Journal of International Economics 112 (2018) 200–218

Contents lists available at ScienceDirect

Journal of International Economics

journal homepage: www.elsevier.com/locate/jie

Written for the NBER International Seminar on Macroeconomics

Commodity booms and busts in emerging economies☆,☆☆

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ARTICLE INFO

Article history:
Received 25 August 2017
Received in revised form 20 December 2017
Accepted 28 December 2017
Available online 30 December 2017

Research data related to this submission:
https://data.mendeley.com/datasets/zjz3vfsyxf/1

JEL classification:
E13
E32
F43
O11
O16

Keywords:
Business cycles
Small open economy
Emerging markets
Commodity prices
Argentina's economy

ABSTRACT

Emerging economies, particularly those dependent on commodity exports, are prone to highly disruptive economic cycles. This paper proposes a small open economy model for a net commodity exporter to quantitatively study the triggers of these cycles. The economy consists of two sectors, one of which produces commodities with prices subject to exogenous international fluctuations. These fluctuations affect both the competitiveness of the economy and its borrowing terms, as higher commodity prices are associated with lower spreads between the country's borrowing rate and world interest rates. Both effects jointly result in strongly positive effects of commodity price increases on GDP, consumption, and investment, and a negative effect on the total trade balance. Furthermore, they generate excess volatility of consumption over output and a large volatility of investment. Besides explicitly incorporating a double role of commodity prices, the model structure nests the various candidate sources of shocks proposed in previous work on emerging economy business cycles. Estimating the model on Argentine data, we find that the contribution of commodity price shocks to fluctuations in post-1950 output growth is in the order of 38%. In addition, commodity prices account for around 42% and 61% of the variation in consumption and investment growth, respectively. We find transitory productivity shocks to be an important driver of output fluctuations, exceeding the contribution of shocks to the trend, which, though smaller, is not negligible.

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1. Introduction

Emerging economies, particularly those that are dependent on commodity exports, have a long history of volatile and disruptive economic cycles. A rich literature in International Macroeconomics has proposed several explanations for these cycles, pointing to different plausible triggers or underlying sources of shocks. The relative importance of the various triggers, however, still divides the literature. Aguiar and Gopinath (2007) argue that the main source of fluctuations is nonstationary total factor productivity (TFP) shocks - the cycle is the trend. García-Cicco et al. (2010) refute the argument, showing that these shocks only explain a negligible fraction of fluctuations. They contend that the main drivers of shocks are stationary TFP shocks as well as exogenous shocks to the country's interest rate. The latter result relates to work by Guimaraes (2011), Neumeyer and Perri (2005), and Uribe and Yue (2006), who highlight the role of changes in global interest rates as a potential driver of the cycle. The role of commodity prices and, more generally, terms of trade, has been equally divisive. Mendoza (1995) and Kose (2002) argue that fluctuations in the terms of trade explain a large fraction of the output variance. However, empirical work by Schmitt-Grohe and Uribe (2017) has raised questions on the ability of terms of trade to match critical features of business cycles in emerging economies. Interestingly, though, estimates by Fernández et al. (2017) suggest

☆ We would like to thank Juan Antolin-Diaz, Neele Balke, Alberto Cavallo, Gianluca Benigno, Francesco Caselli, Wouter Den Haan, Martin Ellison, Andrea Fererro, Jeff Frankel, Pierre-Olivier Gourinchas, Per Krusell, Tommaso Monacelli, Kris Mitchener, Andres Neumeyer, Juan Pablo Nicolini, Ivan Petrella, Ricardo Reis, Helene Rey, Alan Taylor, and seminar participants at the NBER International Seminar on Macroeconomics 2017, LACEA-LAMES 2017, the Workshop in International Economics at Oxford University, and LSE for useful comments and conversations. For superb research assistance, we would like to thank Piero Fortino and Sun Rui. Tenreyro acknowledges support from ERC Consolidator Grant MACROTRADE 681664-Research on Macroeconomic Fluctuations and Trade.
☆☆ This article has gone through the usual refereeing process of the Journal of International Economics.
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https://doi.org/10.1016/j.jinteco.2017.12.009
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that fluctuations in commodity prices account for a significant fraction of output fluctuations.[1] For economies with a comparative advantage in the production of commodities, fluctuations in the terms of trade and in real commodity prices tend to display a highly positive correlation, and hence the tension between these two empirical studies' results invites a fresh take. In turn, these results call for a tighter connection with the aforementioned studies on the relative importance of different productivity and interest rate shocks.

This paper seeks to quantitatively assess the drivers of emerging economy business cycles using a unified model that nests the various sources of shocks advanced in the literature. The model builds on the small open economy setting of Aguiar and Gopinath (2007) and García-Cicco et al. (2010) by adding two elements absent from their analysis. First, it allows for a second sector to capture the separate role of commodities in the economy. Specifically, the analysis focuses on the case of a net commodity exporting country facing exogenous international price changes. Second, the model embeds a negative relation between the interest rate premium and commodity prices. The relevance of this channel has recently been highlighted by Fernández et al. (2015) and Shousha (2016), and is consistent with the empirical evidence.

To study the predictions of our model, we resort both to a calibration exercise and to the estimation of the model with Bayesian methods. The quantitative analysis throughout the paper focuses on Argentina, a quintessential example of a commodity exporting emerging economy. Given the lengthy duration of Argentine cycles, we carry the analysis over a long period (1900–2015) in order to capture multiple cycles.[2] To set the stage, we begin by revisiting a number of empirical regularities. In common with other emerging economies, Argentina displays large and persistent cyclical fluctuations, excess volatility of consumption over output, high volatility of investment, and a negative correlation between output growth and the trade balance. In addition, the Argentine data reveal large positive effects of world commodity price shocks on output, consumption, and investment, as well as negative effects on the trade balance. We identify these shocks using a structural vector autoregression (SVAR) model with a standard Cholesky decomposition, relying on the assumption that world commodity prices are not contemporaneously affected by Argentina's economic activity. Furthermore, the data display a strong negative association between interest rate spreads in Argentina and world commodity prices. Maintaining the assumption that international commodity prices are exogenous to developments in Argentina's economy, we estimate this relation with a set of regressions of measures of Argentine real rates (net of world interest rates) on an international commodity price index and various controls. The strongly negative relation is robust across a number of specifications, with different spread measures and different sets of controls, including output growth, the trade balance and the debt-to-GDP ratio. The lower bound of our estimates suggests that a 10% deviation of commodity prices from their long-run mean can move Argentina's real interest rate spread by almost 2 percentage points. This finding confirms the existing evidence from the literature on interest rate spreads of commodity exporting economies (see in particular Bastourre et al., 2012, Fernández et al., 2015 and Shousha, 2016). It also connects with earlier work by Kaminsky et al. (2005) on the procyclicality of capital flows in developing countries.[3]

In the model calibration exercise we analyze the response of the economy to commodity price shocks of a sensibly calibrated size, which we can directly compare to the impulse response functions obtained from the SVAR. We find that the model impulse response functions line up well with their empirical counterparts. The two effects stemming from commodity prices (that is, the competitiveness effect and the borrowing cost effect) *jointly* produce impulse response functions to a commodity price shock that match the empirical responses. They generate strongly positive effects on GDP, consumption, and investment, and a negative effect on the total trade balance. They also give rise to a somewhat larger response of consumption over output. We show that the first effect alone (akin to a productivity increase) cannot generate a countercyclical trade balance. Similarly, the second effect alone (which is isomorphic to a simple negative interest rate shock) does not give a contemporaneous response in output, while consumption and investment do increase on impact. The net contribution of the two effects can reproduce the empirical regularities.

The aim of the structural estimation of the model is to gauge the quantitative importance of commodity price shocks, relative to other shocks, in driving the business cycle. We apply Bayesian estimation methods, using data on output, consumption, investment, and the trade balance of Argentina. We estimate the stochastic processes of various exogenous disturbances, as well as the two parameters governing the sensitivity of the interest rate spread to commodity prices and to the debt level. Our results suggest a sizeable contribution of commodity price shocks to Argentine business cycle fluctuations. The posterior forecast error variance decomposition based on data from 1900 to 2015 attributes 22% of the observed variation in output growth to commodity price shocks. Furthermore, 24% of consumption growth and 34% of investment growth can be accounted for by commodity price shocks. Reassuringly, the model-implied process for the commodity price shares important features with empirically observed world commodity prices. Since it mimics the data particularly closely after 1950, we carry out the estimation on the post-1950 subsample and find that the contribution of commodity price shocks to output, consumption, and investment growth rises to around 38%, 42%, and 61%, respectively.

Our assessment of the remaining variation in macroeconomic aggregates sheds additional light on the debate about the candidate drivers of emerging economy business cycles previously proposed in the literature. We find that, in general, stationary technology shocks remain the most important source of fluctuations, explaining around half of the variation in output growth. These stationary shocks to TFP are quantitatively more important than non-stationary TFP shocks. While this echoes the conclusion of García-Cicco et al. (2010), who question the notion that the "cycle is the trend" in emerging economies, the contribution of nonstationary shocks remains non-negligible, as these shocks are able to explain 21% of the variation in output growth in both samples used in the estimation.[4] We also find a significant role for preference shocks and interest rate shocks in

[1] Schmitt-Grohe and Uribe (2017) empirically estimate the impulse response functions of GDP and consumption to terms of trade shocks. They find that consumption responds negatively to terms of trade innovations, in sharp contrast to the positive response of GDP. Given the overall positive comovement between consumption and GDP in the data, their work bodes negative prospects for terms of trade as a key driver of the cycle. Empirical results in Fernández et al. (2017) however, suggest that commodity prices potentially account for a significant fraction of output fluctuations, though their paper does not provide impulse response functions for the various macroeconomic aggregates to shed light on the comovements across variables and potential mechanisms. Another empirical paper with a focus on commodity prices, and the resulting procyclicality of fiscal policy, is Cespedes and Velasco (2014).

[2] Shousha (2016) focuses on a quarterly sample from 1994–2013 pooling together various emerging economies. In the case of Argentina, this would not be lengthy enough to capture a full cycle. Aguiar and Gopinath (2007) analyze an even shorter period for Argentina, 1993–2002. Fernández et al. (2015) estimate their model on a pool of countries (Brazil, Chile, Colombia, and Peru) covering the period 2000:Q1 to 2014:Q3. We concur with García-Cicco et al. (2010) in that a long period is necessary in order to distinguish trend and cyclical shocks. They base the analysis on 1900–2010 and hence our results are more directly comparable to theirs.

[3] See also Reinhart and Reinhart (2009), Gavin et al. (1996), Prasad et al. (2006), and Frankel (2011).

[4] Our conclusion with respect to this aspect is quite similar to recent findings of Akinci (2017).

explaining the variation in consumption, investment, and the trade balance.

Taken together, our results suggest that commodity prices should feature prominently in the analysis of business cycles in emerging economies. In terms of quantitative contribution, they are among the three most important shocks driving output growth in Argentina. Importantly, shocks to international commodity prices, in contrast to inherently more opaque concepts such as domestic TFP shocks, are factors that are easier to identify and measure, and potentially act upon, by policy makers.[5]

The rest of the paper is organized as follows. Section 2 presents a number of empirical regularities characterizing Argentine business cycles. As said, many of these regularities are shared with other emerging commodity exporting countries, though for the sake of accuracy in the mapping from the data to the model, we think it is appropriate to focus on a single country. Section 3 introduces the model. Section 4 performs the calibration exercise and studies the role of commodity price shocks in the model. Section 5 estimates the model and carries out a quantitative analysis of the various sources of shocks; it also discusses practical issues concerning the measurement of real GDP. Section 6 contains concluding remarks.

2. Emerging market cycles: empirical regularities

This section presents the main empirical features that characterize the business cycle of Argentina's economy from 1900 to 2015.

