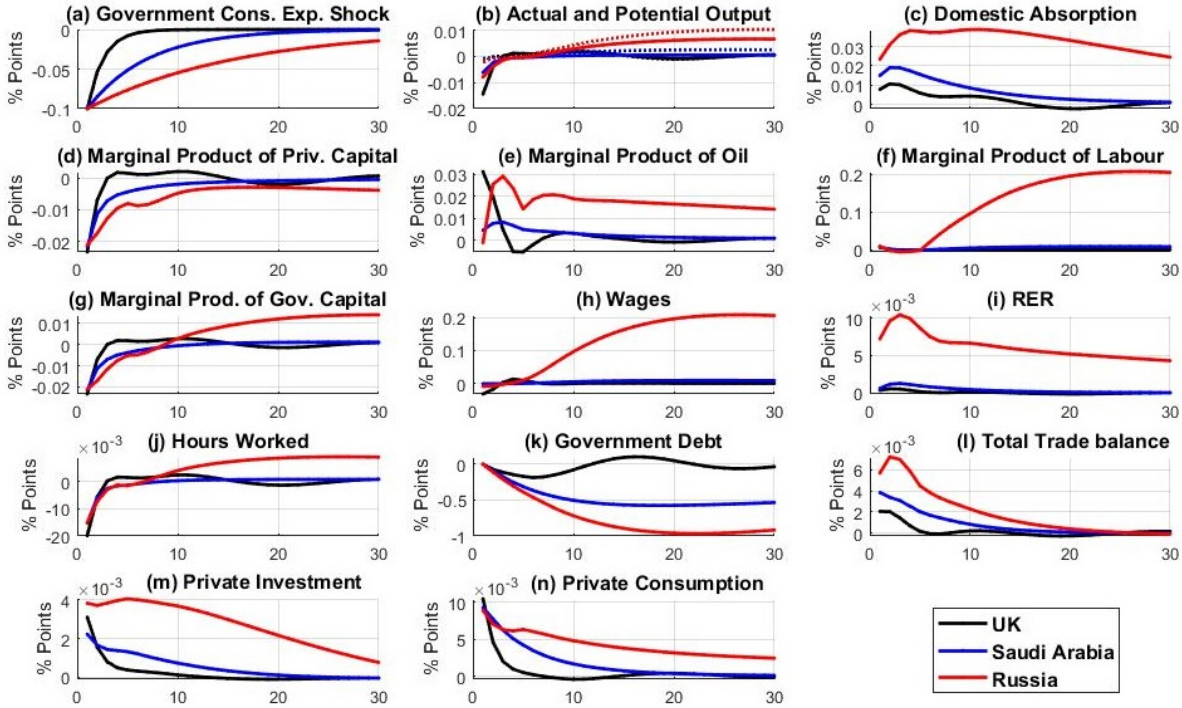
Notes: Top panel has been obtained from Central Bank of Russia (CBR) data and authors' estimates. The dual currency basket consists of US dollar and Euro. CBR FX Interventions correspond to the Bank of Russia US dollar operations, total amount of net purchases in USD billion. Bottom panel: the source is the International Financial Statistics (IMF).

Figure 4: Historical decompositions of GDP



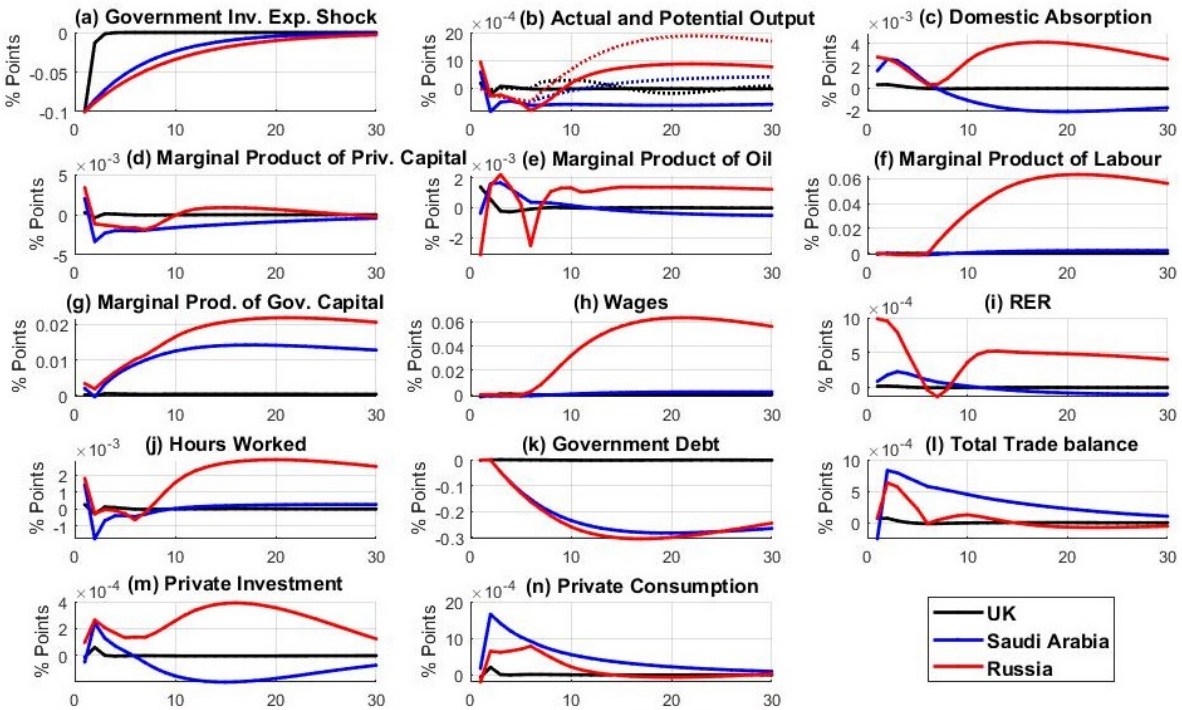
Notes: Authors' estimates from the three DSGE models.