2.1. Data and sample

Although there are strong commonalities across emerging countries, we think it is important to work with a straight mapping from a single country to the model, rather than using averages across different countries, which might confound effects due to aggregation. The focus on a long time period is both insightful and befitting for a number of reasons. First, Argentina's large and persistent economic cycles call for a lengthy time span in order to capture a reasonable number of completed cycles in the analysis. Second, unlike advanced economies, Argentina's cyclical properties have shown virtually no changes over this long period. This is apparent in Fig. 1, Panel (a), which plots the logarithm of Argentine real GDP per capita from 1900 to 2015. Argentina's output volatility in the first half of the 20th century (measured as the standard deviation of real GDP growth rates) is practically the same as the volatility in the post 1950 period, despite the higher levels of development in the latter part of the sample. In the corresponding plot for the United States, shown in Panel (b), marked changes in the volatility of output are visible. This typically leads researchers to separately analyze data before and after the World War II, or before and after the 1980s, which was when the Great Moderation occurred in the United States. Such changes in volatility are not present in Argentina, which supports the case for analyzing fluctuations jointly over the entire period.[6] Third, Argentina's trend growth rate has been remarkably stable since 1900, at 1.2% per year, a constancy that can be fully appreciated by taking a long-term perspective in analyzing its business cycles.[7] In addition to output data, we will focus on typical macroeconomic variables of interest in small open economies, by studying the fluctuations of consumption, investment, and the trade balance. The data come from a variety of sources, including most notably Ferreres (2005).[8]

Furthermore, since our aim is to assess the importance of commodity price fluctuations for Argentina's economy, we need to select an appropriate commodity price index. Our preferred index is the one constructed by Grilli and Yang (1988), which we update following Pfaffenzeller et al. (2007). The index is available from 1900 and reflects *world* commodity prices, which is advantageous because developments in global prices are arguably exogenous to economic conditions in Argentina (see further discussion below). The drawback, of course, is that it may capture price developments of commodities that are unimportant, or even absent, in Argentina's commodity export composition.[9] We therefore cross-check this index with an *Argentina-specific* commodity price index, which we construct using commodity price data provided by the World Bank, together with trade weights available from the UN Comtrade data base. This construction is possible from 1962 onwards. Fig. 2, Panel (a), plots the two indices (in nominal terms) and shows that their year-on-year changes are fairly synchronized, mitigating the concern that the world price index may not be representative of commodity prices faced by Argentina. We deflate the Grilli and Yang (1988) index to be a relative ("real") price using an index of (US-dollar denominated) import prices for Argentina.[10] Fig. 2, Panel (b) plots this time series in deviations from its sample mean. We focus on mean deviations rather than other detrending methods, since we are interested in capturing persistent movements over longer time spans, sometimes referred to as "supercycles" in commodity prices.

We begin our characterization of the empirical regularities by documenting business cycle moments. We then turn to estimating an SVAR in order to gauge the dynamic effects of exogenous commodity price developments on Argentina's economy. Furthermore, we present evidence on the relation of commodity prices and Argentina's real interest rate spread. Finally, we summarize the insights of this section into a set of stylized facts.

2.2. Business cycle moments

Table 1 summarizes key business cycle moments of Argentina's economy. We report mean, standard deviation, persistence, and contemporaneous cross-correlation of GDP growth, consumption growth, investment growth (all per capita), as well as the trade balance, defined as exports minus imports scaled by GDP. As the table shows, many properties of the Argentine business cycle are in line with what is typically observed in advanced economies. Output, consumption, and investment are strongly correlated and investment is much more volatile than output. On the other hand, there are features that are distinctive of fluctuations in emerging

[5] Our model does not feature sovereign default or distress. While sovereign default episodes have been important for Argentina, we think there is a lot of merit in understanding the triggers of the cycles and how they are affected by external factors such as commodity prices in a relatively simple setting, which more realistically would end with a technical default. A better understanding of these regularities may actually help in avoiding default episodes by guiding policy. As will become clear, the model features a negative externality, as households do not take into account the effect of their borrowing on interest rates, which can lead to overborrowing.

[6] A similar argument is made by García-Cicco et al. (2010); they emphasize the importance of a long horizon to disentangle transitory shocks from shocks to trend growth in business cycles of emerging economies, which are the focus of Aguiar and Gopinath (2007). We will also aim at disentangling these two types of shocks in our model estimation, in addition to our focus on commodity prices.

[7] This is also different in the US, where low frequency changes in the trend growth rate are present (see Antolin-Diaz et al., 2017, for comprehensive evidence). We therefore fit a cubic rather than linear trend in Panel (b) of Fig. 1.

[8] We extend the series of Ferreres (2005) to 2015. Compared to García-Cicco et al. (2010), we add another half decade of data. Details on the sources and construction of the data are provided in Appendix A.

[9] Argentina exports mainly agricultural and food commodities such as meat, maize, and soy beans, but to a lesser extent also petroleum, gold, and other non-food commodities.

[10] The import price index updates the series published by Ferreres (2005). We have tried alternative ways of deflating the commodity price series, for example using manufacturing prices (also expressed in US dollars), or the US consumer price index. The changes did not have a material impact on the results we present. We prefer the deflation using import prices (expressed in US dollars), since this brings the observed price index closest to the corresponding concept in our model, which is the relative price between commodities and a final tradable consumption good.

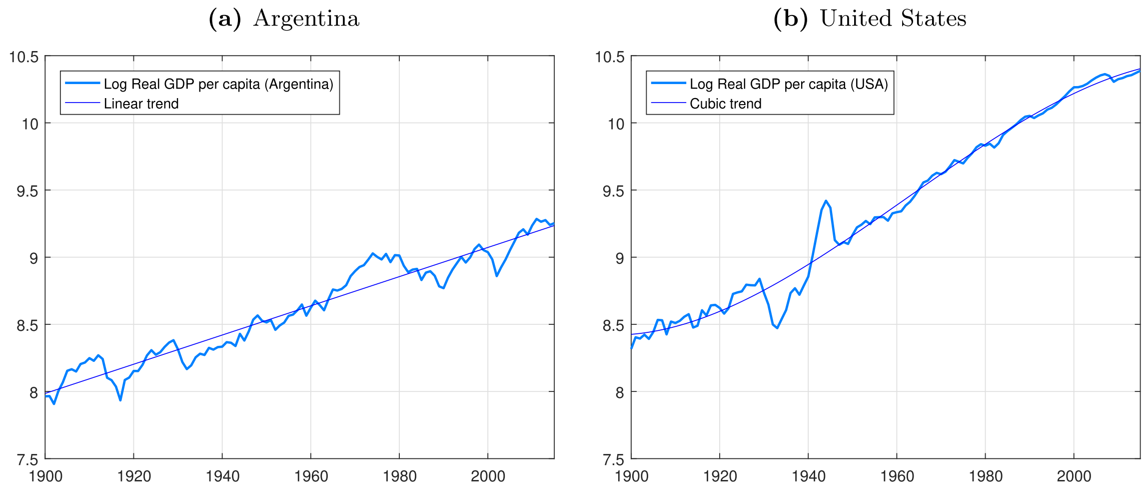

Fig. 1. Output per capita 1900–2015 - Argentina vs. US.
Notes: Panel (a) displays Argentine real GDP per capita in log scale, together with a linear trend. Panel (b) shows the log of US real GDP per capita and adds a cubic trend. The sources are Ferreres (2005) (updated series) and the US Bureau of Economic Analysis, respectively.

markets. In particular, it is worth highlighting that consumption growth is more volatile than output growth.[11] Furthermore, as often observed in emerging markets, the trade balance is countercyclical. In the case of Argentina the contemporaneous correlation with output growth is not large, calculated at −0.07, but the magnitude of the negative correlation is more pronounced with consumption and investment.

2.3. Commodity price shocks and emerging economy business cycles

In order to gauge the effect of international commodity prices on merging market business cycles, we consider the following structural vector autoregression (SVAR):

$$A_0 Z_t = at + A_1 Z_{t-1} + \ldots + A_p Z_{t-p} + u_t, \tag{1}$$

where Z_t is a vector containing the commodity price index in log deviations from mean, as plotted in Fig. 2, together with the log-levels of the business cycle variables of interest - output, consumption, investment, and the trade balance; u_t is a vector of normally distributed structural shocks with covariance matrix $\mathbb{E}(u_t u_t') = I_5$; and t is a linear time trend. We set the number of lags to $p = 2$.[12]

We estimate the reduced form version of Eq. (1) using OLS, obtain the residuals $\hat{\epsilon}_t = \hat{A}_0^{-1} \hat{u}_t$ and then recover commodity price shocks, that is, the element of $\hat{u}_t$ corresponding to commodity prices, using restrictions on A_0. Our underlying identifying assumption is that international commodity prices are not contemporaneously affected by any other variable in the system. Given that Argentina is a relatively small country that should not be a driver of world-wide commodity prices, we believe this assumption is reasonable and justifies ordering the commodity price first in a Cholesky decomposition of the covariance matrix of u_t.[13]

Due to the imperfections in the measurement of commodity prices faced by Argentina discussed earlier, we focus solely on the IRFs of the SVAR, but do not resort to a forecast error variance decomposition. Our working assumption is that the IRFs in response to a shock identified from this specification give a meaningful representation of the dynamics following an exogenous shock to international commodity prices. However, we think that making quantitative statements about the total contribution of commodity prices to the variance of output from this exercise could be misleading given the noisy nature of the Grilli and Yang (1988) index as a measure of the actual price movements faced by Argentina. We instead carry out such a decomposition using the structural model in Section 5.

The impulse response functions to a one standard deviation shock to commodity prices are plotted in Fig. 3. The results show that there is a statistically and economically significant positive response of output, consumption, and investment. The total trade balance response is negative, that is, net exports fall in response to a commodity price increase. All responses are hump-shaped, peaking around two years following the shock, and quite persistent. Measured at peak, a one standard deviation shock in international commodity prices increases the level of real GDP per capita by more than one percent.

2.4. Commodity prices and interest rate spreads

What are possible channels behind the influence of commodity prices on emerging market business cycles? One key observation that has been highlighted in previous research on commodity exporting economies is the strong negative comovement of interest rate spreads and commodity prices. Fernández et al. (2015) highlight the strong negative effect of commodity price increases on country risk premia in sovereign bond spreads. Bastourre et al. (2012) estimate the correlation between a common factor of emerging economy bond returns and a common factor of commodity prices to be −0.81. Shousha (2016) emphasizes that the negative correlation is a major difference between emerging and advanced commodity exporters. Incorporating this effect into our analysis is important, since strongly countercyclical interest rate movements in general have been found to be a key driver of emerging markets business cycles, see for example Uribe and Yue (2006) and Neumeyer and Perri (2005).[14]

To shed further light on the link between the real spread and commodity prices in the case of Argentina, we run a set of regressions of the Argentine real interest rate spread on the real commodity price

[11] Interestingly, the excess volatility of consumption is smaller in our sample than in García-Cicco et al.'s (2010) sample, suggesting that this phenomenon has attenuated in recent years.
[12] This lag length is selected against $p = 1$ using various lag length selection criteria.
[13] We leave the remaining shocks to the system unidentified, so that the ordering of the remaining variables is irrelevant.

[14] This result connects with work on the procyclicality of capital flows and borrowing in emerging and developing economies. See for example Kaminsky et al. (2005).

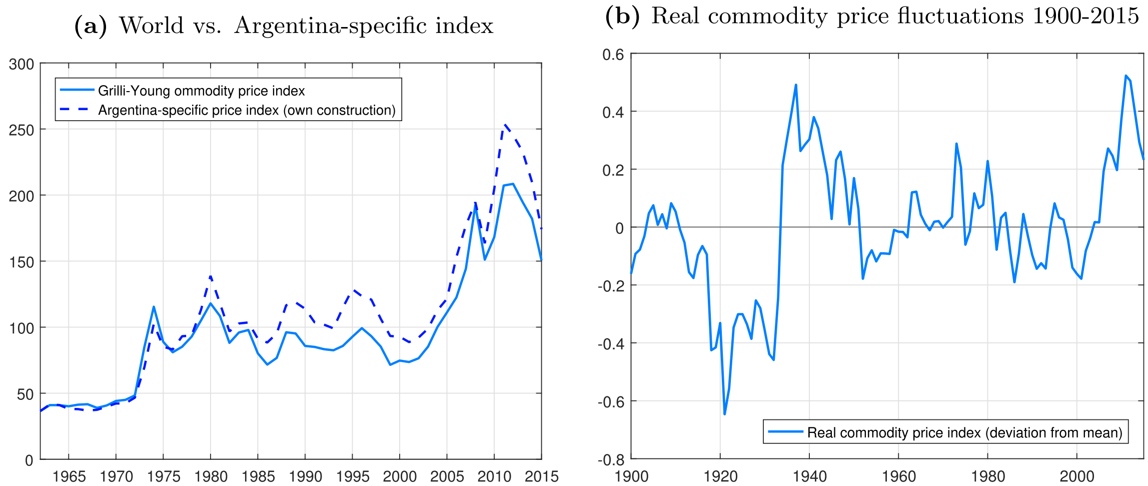

Fig. 2. Commodity prices.
Notes: Panel (a) compares the updated index of Grilli and Yang (1988) with an Argentina-specific commodity price index constructed based on UN Comtrade and World Bank data. These series are in nominal terms and normalized to the same value in 1962. Panel (b) displays the commodity price index of Grilli and Yang (1988), deflated with the Argentine import price index (in US dollars), and in log-deviations from its sample mean.

index (in log deviations from its mean). The regressions are specified as follows:

$$r_t - r_t^* = \alpha + \xi(\ln\tilde{p}_t - \ln\bar{\tilde{p}}) + \beta X_t + v_t, \quad (2)$$

where r_t is the real interest rate of Argentina, r_t^* is a measure of the world interest rate, $\tilde{p}_t$ is the commodity price (with $\ln\tilde{p}_t - \ln\bar{\tilde{p}}$ being the log deviation from mean, which we plot in Fig. 2, Panel (b)), and X_t is a vector of control variables including output growth, the debt-to-GDP ratio and the trade balance. The key parameter of interest is ξ, which denotes the sensitivity of the real interest rate spread with respect to changes in world commodity prices. Note that this sensitivity parameter will also feature in our model and we will calibrate it based on the results presented in this section. Since interest rate data for Argentina are not available over our baseline 1900–2015 sample, we stick to a smaller time period and try different interest rate series available. Specifically, we use the domestic lending rate, savings rate, and the money market rate, which are all provided by the IMF International Financial Statistics in nominal terms. To obtain a real measure we deflate these series using a corrected inflation measure for Argentine inflation ("inflación verdadera"), since several authors have highlighted the misreporting of inflation by official sources in recent years (see Cavallo, 2013, for a discussion).[15] For the world interest rate we use a measure of the UK real interest rate published by the Bank of England. We once again emphasize that the commodity price measure captures international commodity price developments which are arguably exogenous to economic activity in Argentina.

The baseline results are presented in Table 2. We show several other results using different interest rate measures in Appendix B. Our findings across all regressions, including those in the appendix, give negative point estimates of ξ. These estimates are economically significant though not always statistically significant, likely due to the small sample. If we consider the smallest estimate (in absolute value) that is statistically significant, which is −0.199, the interpretation is that a 10% deviation of commodity prices from their long-run mean can move Argentina's real interest spread by almost 2 percentage points. We view this as strong evidence in support of a channel by which exogenous international commodity prices put downward pressure on interest rate premia faced by commodity exporting emerging economies. This evidence will guide our modeling choices below, where we also provide further theoretical discussion of this economic relation.

2.5. Summary of stylized facts

Based on the empirical analysis above, we summarize the following stylized facts around aggregate fluctuations in Argentina 1900–2015:

1. A relatively constant trend in GDP per capita growth at an average of 1.2% annually, with a relatively stable variance throughout the period.
2. Excess volatility of consumption over output.
3. A negative correlation between GDP growth and the trade balance.
4. Large of effects of commodity price shocks on all key business cycle variables.
5. A negative relation between interest spreads and commodity prices.

3. A two-sector small open economy model

We build on the small open economy model formulated by Aguiar and Gopinath (2007) and García-Cicco et al. (2010), which in turn

Table 1
Business cycle moments 1900–2015.

	GDP growth	Cons. growth	Inv. growth	Trade balance
Mean	1.17%	1.12%	1.40%	−0.04%
Standard deviation	5.27%	5.84%	19.16%	4.76%
Persistence	0.14	0.05	0.34	0.72
Correlation with GDP growth	1	0.86	0.76	−0.07
Correlation with Cons. growth	0.86	1	0.49	−0.11
Correlation with inv. growth	0.76	0.49	1	−0.20
Correlation with trade balance	−0.07	−0.11	−0.20	1

Notes: GDP, consumption, and investment growth are real and in per capita terms. The trade balance is defined as total exports minus total imports, scaled by GDP. Persistence is the coefficient from an estimated AR(1) process. The frequency of the data is annual.

[15] In a previous version of the paper we additionally used a real interest rate measure directly provided by the world bank. This series is also based on the IMF lending rate measure but uses the official Argentine GDP deflator to obtain a real series, which we chose to avoid. The results are available on request.

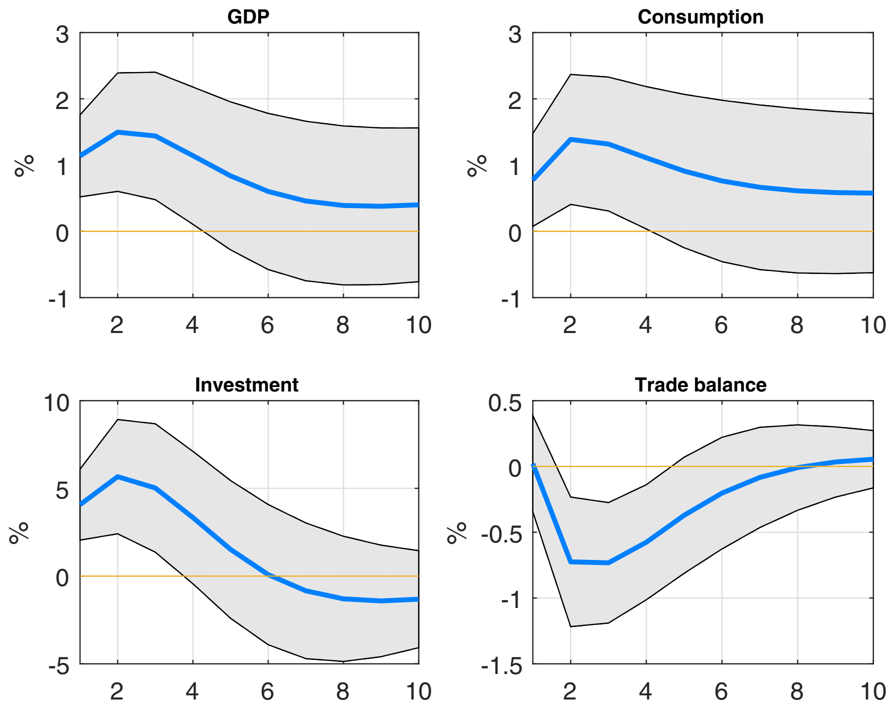

Fig. 3. Impulse responses to 1 S.D. commodity price shock.
Note: The structural shock is identified using Cholesky ordering. 80% confidence bands are plotted, as suggested by Sims and Zha (1999). GDP, consumption, and investment are real, in per-capita terms and in log-levels. The trade balance is defined as exports net of imports divided by GDP.

build on Mendoza (1991).[16] Our model adds two elements absent in their analysis. First it allows for a second sector to capture the distinctive role of commodities present in many emerging economies. Second, as in Shousha (2016), the model embeds a negative relation between the interest rate premium and commodity prices, consistent with the empirical evidence presented above. The model nests the various sources of shocks identified in previous work and allows for a double-role of commodity prices. Increases in commodity prices improve both the competitiveness of the economy (which is a net commodity exporter) and the economy's borrowing terms, as higher prices are associated with lower spreads between the country's borrowing rates and world interest rates.

We begin by describing the technology. There are two sectors in the economy: a final-good sector and a commodity-producing sector. The final good is produced by combining capital K_t^1, commodity inputs $\tilde{M}_t$, and labor N_t^1. It can be consumed, invested and exported or imported. The production function in the final good sector is

$$Y_t = a_t\left(K_t^1\right)^{\alpha_K}\left(\tilde{M}_t\right)^{\alpha_M}\left(X_tN_t^1\right)^{1-\alpha_K-\alpha_M}. \tag{3}$$

Commodities can be produced domestically using capital K_t^2 and labor N_t^2; they can be used as an intermediate input in final goods production or traded on international markets. The production function in the commodity sector is

$$\tilde{Y}_t = \tilde{a}_t\left(K_t^2\right)^{\tilde{\alpha_K}}\left(X_tN_t^2\right)^{1-\tilde{\alpha_K}}. \tag{4}$$

In the production functions, a_t and $\tilde{a}_t$ capture total factor productivities, which are exogenous and assumed to be stationary. X_t is the nonstationary level of labor-augmenting technology common to both sectors. We denote the gross growth rate of the nonstationary technology as $g_t = X_t/X_{t-1}$, which is stochastic with mean g. X_t is introduced to capture shocks to the trend, which has been a key focus in the literature on emerging market business cycles.[17] The price of the final good is normalized to 1 and the price of commodities $\tilde{p}_t$ is exogenously given on world markets and subject to shocks. We assume that a_t, $\tilde{a}_t$, g_t, and $\tilde{p}_t$ follow stochastic processes which will be specified further below.

Firms in both sectors rent capital and hire labor in competitive input markets. The total stock of capital in the economy K_t is measured in final goods and is divided between the two production technologies, so that

$$K_t = K_t^1 + K_t^2. \tag{5}$$

Capital depreciates at rate δ and is accumulated through investment I_t which gives

$$K_{t+1} = (1-\delta)K_t + I_t. \tag{6}$$

The economy is populated by a representative household who supplies the two types of labor, owns and rents out the capital stock, and borrows from abroad. The budget constraint is given by

$$C_t + K_{t+1} + D_t + S_t + \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - g\right)^2 = r_t^{k1}K_t^1 + r_t^{k2}K_t^2 + w_t^1N_t^1 + w_t^2N_t^2 + (1-\delta)K_t + \frac{D_{t+1}}{1+r_t}, \tag{7}$$

[16] We abstract from nominal frictions and the important question of fixed versus nominal exchange rate choice. See for example Frankel (2004), and Mitchener and Pina (2016), who examine the costs and benefits of fixed exchange rates. For a modeling framework that incorporates nominal elements, we refer readers to Gali and Monacelli (2005) and the literature that built on their seminal contribution.

[17] See in particular Aguiar and Gopinath (2007). The fact that in our model the nonstationary technology is common to both sectors ensures that the model admits a non-stochastic balanced growth path (BGP), as shown in Appendix C.

Table 2
Regression results.

LHS variable	Real spread (calculated from domestic lending rate)				
	(1)	(2)	(3)	(4)	(5)
Commodity price	−0.200***	−0.199***	−0.214***	−0.210***	−0.203***
	(0.049)	(0.045)	(0.051)	(0.051)	(0.050)
Output growth		−0.434**			−0.406
		(0.206)			(0.241)
Trade balance			−0.252		−0.164
			(0.224)		(0.385)
Debt-to-GDP ratio				−0.033	0.015
				(0.036)	(0.062)
Constant	0.023*	0.034**	0.024*	0.041*	0.026
	(0.012)	(0.012)	(0.012)	(0.024)	(0.034)
Observations	21	21	21	21	21
R-squared	0.462	0.568	0.497	0.485	0.573

Note: The real spread is calculated by deflating the domestic lending rate, provided by the IMF, with a corrected inflation measure (see Cavallo, 2013), and then subtracting the UK real rate. The commodity price is in log deviations from mean, as plotted in Fig. 2, Panel (b). Appendix A provides details on the sources of the other regressors.
Standard errors in parentheses
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

where C_t is final good consumption, D_t denotes the level of (real) debt, and $\frac{D_{t+1}}{1+r_t}$ is newly issued debt at net interest rate r_t. S_t is exogenous government spending, where $s_t = S_t/X_{t-1}$ will follow a stochastic process to be specified further below. r_t^{kj} and w_t^j, $j = 1, 2$, are the returns from renting out capital and supplying labor to the two sectors, respectively. Note that in equilibrium the expected return on capital will equalize across the two sectors. The presence of $\phi > 0$ captures investment adjustment costs faced by the household.