Figure 5: A government current-spending led consolidation



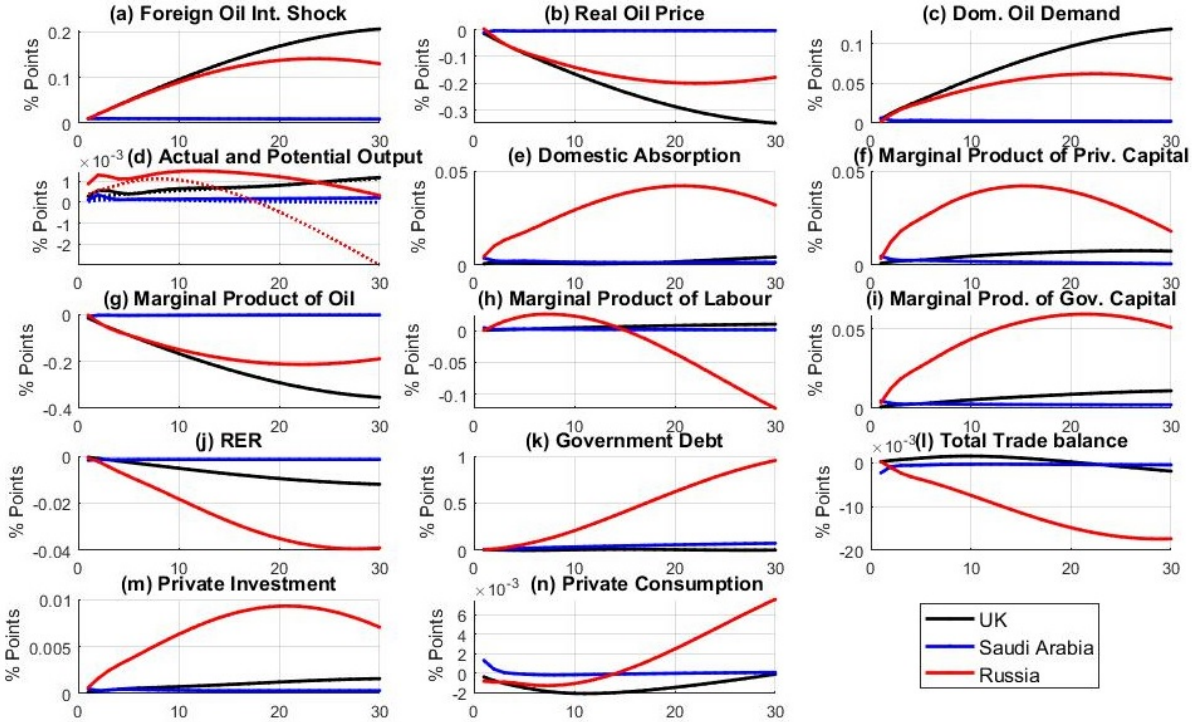
Notes: Simulated 10% reduction in government consumption spending.