The household's objective is to maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \nu_t \beta^t \frac{\left[C_t - \theta\omega^{-1} X_{t-1} \left(N_t^1\right)^{\omega} - \theta\tilde{\omega}^{-1} X_{t-1} \left(N_t^2\right)^{\tilde{\omega}}\right]^{1-\gamma} - 1}{1-\gamma} \tag{8}$$

with $\gamma > 0$, subject to the relevant constraints and a no-Ponzi condition. The parameter β is the discount factor and ν_t captures shocks to preferences. The utility function features Greenwood et al. (1988) preferences, which eliminate the wealth effect on labor supply. Note that the presence of X_{t-1} ensures a constant labor supply along the non-stochastic BGP. The Frisch elasticity of labor supply will be determined by ω and $\tilde{\omega}$, and θ governs the weight on the relative disutility of labor.

Based on the small open economy assumption, the steady state real interest rate is exogenously given. In particular, r_t is determined by the world interest rate r^* and a spread (or premium) term which is further composed of three additive terms:

$$r_t = r^* + \psi\left(e^{D_{t+1}^*/X_t - d^*} - 1\right) + \xi\left(\ln\left(\tilde{p}_t\right) - \ln(\tilde{p})\right) + \left(e^{\mu_t - 1} - 1\right). \tag{9}$$

The first term of the spread in Eq. (9) is standard in the literature. Following Schmitt-Grohe and Uribe (2003), it is assumed that the premium is increasing in the (detrended) level of debt. The presence of D_{t+1}^* is taken as exogenous by the representative household but $D_{t+1} = D_{t+1}^*$ holds in equilibrium. This debt-elastic interest rate ensures a stationary solution of the model after detrending.[18]

The second term determining the spread $r_t - r^*$ captures the robust empirical observation, discussed in detail in Section 2.4, that commodity prices strongly affect interest rate premia of commodity exporting economies. The parameter ξ governs the sensitivity of the interest rate spread with respect to commodity price deviations from steady state and can be calibrated to the corresponding parameter we estimated in Section 2.4. Our approach here is to embed the relation between $r_t - r^*$ and $\tilde{p}_t$ in a reduced-form fashion, similar to Shousha (2016) and Fernández et al. (2015), who also document further empirical evidence in line with our findings. While we do not provide a complete formal rationalization of the relationship and focus mainly on the resulting implications for emerging economy business cycles, the link between commodity prices and interest rate premia can be derived from first principles following different approaches. Specifically, the negative relation between $r_t - r^*$ and $\tilde{p}_t$ may result from the effect of commodity prices on the country's repayment capacity to international creditors. This could come in the form of a borrowing constraint, in which the value of the country's collateral depends directly on commodity prices through export earnings. Creditors decrease the required interest rate premium when commodity prices increase, as the collateral value of the economy is higher.[19] Min et al. (2003) provide empirical evidence for this particular channel, showing that export earnings and better repayment capacity bring down yield spreads. Alternatively, a possible mechanism could entail financial frictions in which domestic firms (rather than the government) borrow against collateral, which is positively linked to the terms of trade, and a relaxation in these constraints leads to a fall in credit spreads.[20]

Finally, the last term in the rate spread in Eq. (9) allows for a simple interest rate premium shock, similar to the one specified in García-Cicco et al. (2010). Since it is central to our objective to trace out the effects of commodity price movements for the economy, we also allow for the presence of μ_t in order to capture possible exogenously driven movements in the interest premium that are unrelated to commodity prices and thereby avoid hardwiring into the model that interest rate movements must be related to commodity prices. An alternative interpretation of this shock is of course an innovation in global interest rates (rather than the interest rate premium). We do not take a strong stance on this distinction in the analysis. From the domestic economy's perspective, exogenous changes in the premium and the global interest rate have similar effects on the domestic interest rate.

Our modeling choice is arguably restrictive, as apart from commodity prices we only allow one additional shock to directly affect interest rates via the last term in the spread. This restrictiveness has the benefit of allowing a direct comparison of the relative importance of the mechanism we introduce vis-à-vis a collection of exogenous disturbances which are defined in the same way as in García-Cicco et al. (2010). These authors also estimate their model on Argentine data over a similar time period and their results therefore provide our preferred benchmark for the estimation results.

Eqs. (3) to (9) feature a set of exogenous disturbances to technology, preferences and prices, $\{a_t, \tilde{a}_t, g_t, \tilde{p}_t, s_t, \nu_t, \mu_t\}$, which we specify to follow autoregressive processes in logs that are subject to stochastic shocks $\left\{\epsilon_t^a, \epsilon_t^{\tilde{a}}, \epsilon_t^g, \epsilon_t^{\tilde{p}}, \epsilon_t^s, \epsilon_t^{\nu}, \epsilon_t^{\mu}\right\}$. The shocks are normally distributed with mean zero and standard deviations $\{\sigma_a, \sigma_{\tilde{a}}, \sigma_g, \sigma_p, \sigma_s, \sigma_\nu, \sigma_\mu\}$. The processes for g_t, s_t and $\tilde{p}_t$ have deterministic means different

[18] See also Lubik (2007) for further discussion.

[19] In Appendix E we formally illustrate this idea in a simple setting that gives rise to the postulated relation.

[20] Akinci (2017), for example, generates a countercyclical country risk premium by introducing financial frictions in the spirit of Bernanke et al. (1999) to the economy's firm sector. Her model does not feature a commodity sector, but an extension to include it seems natural. Fernández et al. (2015) allow *future* commodity prices to affect the spread. In justifying their modeling assumptions regarding the relation between spreads and commodity prices, they make very similar arguments to the ones we have provided here.

from 1 that are parametrized as g, s, and $\tilde{p}$, and which will be calibrated to match business cycle moments of the steady state model. We specify autoregressive processes of order one for all shock processes, but allow the log of the commodity price $\tilde{p}_t$ to follow an AR(2). This enables us to calibrate the parameters to the ones obtained from the SVAR analysis in Section 2.3. The processes are

$$\ln(a_t) = \rho_a \ln(a_{t-1}) + \epsilon_t^a \tag{10}$$

$$\ln(\tilde{a}_t) = \rho_{\tilde{a}} \ln(\tilde{a}_{t-1}) + \epsilon_t^{\tilde{a}} \tag{11}$$

$$\ln\left(\frac{g_t}{g}\right) = \rho_g \ln\left(\frac{g_{t-1}}{g}\right) + \epsilon_t^g \tag{12}$$

$$\ln\left(\frac{s_t}{s}\right) = \rho_s \ln\left(\frac{s_{t-1}}{s}\right) + \epsilon_t^s \tag{13}$$

$$\ln(\nu_t) = \rho_\nu \ln(\nu_{t-1}) + \epsilon_t^\nu \tag{14}$$

$$\ln(\mu_t) = \rho_\mu \ln(\mu_{t-1}) + \epsilon_t^\mu \tag{15}$$

and

$$\ln\left(\frac{\tilde{p}_t}{\tilde{p}}\right) = \rho_{\tilde{p}}^1 \log\left(\frac{\tilde{p}_{t-1}}{\tilde{p}}\right) + \rho_{\tilde{p}}^2 \log\left(\frac{\tilde{p}_{t-2}}{\tilde{p}}\right) + \epsilon_t^{\tilde{p}}. \tag{16}$$

The model features the following resource constraints. In the final good sector the resource constraint is given by

$$Y_t = C_t + I_t + S_t + \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - g\right)^2 + TB_t \tag{17}$$

where TB_t denotes the trade balance in final goods. The commodity market resource constraint reads as

$$\tilde{p}_t\tilde{Y}_t = \tilde{p}_t\tilde{M}_t + \tilde{TB}_t, \tag{18}$$

where $\tilde{TB}_t$ denotes the real commodity trade balance, that is, net exports of commodities measured in terms of final goods. Carrying out some further national accounting, we compute the GDP and the total trade balance of the economy, both measured in terms of final goods, as

$$Y_t^{GDP} = Y_t + \tilde{p}_t\tilde{Y}_t - \tilde{p}_t\tilde{M}_t \tag{19}$$

$$TB_t^{Total} = TB_t + \tilde{TB}_t. \tag{20}$$

The complete list of optimality conditions derived in this model is provided in Appendix C. The Appendix also contains the derivation of a normalized version of the model that is stationary, that is, where all variables that grow in equilibrium are divided by X_{t-1}. This results in a stationary system in normalized variables, which we denote with lower case letters, and which we solve numerically with standard perturbation techniques. We carry out both a calibration exercise and a structural estimation of the model in order to asses the quantitative contribution of different shocks to fluctuations in the main macroeconomic aggregates.

4. Calibration and business cycle characteristics

The goal of this section is to study the business cycle characteristics of the model that are induced by shocks to the commodity price. To do so, we calibrate all structural parameters of the model, including the parameters governing the stochastic process of $\ln(\tilde{p}_t)$.

Table 3
Model calibration.

Parameter	Value	Calibration target/source
$\tilde{p}$	0.5244	Target commodity net exports to GDP in the data (8.60%)
d^*	−0.001	Target trade balance to GDP in the data (−0.041%)
s	0.0189	Target gov't spending to GDP in the data (9.38%)
ξ	−0.199	Estimated coefficient in Section 2.4
g	1.0117	Average GDP growth in the data
ψ	2.8	Estimate of García-Cicco et al. (2010)
α_k	0.32	García-Cicco et al. (2010)
α_m	0.05	Shousha (2016)
$\tilde{\alpha}_k$	0.32	Impose equal capital share across both sectors
δ	0.1255	García-Cicco et al. (2010)
ϕ	6	Roughly match impact responses in SVAR
β	0.93	Steady state interest rate ≈ 10%
γ	2	Standard value in business cycle analysis
θ	1.6	$N^1 + N^2 \approx 1/3$
$\omega, \tilde{\omega}$	1.6	Standard in SOE literature
$\rho_{\tilde{p}}^1$	0.95	Estimated SVAR coefficient (Section 2.3)
$\rho_{\tilde{p}}^2$	−0.13	Estimated SVAR coefficient (Section 2.3)
$\sigma_{\tilde{p}}$	0.1064	Estimated SVAR coefficient (Section 2.3)

We then generate impulse response functions, focusing exclusively on commodity price shocks.[21]

4.1. Calibration

Table 3 summarizes our baseline calibration. Many of the parameter values are standard in business cycle research, but several are worth highlighting. Both the mean of the commodity sector productivity $\tilde{a}_t$ as well as the steady state relative price of commodities $\tilde{p}$ can be adjusted to determine the relative size of the two sectors in the economy. We have normalized the mean technology in both sectors to 1 - as can be seen in Eqs. (10) and (11) - and find the value of $\tilde{p}$ that matches the ratio of net exports of commodities to GDP observed in Argentine data (8.60%).[22] This pins down the relative size of the commodity price sector that is in line with Argentine data. The parameter d^* in Eq. (9) is calibrated to match the average trade balance to output ratio in the data (−0.041%, consistent with Table 1). We calibrate the mean of the exogenous spending process s to match the average government spending to GDP ratio observed in the data (9.38%). The parameter ξ, which governs the sensitivity of the interest rate spread to commodity prices, is calibrated to the value obtained from the regressions in Section 2.4. To be conservative, we take the lower bound of −0.199 among the statistically significant estimates we have obtained across a broad range of regression specifications. The average technology growth rate of the economy g is set directly to 1.0117 in order to generate the observed mean output growth in the data. We impose equal capital shares in both sectors ($\alpha_k = \tilde{\alpha}_k$) and set the commodity share in the final goods production to $\alpha_m = 0.05$ following Shousha (2016). The parameter ψ is typically positive but close to zero in the small open economy literature (see e.g. Schmitt-Grohe and Uribe, 2003). The estimation results of García-Cicco et al. (2010), however, highlight that the data support a larger value of this parameter. In particular, a large value is necessary to generate a standard deviation of the trade balance roughly as big as the one of output growth and a decreasing autocorrelation function of the trade balance. We therefore set $\psi = 2.8$ in line with their posterior estimate.[23] We set the adjustment cost parameter to $\phi = 6$, slightly higher than in one-sector models in the literature because

[21] We provide impulse responses functions to all other shocks in Appendix D.

[22] To compute this target ratio in the data, we use a broad measure of commodity exports which includes manufactures of commodities. Due to data availability we use an annual sample starting in 1980.

[23] In our estimation exercise we proceed similar to García-Cicco et al. (2010) and estimate ψ.

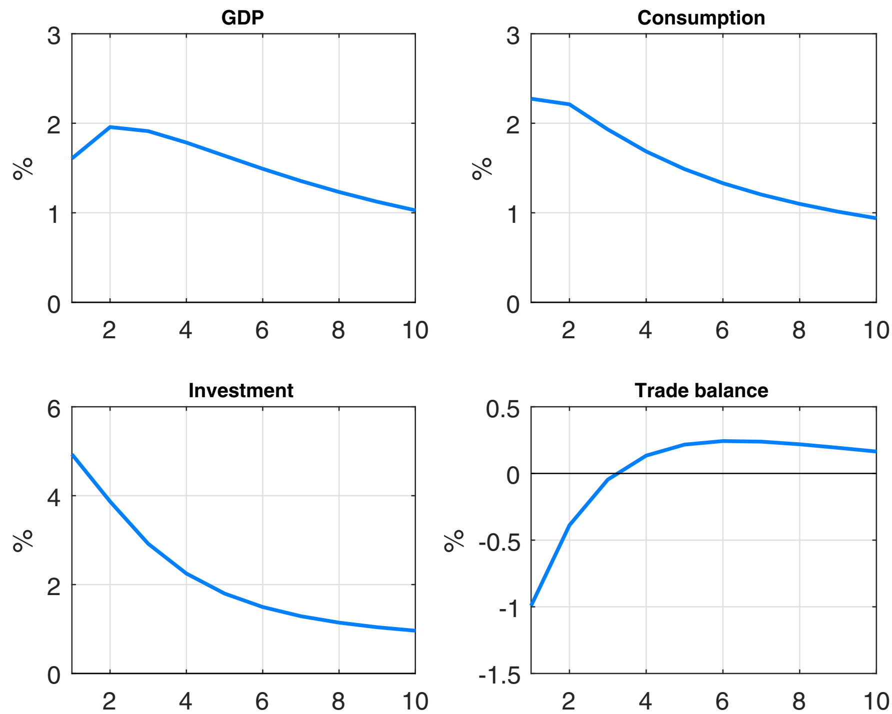

Fig. 4. Impulse response functions to commodity price shock.
Notes: Model impulse response functions to a one-standard deviation commodity price shock $\epsilon_t^{\tilde{p}}$, using the calibration described in the text.

this reduces the impact response of the economy to commodity shocks, which is needed to match our SVAR results (lower values would overstate the effect of commodity prices).[24] The stochastic process of $\ln(\tilde{p}_t)$ is calibrated to be in line with the estimated SVAR coefficients in Section 2.3, which gives $\rho_{\tilde{p}}^1 = 0.95$, $\rho_{\tilde{p}}^2 = -0.13$, and $\sigma_{\tilde{p}} = 0.1064$.

4.2. Impulse response functions to commodity price shocks

Fig. 4 displays the impulse response functions to a one-standard deviation commodity price shock $\epsilon_t^{\tilde{p}}$, using the calibration described above. The figure shows that the responses on impact are in line with the stylized facts of the business cycle of Argentina highlighted in Section 2. Positive commodity price shocks boost the economy by increasing total output, consumption, and investment. The investment response is the strongest, and the consumption response is larger in magnitude than the output response. The total trade balance response is negative, rendering total net exports countercyclical.

To understand the mechanism behind the dynamics visible in Fig. 4, note that commodity prices in the model give rise to two effects. The first effect goes through commodity trade revenues. The economy needs to trade off the cost of more expensive commodity inputs in the production of final goods with the benefits of being able to produce and export commodities at higher prices (thus generating trade revenues). The second effect is governed by the negative sensitivity of the interest spread $r_t - r^*$ to commodity prices present in Eq. (9) and based on the empirical evidence in Section 2.4. Both of these effects are necessary to generate the responses in Fig. 4. To highlight this, Figs. 5 and 6 open up the double role of commodity prices in our model, by plotting impulse response functions for the two effects separately and inspecting them across the two sectors of the economy. In both cases, the responses of consumption and investment growth are omitted.

Fig. 5 studies the first effect of commodity price shocks, which we dub "competitiveness effect." The figure plots the responses of GDP and the total trade balance to a commodity price shock when setting $\xi = 0$, that is, shutting off the channel through the interest rate, which we will analyze separately below. It also breaks down these responses into the dynamics in both sectors, that is, the final good sector and the commodity sector, separately. What the left panels of the figure reveal is that after a commodity prices increase, the value-added in the commodity sector increases significantly, as higher international prices make it attractive to increase production and exports. The final good sector actually suffers, as intermediate commodity inputs necessary to produce final goods become more expensive. This effect, however, is dwarfed by the boom in the commodity sector and total production in the economy increases. The trade balances in the two sectors, shown in the right panels of the figure, move in different directions. The economy starts exporting more commodities and importing final goods, as the former are very attractive to sell abroad and the latter less attractive to produce domestically. Looking at the two sectors together, the *total* trade surplus increases with the commodity price increase. This highlights that the first effect alone does not generate a countercyclical *total* trade balance, which is a salient feature in emerging economy business cycle data.

Fig. 6 shows the dynamics arising from the second effect, which we call "borrowing cost effect." The figure plots the IRFs of total GDP and the total trade balance to a simple interest rate shock. This shock is (qualitatively) isomorphic to an increase in commodity prices that only goes through the presence of $\tilde{p}_t$ in Eq. (9) but that does not *directly* affect production in either sector.[25] It thus completely shuts off the competitiveness channel described above and only shows the

[24] Note that the literature in general gives little guidance on sensible values for ϕ.

[25] For the purpose of the comparison, the standard deviation of the interest rate shock is calibrated to have the same maximum output response as the total response in Fig. 4. The persistence is set to 0.9.

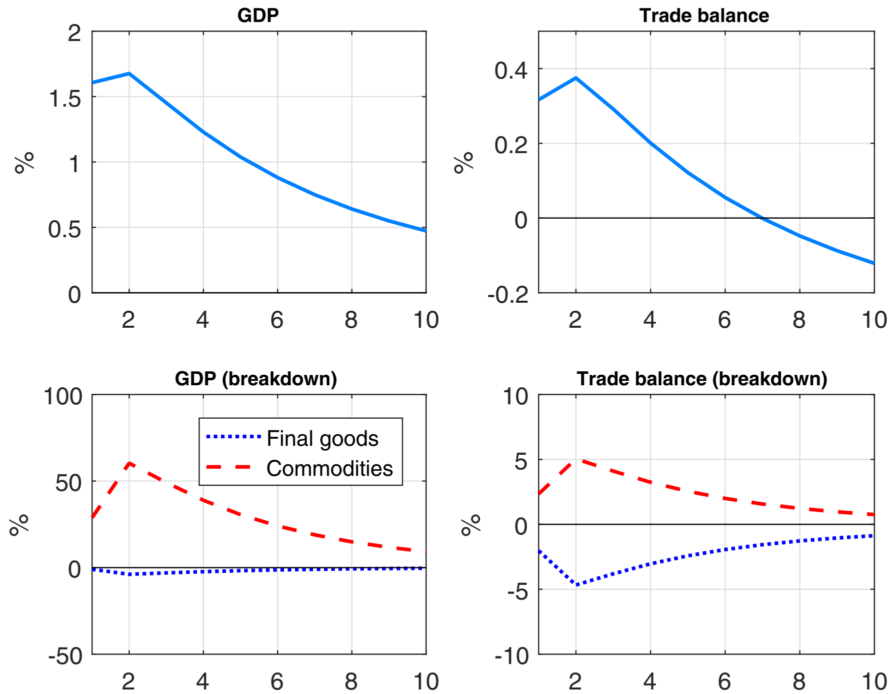

Fig. 5. Breakdown of IRFs: no interest rate channel ($\xi = 0$).
Notes: Model impulse response functions to a one-standard deviation commodity price shock $\epsilon_t^{\tilde{p}}$, using the calibration described in the text but setting $\xi = 0$.

effect that commodity price have through the spread between the economy's borrowing rate and the world interest rate. As before, the figure breaks down the response by displaying the dynamics in each sector separately. The figure shows that the exogenous fall in borrowing rates allows households and firms to bring resources to the present by borrowing funds and decreasing the final good trade balance, that is, importing final goods. Some of these resources will be consumed (consumption goes up on impact, not shown in the figure), and some will be invested into capital (investment goes up on impact, not shown in the figure) in order to produce final goods and maintain a smooth path of consumption. Some of the capital will also be used to produce commodities, which are a required intermediary

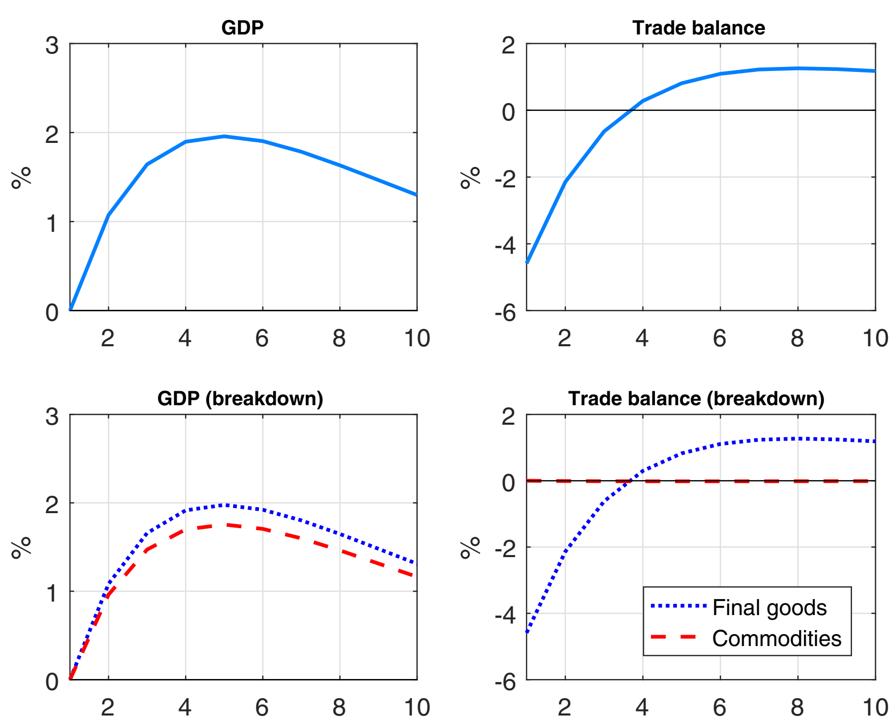

Fig. 6. Breakdown of IRFs: pure interest rate shock.
Notes: Model impulse response functions to a one-standard deviation interest rate shock ϵ_t^{μ}, using the calibration described in the text.

input to final good production. This gives a slow and hump-shaped increase in the GDP of each sector and of the total economy. Hence, the total trade balance falls and output increases, but not on impact. This lack of impact response in output stands in contrast with the empirical impulse responses and suggests that this channel alone cannot mimic the data.

In conclusion, the double-role of commodity prices in our model, through the *joint* impact of the competitiveness and the borrowing cost channels, gives rise to dynamics that are well in line with the empirical regularities observed in Argentina, as shown by comparing the SVAR results from Fig. 3 with the model responses presented in Fig. 4. This insight further highlights the importance of endogenously countercyclical spreads for aggregate fluctuations in commodity exporting economies, as recently also noted by Fernández et al. (2015) and Shousha (2016).[26]

We emphasize again that the focus of the calibration exercise in this section lies on explaining the dynamics that arises from commodity shocks alone. This is done to highlight our mechanism in light of the facts present in the data.[27] In order to systematically gauge the fraction of aggregate fluctuations that can be accounted for by commodity price shocks, in comparison to all other shocks, we move on to estimating the model in the next section.