Figure 6: A government investment-led consolidation



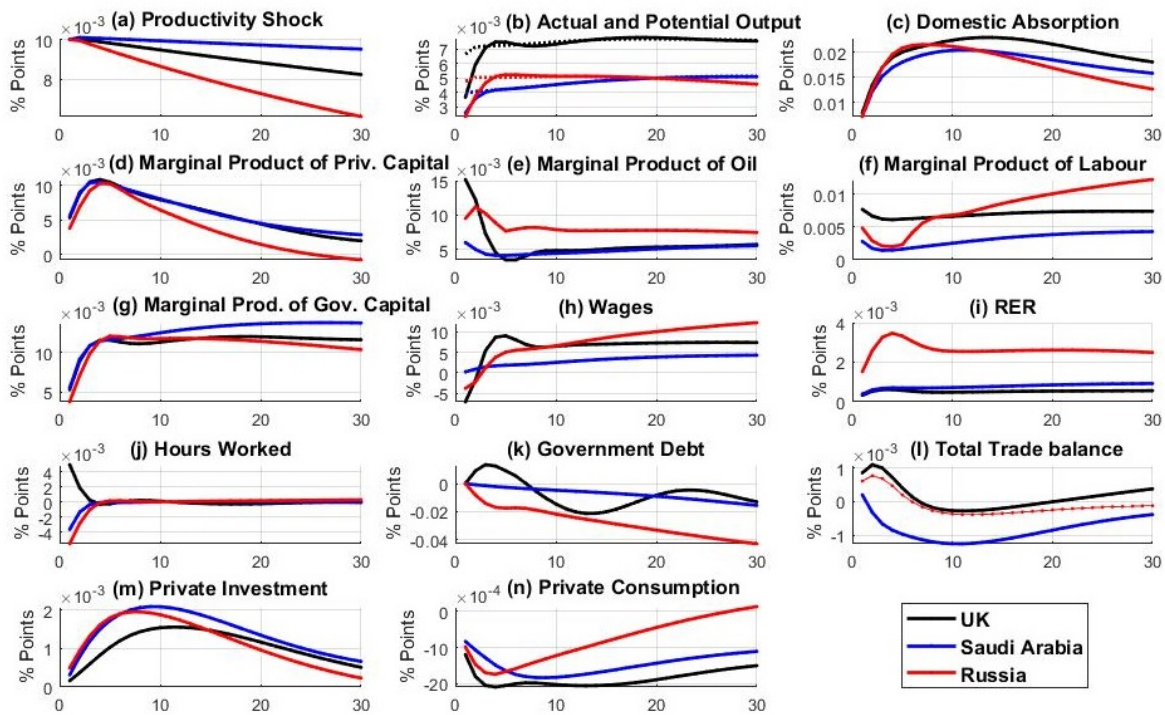
Notes: Simulated 10% reduction in government investment.

Figure 7: A small shift away from oil by the rest of the world



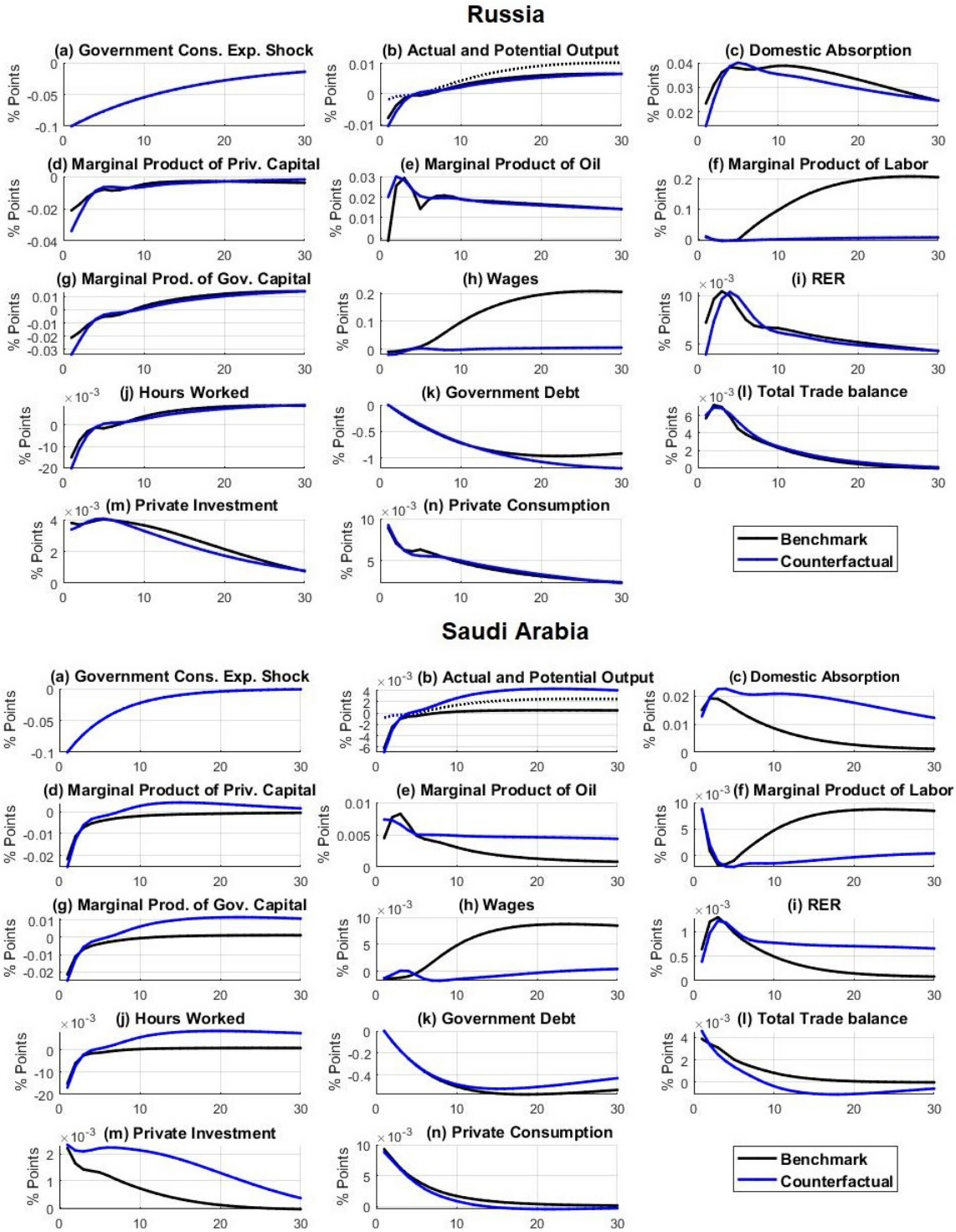
Notes: Simulated 1% increase in foreign oil intensity.

Figure 8: A positive domestic productivity shock



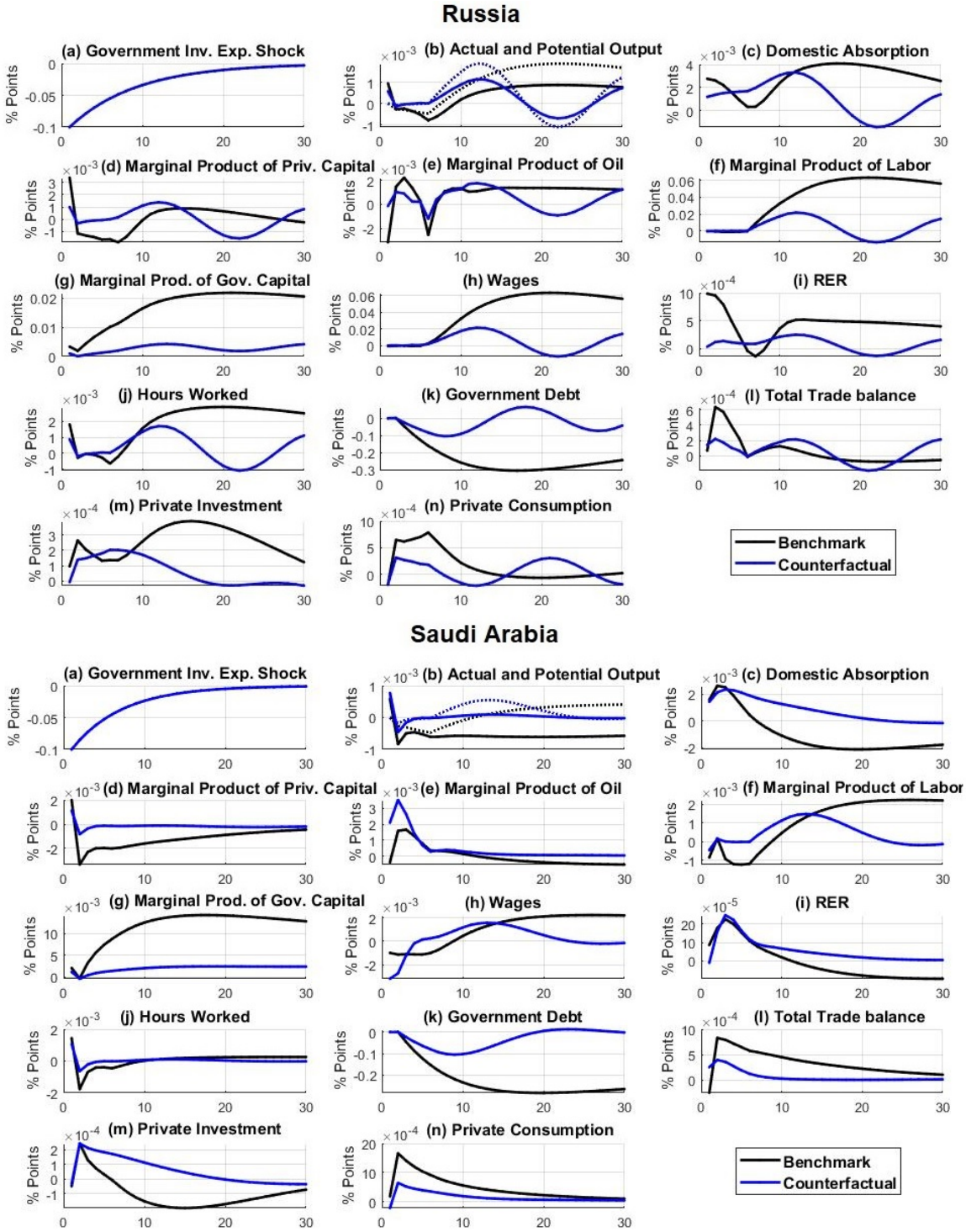
Notes: Simulated 1% increase in domestic techology.