5. Estimation: assessing the quantitative contribution of different sources of shocks in emerging economies

In this section our goal is to assess the quantitative contribution of different shocks to aggregate fluctuations in emerging economies for which commodity exports are potentially important. To do so, we take the model to Argentine data and structurally estimate it with the goal of running a "horse race" between the various shocks that possibly drive the business cycle. We maintain the calibration of most of the parameters (see Table 3), and estimate the stochastic processes of the exogenous disturbances defined by Eqs. (10) to (16). In addition, we also estimate two key structural parameters. The first is at the heart of our mechanism: ξ, which governs the sensitivity of the real interest rate spread to commodity prices. Estimating this parameter allows the data to speak about the strength of this mechanism within our model structure. Furthermore, we estimate ψ, a parameter that governs the trade balance dynamics in the economy.[28] In carrying out the estimation exercise, we give equal footing to all different shocks, which correspond to the candidate triggers previously proposed in the literature.

5.1. Estimation specification

We carry out a Bayesian estimation defining standard priors on the estimated parameters. We run a Markov Chain Monte Carlo (MCMC) algorithm to obtain draws from the marginal posterior distributions of the parameters.[29] We then compute forecast error variance decompositions as well as historical variance decompositions of the observables at the estimated posterior modes. To estimate the model we add the following measurement equations

$$\Delta \ln Y_t^{GDP,obs} = \ln Y_t^{GDP} - \ln Y_{t-1}^{GDP} \tag{21}$$

Table 4
Estimated parameters and priors.

Parameter	Prior	Mean	Std. dev.
ξ	Normal	−0.199	0.045
ψ	Normal	2.8	0.5
$\rho_{\tilde{p}}^1$	Beta	0.8	0.2
$-\rho_{\tilde{p}}^2$	Beta	0.15	0.1
$\sigma_{\tilde{p}}$	Inverse-Gamma	0.05	2
ρ_i	Beta	0.5	0.2
σ_i	Inverse-Gamma	0.05	2
$i = a, \tilde{a}, g, s, \nu, \mu$			

$$\Delta \ln C_t^{obs} = \ln C_t - \ln C_{t-1} \tag{22}$$

$$\Delta \ln I_t^{obs} = \ln I_t - \ln I_{t-1} \tag{23}$$

$$TB^{Total,obs}/Y_t^{GDP,obs} = TB_t^{Total}/Y_t^{GDP}, \tag{24}$$

where $\Delta lnY_t^{GDP,obs}, \Delta lnC_t^{obs}, \Delta lnI_t^{obs}$ and $\Delta TB^{Total,obs}$ correspond to the empirically observed time series which we analyzed in Section 2.[30] The variables on the right hand side of Eqs. (21) to (24) are model concepts defined in Section 3.[31] As explained above, we estimate the parameters governing the stochastic processes of all shocks, as well as ξ and ψ (all other parameters are calibrated as before). Table 4 summarizes the priors imposed on the parameters. As is standard in the estimation of DSGE models, we use beta priors on the persistence parameters and inverse-gamma priors on the standard deviations. The parameter values of the priors are the same as in Smets and Wouters (2007) and a number of related papers, except for the commodity price process. Since the latter is specified as an AR(2), we use priors that at the mode impose the same maximum root as for the other disturbances.[32] We set identical scale parameters on the standard deviation of the shocks to remain agnostic about the relative importance of the different shocks. We put a normal prior on ξ, which is centered around the smallest statistically significant regression estimate from Section 2.4, with the standard deviation equal to the standard error obtained from the regression. Finally, our prior on ψ, also normal, is centered around the estimate obtained by García-Cicco et al. (2010).

5.2. Estimation results

How large is the contribution of different structural shocks to the variation in output, consumption, investment and the trade balance in emerging economies? We address this question using the results in Table 5. Panel (a) of the table shows the results of an (infinite horizon) forecast error variance decomposition based on the posterior estimates of our model using Argentine data from 1900 through to 2015.[33] For each of the variables used as observables, this gives the share of variation that can be explained by a particular shock. We begin by focusing on the commodity price shock, as this

[26] Recent work by Ben Zeev et al. (2017) and Farias and da Silva (2017) focuses on commodity price news shocks. These news shocks might also be connected with (and in fact be capturing) the interest rate effect, a link that deserves further exploration.

[27] In Appendix D we report the IRFs to all of the other shocks we have defined in the model.

[28] The importance of estimating this parameter has been stressed by García-Cicco et al. (2010).

[29] We take 10 million draws. We discard the first 25% of draws and keep the remaining ones for inference. The acceptance ratio is 27.3%.

[30] In principle we could add the commodity price series, which we used for parts of the calibration of the model, as an observable. However, since the Grilli and Yang (1988) may capture some dynamics unrelated to prices actually faced by Argentina, and an Argentina-specific index is only available for a much shorter sample, our preferred specification is to estimate the model without this observable and then compare the model-implied commodity price process with the empirically observed index. See the discussion further below.

[31] Note that while we solve the (linearized) model in variables that are normalized by X_{t-1} (see Appendix C), we here use growth rates in the original non-normalized variables. This is possible, as the implied nonstationary variables can be recomputed from the model solution.

[32] $\rho_{\tilde{p}}^1 = 0.8$ and $\rho_{\tilde{p}}^2 = -0.15$ imply that the larger root of the process 0.5, which is the same for an AR(1) processes with $\rho = 0.5$.

[33] Table 8 in the appendix reports posterior mean and credible intervals of the individual parameters we estimate.

Table 5
Variance decomposition for baseline estimation.

	Stationary technology	Nonstat. technology	Interest rate	Comm. price	Spending shock	Pref. shock
(a) Baseline sample from 1900–2015						
Output growth	51.15%	20.55%	1.12%	21.67%	0.19%	5.33%
Consumption growth	35.32%	10.87%	3.24%	24.02%	1.51%	25.05%
Investment growth	11.68%	2.15%	23.8%	34.11%	1.9%	26.35%
Trade balance	1.19%	2.53%	64.71%	16.33%	2.08%	64.71%
(b) Shorter sample from 1950–2015						
Output growth	39.14%	20.57%	0.69%	37.97%	0.08%	1.54%
Consumption growth	28.47%	11.72%	2.01%	42.28%	1.14%	14.39%
Investment growth	9.48%	2.57%	15.35%	61.11%	0.50%	10.99%
Trade balance	1.28%	3.03%	52.83%	31.56%	0.42%	10.87%

Notes: Forecast error variance decomposition (at infinite horizon) of the observables used for estimation, calculated at the posterior modes. Stationary technology is the sum of the contribution of a_t and $\tilde{a}_t$. These estimates are obtained from the baseline estimation specification explained in the text.

is the main difference with respect to Aguiar and Gopinath (2007) and García-Cicco et al. (2010). As the table reveals, a sizable fraction of output (21.67%), consumption (24.02%) and investment growth (34.11%) can be explained by commodity price shocks. This confirms the intuition we derived from the calibration exercise and from the responses that were present in our SVAR analysis.

Turning to the other shocks, the table shows that our estimation attributes most of the variation in output growth (51.15%) to transitory technology shocks (the table reports the joint contribution of a_t and $\tilde{a}_t$). This finding is in line with García-Cicco et al. (2010). We do not, however, confirm their conclusion regarding the very small contribution of shocks to nonstationary technology à la Aguiar and Gopinath (2007). We find the contribution of these shocks to be sizable, explaining 20.55% of the variation in output growth in Argentina.[34] Preference shocks and interest shocks also play an important role in understanding the business cycle. The former, affecting directly the intertemporal choices of the household, explains in particular consumption and investment growth, as well as trade balance variation, while the latter also contributes substantially to the variance of investment growth. The government spending (endowment) shock is generally found to be unimportant, which is in line with the previous literature.

To shed further light on our findings with respect to commodity prices, in Fig. 7 we plot two series. The first one, indicated with the dashed black line, corresponds to the model-implied commodity price process, that is, the time series of $\tilde{p}_t$ obtained from feeding the estimated shocks $\epsilon_t^{\tilde{p}}$ into Eq. (16) and setting the parameters $\rho_{\tilde{p}}^1$ and $\rho_{\tilde{p}}^2$ to their estimated posterior mode. The second series, indicated with a solid blue line, shows the real commodity price index, which we have plotted and used for calibrating parts of the model above. It is apparent that, reassuringly, the two time series broadly share common features, such as a similar volatility and reasonably synchronized movements. This is particularly the case in the post-1950 period, while the war and interwar period give rise to some large level differences between the two price series. The wars are special periods in which trade barriers an production are affected, giving room to large swings in trade and commodity prices that were not connected in the way our theory would prescribe. (Trade barriers fluctuated significantly during this period, opening a volatile gap between international commodity prices and the actual prices received by Argentine producers.) Furthermore, we point out that the commodity price index by Grilli and Yang (1988) captures world commodity prices and not necessarily those commodity prices faced by Argentina. With growing financial integration, the global cross-section of commodity prices has become more correlated over time and thus may render the index more closely related to the actual commodity prices faced by Argentina in the later parts of the estimation sample.

Given these concerns, we re-estimated the model using a subsample of the data from 1950 to 2015. The results of the forecast error variance decomposition are shown in Table 5, Panel (b). In this sample, the quantitative contribution of commodity price shocks is estimated to be even larger. Commodity price shocks explain 37.97% of the variance in output growth, 42.28% in consumption growth and 61.11% in investment growth. The relative importance of other shocks remains broadly similar in this sample.

While we primarily focus on comparing our quantitative results to García-Cicco et al. (2010), as these authors use a similarly long sample for Argentina, our findings are also broadly in line with comparable recent work on commodity price shocks in emerging markets that

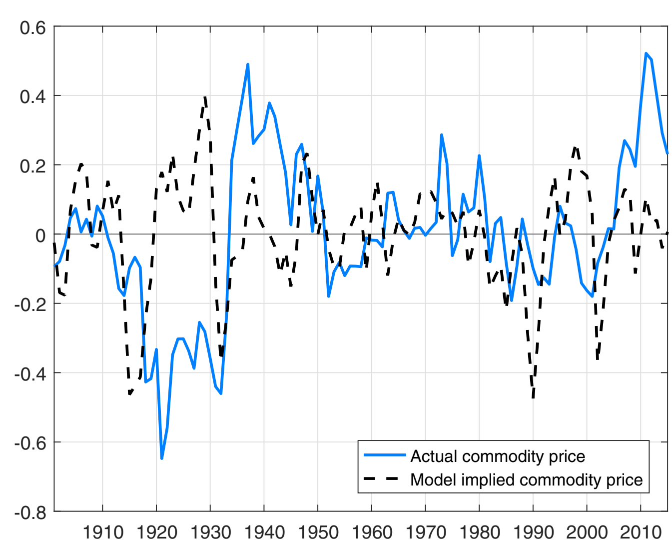

Fig. 7. Estimated and actual process for commodity prices.
Note: The blue solid line repeats the commodity price series from Fig. 2. The dashed black line is the commodity price process $\tilde{p}_t$ that is implied by the posterior estimates of the parameters and shocks of the estimated model.

[34] Interestingly, Akinci (2017) also finds both types of technology shocks to be important in the context of a model that features financial frictions and time-varying risk premia. This is in contrast with Chang and Fernandez (2013), who find that nonstationary productivity shocks play a minor role relative to stationary TFP and interest shocks, broadly confirming the results of García-Cicco et al. (2010). None of these studies feature a role for commodity prices.