Figure 9: Counterfactual analysis - further fiscal and monetary reforms, with spending led fiscal consolidation



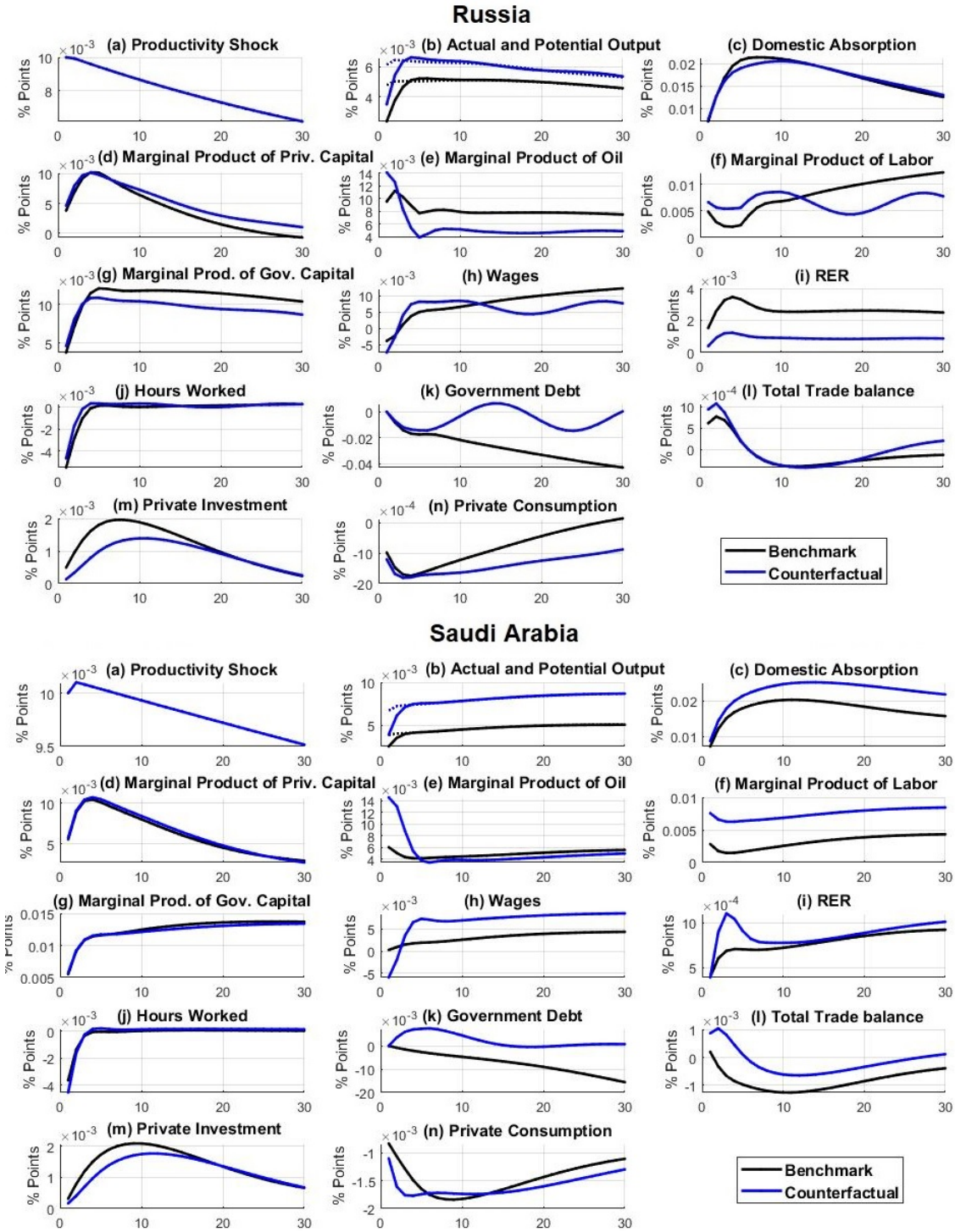
Notes: Simulated 10% reduction in government consumption spending.

Figure 10: Counterfactual analysis - structural reforms, with investment led fiscal consolidation



Notes: Simulated 10% reduction in government investment spending.

Figure 11: Counterfactual analysis - structural reforms with a gain in productivity



Notes: Simulated 1% increase in domestic technology.

10 Tables

Table 1: Government expenditures in the UK, Russia and Saudi Arabia

Year	**Government Consumption / GDP (%)**			**Government Investment / GDP (%)**		
	UK	*Russia*	*Saudi Arabia*	*UK*	*Russia*	*Saudi Arabia*
1996	19	28	13	1	2	2
1998	19	29	13	1	3	2
2000	19	26	20	1	2	3
2002	19	24	21	1	6	3
2004	20	22	19	1	4	4
2006	20	20	21	2	4	7
2008	20	18	20	2	5	10
2010	21	18	20	2	4	11
2012	20	18	22	2	4	12
2014	20	18	26	2	4	14

Source: Authors' estimates based on the IMFs April 2018 World Economic Outlook database.

Table 2: Rates of main taxes in the UK, Russia and Saudi Arabia

Year	**Tax Rates (%) - Average 1995-2014**		
	UK	*Russia*	*Saudi Arabia*
Consumption Tax	10	15*	4
Income Tax	18	13*	-
Social Security Tax (households)	12	-	10
Social Security Tax (firms)	12	30*	2
Oil Consumption Tax	44	-	-
Corporation Tax	15	58	1
Oil Revenue Tax	35	50*	70

Sources: Authors' calculations based on data from UK ONS and the IMF's April 2018 World Economic Outlook database. Notes: Numbers with * have not been estimated but are approximated courtesy of the IMF's Russia team.

Table 3: Fixed parameters of the three models

Par.	**Description**	**Value**		
		Russia	*Saudi Arabia*	*UK*
β_1	Discount Factor	0.9900	0.9900	0.9900
δ_1	Priv. Cap. Deprec. Rate	0.0250	0.0250	0.0250
σ_1	IES	1.0000	1.0000	1.0000
L_1^{SS}	Labour Steady State	0.4000	0.2500	0.3300
ϕ_1^b	Bond Intermediation Cost	0.0005	0.0002	0.0001
ρ_1^v	Determines K-L Elas. Sub	-2.0000	-2.0000	-3.0000
δ_1^g	Gov. Cap. Deprec. Rate	0.0150	0.0150	0.0025