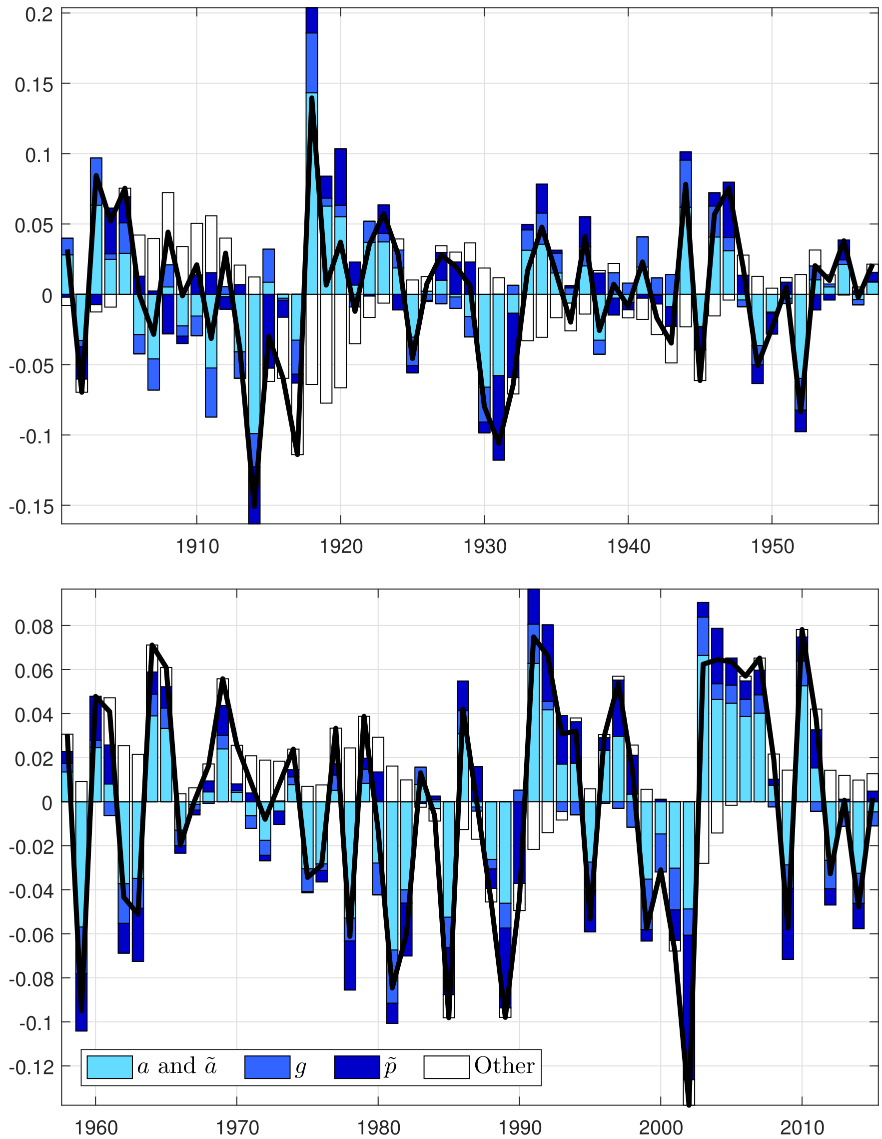

Fig. 8. Historical decomposition of Argentine output growth 1900–2015.
Note: The line displays the actual time series of real GDP per capita growth, which is used as one of the observables in the estimation. The bars represent the contribution of different shocks to the movements in this series at a given point in time. The estimates are obtained using the baseline estimation specification explained in the text. "Other" includes ν, s, μ and the contribution of initial values, which is negligible.

has estimated quantitative models on shorter samples. Fernández et al. (2015), for example, estimate that the share of commodity shocks in the variance of real output across a number of emerging economies is 42%, a number that is very similar to our post-1950 estimate.

In addition to the decomposition given in Table 5, which is a theoretical object computed at the posterior modes, it is also possible to construct a *historical* variance decomposition that breaks down the movements of a variable *at a given point in the actual data sample* into the contribution of the different shocks. Fig. 8 presents such a decomposition for Argentine output growth from 1900 to 2015. The black line displays the actual time series of growth in real GDP per capita, which is used as one of the observables in the estimation. The bars represent the contribution of different shocks to the movements in the output time series at given points in time. Overall, the figure mirrors the insights from Table 5, given that commodity price shocks and technology shocks (of both types), capture most of the variation in output growth. Fig. 8, in addition, enables us to inspect particular episodes in the economic history of Argentina, as scrutinized for example by Taylor (2014), and interpret them through the lens of our model.

Taken altogether, our results suggest that commodity prices should feature prominently in the analysis of business cycles in emerging economies. In terms of quantitative contribution, we find that they are among the three most important shocks in driving output growth in Argentina. Importantly, shocks to international commodity prices, in contrast to inherently very different concepts such as domestic TFP shocks, are easier to measure and identify, and eventually act upon, by policy makers.

5.3. Further discussion: measurement of GDP

How "direct" is the effect of commodity price variation on real GDP? The relative price $\tilde{p}_t$ directly enters the calculation of real GDP in our model, but national accounting techniques in practice may not reflect the full variation in relative prices in the way our measurement

Eq. (19) prescribes.[35] It is therefore of interest to break down the variation in GDP resulting from commodity price fluctuations into the share that comes directly from $\tilde{p}_t$ and the share that arises from the endogenous changes in quantities following commodity price changes. This latter effect on quantities would be the only source of change in measured real GDP if the statistical office kept prices constant in its measurement. If this share of the variation is important, then the effect of commodity price shocks on GDP that we measure would be more robust to the specific measurement of real GDP in practice.

To study this question, Fig. 10 in the Appendix plots two alternative measures of GDP from a simulation exercise. The exercise consists of feeding observed commodity prices into the model, holding all other disturbances constant, and then computing two alternative GDP measures. The first measure is Y_t^{GDP} computed as in Eq. (19), whereas the second one, $Y_t^{GDP^*}$, computes the economy's GDP holding commodity prices fixed at their steady state value $\tilde{p}$, that is,

$$Y_t^{GDP^*} = Y_t + \tilde{p}\tilde{Y}_t - \tilde{p}\tilde{M}_t. \tag{25}$$

The figure shows that the two resulting series are very similar, and the variation in $Y_t^{GDP^*}$ accounts for most of the variation in Y_t^{GDP}.[36] This highlights that the economy's endogenous dynamics in response to changes in international commodity prices accounts for the major bulk in the variation of total real value added. This makes the results in our paper robust to different methods used to measure real GDP.

6. Conclusion

This paper has sought to answer a classical question in International Macroeconomics: what causes the large swings in economic activity in emerging markets? The literature has proposed a variety of triggers, but remains split on the answers. We study the question anew, combining a model that nests the previous sources of shocks advanced in the literature and historical data for Argentina going back to 1900.

The model features two key elements. First, it allows for a second sector to capture the separate role of commodities in the economy. Specifically, the analysis focuses on the case of a net commodity exporting country, facing exogenous price changes. Second, the model embeds a negative relation between the interest rate premium and commodity prices, which is consistent with the empirical evidence. Exogenous increases in commodity prices improve both the competitiveness of the economy and its borrowing terms through the negative effect of higher prices on the spread between the country's borrowing rates and world interest rates. Both effects jointly result in strongly positive effects of commodity price movements on GDP, consumption, and investment, and a negative effect on the total trade balance. They also generate an excess response of consumption over output.

We estimate the model using data on Argentina from 1900 to 2015 to provide a quantitative evaluation of the various sources of shocks and their effect on macroeconomic aggregates. Our estimate of the contribution of commodity price shocks to fluctuations in output growth of Argentina is in the order of 22%. Furthermore, commodity prices account for 24% and 34% of the variation in consumption and investment growth, respectively. The contribution of these shocks is even bigger on a post-1950 data sample, accounting for 38% of the variance of output growth, 42% of consumption, and 61% of investment. We also find a role for non-stationary productivity shocks - albeit much smaller than the one documented in Aguiar and Gopinath (2007), though bigger than García-Cicco et al. (2010) - and an important role for stationary productivity shocks, consistent with previous findings.

Though in this paper we do not address normative issues, the results offer hope. Insofar as part of the cycle can be accounted for by observable variables (international commodity prices) that cannot be manipulated for political goals, contingent macroeconomic policies can be designed to help mitigate the cycle. Given the nature of the driver, sovereign wealth funds may offer a promising avenue for tackling volatility in commodity producing countries like Argentina. A proper normative analysis would require, at a minimum, an extension of the model to incorporate default, a task we leave for future work.

Appendix A. Details on data

A.1. GDP and its components

Data on real GDP, Investment, Consumption, Government Spending and Net Exports from 1900 through to 2009 come from Ferreres (2005) - Ferreres has extended these series to 2009. We extend the data further to 2015 using the corresponding series from the Argentine Finance Ministry "Ministerio de Economia (Ejecución Presupuestaria de la Administración Nacional)," available online. The growth rate of the latter series was applied to Ferreres' 2009 figure.

A.2. Commodity prices

Data on world commodity prices are based on the Grilli and Yang (1988) commodity price index series updated by Pfaffenzeller et al. (2007), which runs from 1900 through to 2011. We update the series to 2015, following Pfaffenzeller et al.'s (2007) procedure.

The Argentina-specific price index is constructed using Argentine export weights available in the UN Comtrade data base. We match these weights with commodity-specific price indeces provided by the World Bank. This is done for the broad commodity categories fuel, timber, food, beverages and fertilizer from 1962.

As a deflator for the commodity price series we use the index of US-dollar import prices for Argentina provided by Pfaffenzeller et al. (2007), which we update till 2015 using the figures from INDEC. For robustness we also tried manufacturing prices (expressed in US dollars), and the US consumer price index, available via FRED. The results remain broadly unchanged using these deflators.

A.3. World real interest rate

To measure global real interest rates we use the UK nominal interest rate series published by the Bank of England from 1900 through 2015 and subtract the UK inflation rate provided by the UK Office for National Statistics (ONS).

[35] This could be due to base-year pricing, chain-linking or simply due to price mismeasurement or interpolation. Kehoe and Ruhl (2008), for example, argue that changes in the terms of trade have no first-order effect if output is measured as chain-weighted real GDP.

[36] The R-squared from regressing one series on the other is 0.95.

A.4. Domestic real interest rates

We use the nominal domestic lending rate, savings rate and money market rate, provided by the IMF International Financial Statistics. We deflate these series using the corrected inflation measure available at http://.inflacionverdadera.com/. See Cavallo (2013) for a discussion.

A.5. Government debt

Data on Debt-to-GDP ratios come from Argentina's national statistical office, INDEC (Online, Table 7.10).

Appendix B. Additional regression results

Table 6
Additional regression results: using the lending rate.

LHS variable	Real spread (based on savings rate)				
	(1)	(2)	(3)	(4)	(5)
Commodity price	−0.131	−0.123	−0.174	−0.138	−0.188
	(0.111)	(0.113)	(0.117)	(0.116)	(0.119)
Output growth		−0.317			−0.259
		(0.426)			(0.427)
Trade balance			−0.526		−1.398
			(0.478)		(0.906)
Debt-to-GDP ratio				−0.020	0.154
				(0.075)	(0.139)
Constant	−0.113***	−0.107***	−0.106***	−0.102*	−0.176**
	(0.026)	(0.027)	(0.026)	(0.050)	(0.075)
Observations	25	25	25	25	25
R-squared	0.057	0.080	0.106	0.060	0.183

Note: The real spread is calculated by deflating the domestic savings rate, provided by the IMF, with a corrected inflation measure (see Cavallo, 2013), and then subtracting the UK real rate. The commodity price is in log deviations from mean, as plotted in Fig. 2, Panel (b). Appendix A provides details on the sources of the other regressors.
Standard errors in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Table 7
Additional regression results: using the money market rate.