Table 4: Calibrated parameters according to real data for the three models

Description	**Value**					
	Russia		*Saudi Arabia*		*UK*	
	Home Country	Foreign Country	Home Country	Foreign Country	Home Country	Foreign Country
Priv. Cap. Weight in Goods Prod.	$\phi_1^k = 0.2941$	$\phi_2^k = 0.4445$	$\phi_1^k = 0.3539$	$\phi_2^k = 0.4698$	$\phi_1^k = 0.2488$	$\phi_2^k = 0.3260$
Gov. Cap. Weight in Goods Prod.	$\phi_1^{kg} = 0.1088$	-	$\phi_1^{kg} = 0.1218$	-	$\phi_1^{kg} = 0.0442$	-
Weight of Oil in Production	$\omega_1^{oy} = 0.2083$	$\omega_2^{oy} = 0.2593$	$\omega_1^{oy} = 0.3080$	$\omega_2^{oy} = 0.2502$	$\omega_1^{oy} = 0.0253$	$\omega_2^{oy} = 0.0573$
Weight of Oil in Consumption	$\omega_1^{oc} = 0.0646$	$\omega_2^{oc} = 0.1371$	$\omega_1^{oc} = 0.0925$	$\omega_2^{oc} = 0.1360$	$\omega_1^{oc} = 0.0167$	$\omega_2^{oc} = 0.0300$
Weight of Cons. in Tot. Imp.	$\omega_1^{mc} = 0.1770$	$\omega_2^{mc} = 0.3037$	$\omega_1^{mc} = 0.3137$	$\omega_2^{mc} = 0.4864$	$\omega_1^{mc} = 0.3522$	$\omega_2^{mc} = 0.5040$
Weight of Services in Tot. Imp.	$\omega_1^{mi} = 0.2145$	$\omega_2^{mi} = 0.1668$	$\omega_1^{mi} = 0.5464$	$\omega_2^{mi} = 0.1620$	$\omega_1^{mi} = 0.3974$	$\omega_2^{mi} = 0.3454$
Share of Oil Production	$\frac{\frac{\zeta_1}{\zeta_2}\left(Y_1^o\right)^{SS}}{\frac{\zeta_1}{\zeta_2}\left(Y_1^o\right)^{SS}+\left(Y_2^o\right)^{SS}} = 0.1200$	$\frac{\left(Y_2^o\right)^{SS}}{\frac{\zeta_1}{\zeta_2}\left(Y_1^o\right)^{SS}+\left(Y_2^o\right)^{SS}} = 0.8800$	$\frac{\frac{\zeta_1}{\zeta_2}\left(Y_1^o\right)^{SS}}{\frac{\zeta_1}{\zeta_2}\left(Y_1^o\right)^{SS}+\left(Y_2^o\right)^{SS}} = 0.1329$	$\frac{\left(Y_2^o\right)^{SS}}{\frac{\zeta_1}{\zeta_2}\left(Y_1^o\right)^{SS}+\left(Y_2^o\right)^{SS}} = 0.8671$	$\frac{\frac{\zeta_1}{\zeta_2}\left(Y_1^o\right)^{SS}}{\frac{\zeta_1}{\zeta_2}\left(Y_1^o\right)^{SS}+\left(Y_2^o\right)^{SS}} = 0.0356$	$\frac{\left(Y_2^o\right)^{SS}}{\frac{\zeta_1}{\zeta_2}\left(Y_1^o\right)^{SS}+\left(Y_2^o\right)^{SS}} = 0.9644$
Share of Oil Consumption	$\frac{\frac{\zeta_1}{\zeta_2}(O_1)^{SS}}{\frac{\zeta_1}{\zeta_2}(O_1)^{SS}+(O_2)^{SS}} = 0.0756$	$\frac{(O_2)^{SS}}{\frac{\zeta_1}{\zeta_2}(O_1)^{SS}+(O_2)^{SS}} = 0.9244$	$\frac{\frac{\zeta_1}{\zeta_2}(O_1)^{SS}}{\frac{\zeta_1}{\zeta_2}(O_1)^{SS}+(O_2)^{SS}} = 0.0820$	$\frac{(O_2)^{SS}}{\frac{\zeta_1}{\zeta_2}(O_1)^{SS}+(O_2)^{SS}} = 0.9180$	$\frac{\frac{\zeta_1}{\zeta_2}(O_1)^{SS}}{\frac{\zeta_1}{\zeta_2}(O_1)^{SS}+(O_2)^{SS}} = 0.0149$	$\frac{(O_2)^{SS}}{\frac{\zeta_1}{\zeta_2}(O_1)^{SS}+(O_2)^{SS}} = 0.9851$
Bloc Size	$\zeta_1 = 0.0705$	$\zeta_2 = 0.9295$	$\zeta_1 = 0.0725$	$\zeta_2 = 0.9275$	$\zeta_1 = 0.0255$	$\zeta_2 = 0.9745$
S.S. VAT Rate	$\left(\tau_1^c\right)^{SS} = 0.1500^*$	-	$\left(\tau_1^c\right)^{SS} = 0.0412$	-	$\left(\tau_1^c\right)^{SS} = 0.0966$	-
S.S. Income Tax Rate	$\left(\tau_1^l\right)^{SS} = 0.1300^*$	-	-	-	$\left(\tau_1^l\right)^{SS} = 0.1898$	-
S.S. Soc. Sec. Tax Rate (households)	-	-	$\left(\tau_1^{wh}\right)^{SS} = 0.1000$	-	$\left(\tau_1^{wh}\right)^{SS} = 0.1176$	-
S.S. Soc. Sec. Tax (Firms)	$\left(\tau_1^{wf}\right)^{SS} = 0.3000^*$		$\left(\tau_1^{wf}\right)^{SS} = 0.0161$	-	$\left(\tau_1^{wf}\right)^{SS} = 0.1176$	-
S.S. Fuel Duty Tax Rate	-	-	-	-	$\left(\tau_1^{oc}\right)^{SS} = 0.4394$	-
S.S. Corporation Tax Rate	$\left(\tau_1^d\right)^{SS} = 0.5837$	-	$\left(\tau_1^d\right)^{SS} = 0.0050$	-	$\left(\tau_1^d\right)^{SS} = 0.1450$	-
S.S. PRT Tax Rate	$\left(\tau_1^{yo}\right)^{SS} = 0.5000^*$	-	$\left(\tau_1^{yo}\right)^{SS} = 0.7053$	-	$\left(\tau_1^{yo}\right)^{SS} = 0.3500$	-
Share Gov. Cons. Exp. / GDP	$\frac{\left(G_1^d\right)^{SS}}{\left(Y_1^d\right)^{SS}} = 0.2207$	-	$\frac{\left(G_1^d\right)^{SS}}{\left(Y_1^d\right)^{SS}} = 0.1906$	-	$\frac{\left(G_1^d\right)^{SS}}{\left(Y_1^d\right)^{SS}} = 0.1965$	-
Share Gov. Inv. Exp. / GDP	$\frac{\left(I_1^g\right)^{SS}}{\left(Y_1^d\right)^{SS}} = 0.0354$		$\frac{\left(I_1^g\right)^{SS}}{\left(Y_1^d\right)^{SS}} = 0.0673$	-	$\frac{\left(I_1^g\right)^{SS}}{\left(Y_1^d\right)^{SS}} = 0.0173$	-

Table 5: Priors and posterios for the endogenous parameters of the three models

Par.	**Description**	**Priors**									**Posteriors**								
		Russia			*Saudi Arabia*			*UK*			*Russia*			*Saudi Arabia*			*UK*		
		Distr.	Mean	St. Dev.	Distr.	Mean	St. Dev.	Distr.	Mean	St. Dev.	Mean	Conf.	Inter.	Mean	Conf.	Inter.	Mean	Conf.	Inter.
κ_1	Cons. Habit Pers.	B	0.50	0.20	B	0.70	0.20	B	0.90	0.05	0.94	0.91	0.97	0.35	0.26	0.44	0.83	0.75	0.92
φ_1^i	Inv. Adjustment Cost	G	4.50	0.50	G	4.00	0.50	G	4.00	1.50	4.96	4.12	5.77	4.16	3.37	4.93	7.71	6.01	9.99
χ_1	Lab. Sup. El. ($\frac{1}{2\chi}$)	G	33.00	0.75	G	33.00	0.75	G	25.00	0.75	32.84	31.62	34.07	32.74	31.51	33.97	25.47	24.21	26.73
ξ_1^w	Calvo Wages Prob.	B	0.55	0.05	B	0.55	0.05	B	0.50	0.05	0.71	0.64	0.78	0.79	0.75	0.82	0.33	0.26	0.40
ξ_1^p	Calvo Prices Prob.	B	0.55	0.05	B	0.55	0.05	B	0.50	0.05	0.63	0.58	0.79	0.56	0.50	0.62	0.71	0.67	0.78
ι_1^w	Degree of Wage Ind.	B	0.20	0.05	B	0.20	0.05	B	0.40	0.05	0.21	0.13	0.29	0.26	0.17	0.36	0.32	0.25	0.40
ι_1^p	Degree of Price Ind.	B	0.90	0.05	B	0.90	0.05	B	0.40	0.05	0.91	0.84	0.98	0.79	0.66	0.93	0.46	0.38	0.54
$\frac{1+\rho_1^o}{\rho_1^o}$	Price Elast. of Oil Dem.	G	0.40	0.05	G	0.35	0.05	G	0.40	0.20	0.18	0.16	0.21	0.14	0.12	0.16	0.07	0.02	0.12
$\frac{1+\rho_1^c}{\rho_1^c}$	Trade Elast.	G	1.70	0.10	G	1.80	0.10	G	2.50	0.10	1.53	1.43	1.62	2.08	1.96	2.20	2.75	2.60	2.89
$\gamma_1^{\pi^{core}}$	T.R. Coef. on Core Inf.	-	-	-	-	-	-	G	0.50	0.05	-	-	-	-	-	-	0.46	0.38	0.53
$\gamma_1^{\pi^{head}}$	T.R. Coef. on Headline Inf.	G	0.30	0.05	G	0.25	0.05	-	-	-	0.33	0.25	0.40	0.21	0.15	0.27	-	-	-
γ_1^y	T.R. Coef. on Output	G	0.20	0.05	G	0.20	0.10	G	0.30	0.10	0.30	0.21	0.39	0.12	0.03	0.21	0.14	0.07	0.21
γ_1^i	Int. Rate Smooth. in T.R.	B	0.70	0.05	B	0.30	0.05	B	0.90	0.05	0.90	0.89	0.92	0.19	0.15	0.24	0.94	0.93	0.95
γ_1^e	T.R. Coef. on Ex. Rate	G	1.20	0.10	G	1.20	0.10	-	-	-	0.82	0.72	0.92	1.05	0.93	1.18	-	-	-
ψ_1^{cc}	VAT / Priv. Cons. Coef.	G	0.90	0.40	G	0.90	0.40	G	0.90	0.40	0.92	0.28	1.54	0.69	0.41	1.00	1.06	0.33	1.78
ψ_1^{ly}	Lab. Inc. Tax / GDP Coef.	G	0.90	0.40	-	-	-	G	0.90	0.30	1.03	0.33	1.73	-	-	-	1.00	0.47	1.51
ψ_1^{lb}	Lab. Inc. Tax / Debt Coef.	G	0.90	0.05	-	-	-	G	0.60	0.05	0.92	0.84	1.00	-	-	-	0.58	0.50	0.65
ψ_1^{whb}	Soc. Sec. Tax (hh.) / Debt Coef.	-	-	-	G	0.70	0.05	G	0.10	0.05	-	-	-	0.68	0.60	0.76	0.08	0.02	0.14
ψ_1^{wfb}	Soc. Sec. Tax (f.) / Debt Coef	G	0.90	0.05	G	0.90	0.05	G	0.10	0.05	0.89	0.81	0.98	0.90	0.82	0.98	0.08	0.02	0.14
ψ_1^{ococ}	FD Tax / Oil Dem. Coef.	-	-	-	-	-	-	G	0.90	0.05	-	-	-	-	-	-	0.89	0.81	0.98
ψ_1^{dd}	Corp. Tax / Div. Coef.	G	0.90	0.05	G	0.90	0.40	G	0.60	0.10	1.01	0.92	1.10	0.91	0.28	1.51	0.41	0.30	0.51
ψ_1^{yopo}	PRT / Oil Price Coef.	G	0.90	0.40	G	0.90	0.40	G	0.15	0.05	1.01	0.52	1.48	1.02	0.40	1.61	0.15	0.07	0.23