LHS variable	Real spread (based on money market rate)				
	(1)	(2)	(3)	(4)	(5)
Commodity price	−0.183	−0.165	−0.175	−0.162	−0.178
	(0.187)	(0.184)	(0.206)	(0.196)	(0.207)
Output growth		−0.941			−0.931
		(0.641)			(0.661)
Trade balance			0.088		−0.579
			(0.829)		(1.377)
Debt-to-GDP ratio				0.052	0.107
				(0.122)	(0.203)
Constant	0.031	0.044	0.030	0.003	−0.004
	(0.038)	(0.039)	(0.042)	(0.078)	(0.102)
Observations	34	34	34	34	34
R-squared	0.029	0.092	0.029	0.035	0.101

Note: The real spread is calculated by deflating the money market rate, provided by the IMF, with a corrected inflation measure (see Cavallo, 2013), and then subtracting the UK real rate. The commodity price is in log deviations from mean, as plotted in Fig. 2, Panel (b). Appendix A provides details on the sources of the other regressors.
Standard errors in parentheses
***$p < 0.01$.
**$p < 0.05$
*$p < 0.1$

Appendix C. Model details

C.1. Optimality conditions

C.1.1. Firms

The first-order conditions for final goods producers with respect to K_t^1, N_t^1 and $\tilde{M}_t$ are

$$r_t^{k1} = \alpha_K a_t \left(K_t^1\right)^{\alpha_K - 1} \left(\tilde{M}_t\right)^{\alpha_M} \left(X_t N_t^1\right)^{1-\alpha_K-\alpha_M} \tag{26}$$

$$w_t^1 = (1 - \alpha_K - \alpha_M)\, a_t \left(K_t^1\right)^{\alpha_K} \left(\tilde{M}_t\right)^{\alpha_M} \left(X_t N_t^1\right)^{-\alpha_K-\alpha_M} X_t \tag{27}$$

$$\tilde{p}_t = \alpha_M a_t \left(K_t^1\right)^{\alpha_K} \left(\tilde{M}_t\right)^{\alpha_M - 1} \left(X_t N_t^1\right)^{1-\alpha_K-\alpha_M}. \tag{28}$$

The first-order conditions for commodity producers with respect to K_t^1 and N_t^1 are

$$r_t^{k2} = \tilde{\alpha_K} \tilde{p}_t \tilde{a}_t \left(K_t^2\right)^{\tilde{\alpha_K} - 1} \left(X_t N_t^2\right)^{1-\tilde{\alpha_K}} \tag{29}$$

$$w_t^2 = (1 - \tilde{\alpha_K})\, \tilde{p}_t \tilde{a}_t \left(K_t^2\right)^{\tilde{\alpha_K}} \left(X_t N_t^2\right)^{-\tilde{\alpha_K}} X_t \tag{30}$$

C.1.2. Representative household

Setting up the dynamic Lagrangian

$$\begin{aligned}\mathcal{L} = \sum_{t=0}^{\infty} \nu_t \beta^t \Bigg\{ & \frac{\left[C_t - \theta\omega^{-1} X_{t-1} (N_t^1)^{\omega} - \theta\tilde{\omega}^{-1} X_{t-1} (N_t^2)^{\tilde{\omega}}\right]^{1-\gamma} - 1}{1-\gamma} \\ & - X_{t-1}^{-\gamma} \lambda_t \Bigg[C_t + K_{t+1}^1 + K_{t+1}^2 + D_t + S_t + \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - g\right)^2 \\ & - r_t^{k1}\left(K_t^1\right) - r_t^{k2}\left(K_t^2\right) - w_t^1 N_t^1 - w_t^2 N_t^2 - (1-\delta)K_t^1 - (1-\delta)K_t^2 - \frac{D_{t+1}}{1+r_t} \Bigg] \Bigg\},\end{aligned} \tag{31}$$

the first-order conditions with respect to C_t, N_t^1, N_t^2, D_{t+1}, K_{t+1}^1, and K_{t+1}^2 are derived as follows:

$$\left[C_t - \theta\omega^{-1} X_{t-1} \left(N_t^1\right)^{\omega} - \theta\tilde{\omega}^{-1} X_{t-1} \left(N_t^2\right)^{\tilde{\omega}}\right]^{-\gamma} = \lambda_t X_{t-1}^{-\gamma} \tag{32}$$

$$\left[C_t - \theta\omega^{-1} X_{t-1} \left(N_t^1\right)^{\omega} - \theta\tilde{\omega}^{-1} X_{t-1} \left(N_t^2\right)^{\tilde{\omega}}\right]^{-\gamma} \theta X_{t-1} \left(N_t^1\right)^{\omega-1} = \lambda_t X_{t-1}^{-\gamma} w_t^1 \tag{33}$$

$$\left[C_t - \theta\omega^{-1} X_{t-1} \left(N_t^1\right)^{\omega} - \theta\tilde{\omega}^{-1} X_{t-1} \left(N_t^2\right)^{\tilde{\omega}}\right]^{-\gamma} \theta X_{t-1} \left(N_t^2\right)^{\tilde{\omega}-1} = \lambda_t X_{t-1}^{-\gamma} w_t^2 \tag{34}$$

$$\nu_t \lambda_t X_{t-1}^{-\gamma} = \beta(1 + r_t) X_t^{-\gamma} \mathbb{E}_t(\nu_{t+1}\lambda_{t+1}) \tag{35}$$

$$\nu_t \lambda_t X_{t-1}^{-\gamma}\left[1+\phi\left(\frac{K_{t+1}}{K_t}-g\right)\right] = \beta X_t^{-\gamma}\mathbb{E}_t\left\{\nu_{t+1}\lambda_{t+1}\left[r_{t+1}^{k1}+1-\delta+\phi\left(\frac{K_{t+2}}{K_{t+1}}-g\right)\frac{K_{t+2}}{K_{t+1}} -\frac{\phi}{2}\left(\frac{K_{t+2}}{K_{t+1}}-g\right)^2\right]\right\} \tag{36}$$

$$\nu_t \lambda_t X_{t-1}^{-\gamma}\left[1+\phi\left(\frac{K_{t+1}}{K_t}-g\right)\right] = \beta X_t^{-\gamma}\mathbb{E}_t\left\{\nu_{t+1}\lambda_{t+1}\left[r_{t+1}^{k2}+1-\delta+\phi\left(\frac{K_{t+2}}{K_{t+1}}-g\right)\frac{K_{t+2}}{K_{t+1}} -\frac{\phi}{2}\left(\frac{K_{t+2}}{K_{t+1}}-g\right)^2\right]\right\} \tag{37}$$

Note that Eqs. (36) and (37) imply that the expected return on capital is equalized across the two sectors in the economy.

C.2. Stationary version of equilibrium

Imposing market clearing and denoting $c_t = \frac{C_t}{X_{t-1}}$, $k_t^1 = \frac{K_t^1}{X_{t-1}}$, $k_t^2 = \frac{K_t^2}{X_{t-1}}$ etc., and using the fact that $g_t = X_t/X_{t-1}$, the first-order conditions (32) to (37) can be rewritten in stationary form as:

$$\left[c_t-\theta\omega^{-1}\left(N_t^1\right)^{\omega}-\theta\tilde{\omega}^{-1}\left(N_t^2\right)^{\tilde{\omega}}\right]^{-\gamma}=\lambda_t \tag{38}$$

$$\left[c_t-\theta\omega^{-1}\left(N_t^1\right)^{\omega}-\theta\tilde{\omega}^{-1}\left(N_t^2\right)^{\tilde{\omega}}\right]^{-\gamma}\theta\left(N_t^1\right)^{\omega-1} = \lambda_t g_t^{(1-\alpha_K-\alpha_M)}(1-\alpha_K-\alpha_M)a_t\left(k_t^1\right)^{\alpha_K}(\tilde{m}_t)^{\alpha_M}\left(N_t^1\right)^{-\alpha_K-\alpha_M} \tag{39}$$

$$\left[C_t-\theta\omega^{-1}\left(N_t^1\right)^{\omega}-\theta\tilde{\omega}^{-1}\left(N_t^2\right)^{\tilde{\omega}}\right]^{-\gamma}\theta\left(N_t^2\right)^{\tilde{\omega}-1} = \lambda_t g_t^{(1-\tilde{\alpha}_K)}\left(1-\tilde{\alpha}_K\right)\tilde{p}_t\tilde{a}_t\left(k_t^2\right)^{\tilde{\alpha}_K}\left(N_t^2\right)^{-\tilde{\alpha}_K} \tag{40}$$

$$\lambda_t=\beta(1+r_t)g_t^{-\gamma}\mathbb{E}_t\left(\frac{\nu_{t+1}}{\nu_t}\lambda_{t+1}\right) \tag{41}$$

$$\tilde{p}_t=\alpha_M g_t^{(1-\alpha_K-\alpha_M)}a_t\left(k_t^1\right)^{\alpha_K}(\tilde{m}_t)^{\alpha_M-1}\left(N_t^1\right)^{1-\alpha_K-\alpha_M} \tag{42}$$

$$\nu_t\lambda_t\left[1+\phi\left(\frac{k_{t+1}}{k_t}g_t-g\right)\right] = \beta g_t^{-\gamma}\mathbb{E}_t\left\{\nu_{t+1}\lambda_{t+1}\left[g_t^{1-\alpha_K-\alpha_M}\alpha_K a_{t+1}\left(k_{t+1}^1\right)^{\alpha_K-1}(\tilde{m}_{t+1})^{\alpha_M}\left(N_{t+1}^1\right)^{1-\alpha_K-\alpha_M} +1-\delta+\phi\left(\frac{k_{t+2}}{k_{t+1}}g_{t+1}-g\right)\frac{k_{t+2}}{k_{t+1}}-\frac{\phi}{2}\left(\frac{k_{t+2}}{k_{t+1}}g_{t+1}-g\right)^2\right]\right\} \tag{43}$$

$$\nu_t\lambda_t\left[1+\phi\left(\frac{k_{t+1}}{k_t}g_t-g\right)\right] = \beta g_t^{-\gamma}\mathbb{E}_t\left\{\nu_{t+1}\lambda_{t+1}\left[g_t^{1-\tilde{\alpha}_K}\tilde{\alpha}_K\tilde{p}_{t+1}\tilde{a}_{t+1}\left(k_{t+1}^2\right)^{\tilde{\alpha}_K-1}\left(N_{t+1}^2\right)^{1-\tilde{\alpha}_K} +1-\delta+\phi\left(\frac{k_{t+2}}{k_{t+1}}g_{t+1}-g\right)\frac{k_{t+2}}{k_{t+1}}-\frac{\phi}{2}\left(\frac{k_{t+2}}{k_{t+1}}g_{t+1}-g\right)^2\right]\right\} \tag{44}$$

The remaining equations of the system that define the stationary equilibrium are given by the budget constraint (with factor prices eliminated), the production functions and the interest rate equation, all normalized in the same way, i.e. by

$$c_t+k_{t+1}g_t+\tilde{p}_t\tilde{m}_t+d_t+s_t+\frac{\phi}{2}\left(\frac{k_{t+1}}{k_t}g_t-g\right)^2=y_t+\tilde{p}_t\tilde{y}_t+(1-\delta)k_t+\frac{d_{t+1}}{1+r_t}g_t \tag{45}$$

$$y_t=a_t\left(k_t^1\right)^{\alpha_K}(\tilde{m}_t)^{\alpha_M}\left(N_t^1\right)^{1-\alpha_K-\alpha_M} \tag{46}$$

$$\tilde{y}_t=\tilde{a}_t\left(k_t^2\right)^{\tilde{\alpha}_K}\left(N_t^2\right)^{1-\tilde{\alpha}_K} \tag{47}$$

$$r_t=r^*+\psi\left(e^{d_{t+1}-d^*}-1\right)-\xi\left(\log\left(\tilde{p}_t\right)-\log\left(\tilde{p}\right)\right)+\left(e^{\mu_t-1}-1\right) \tag{48}$$

and by the stochastic processes (10) to (16) in the body of the paper. The total trade balance and GDP of the economy can be calculated accordingly.

C.3. Steady state

To compute the steady state, we can proceed as follows:

1. Drop all time subscripts.
2. Steady state must fulfill $r = r^* = \frac{1}{\beta}g^{-\gamma}-1$ and $d = d^*$ from Eqs. (41) and (48).
3. Solve Eq. (44) for the steady state capital-labor ratio in the commodity sector as a function of primitives
4. Combine Eqs. (38) and (39) through λ. Plug in the capital-labor ratio. It is possible to solve analytically for N^2 as a function of primitives. Using the capital-labor ratio, can solve for k^2.
5. Combine Eqs. (38), (40), (42), and (43) to eliminate λ, k^1, $\tilde{m}$. Obtain an equation for N^1 as an implicit function of primitives. Solve this equation for N^1 *numerically*.
6. Use the equations combined in the previous step to solve for k^1 and $\tilde{m}$ given the solution for N^1.
7. Use the budget constraint to solve for c.

Appendix D. Additional model results

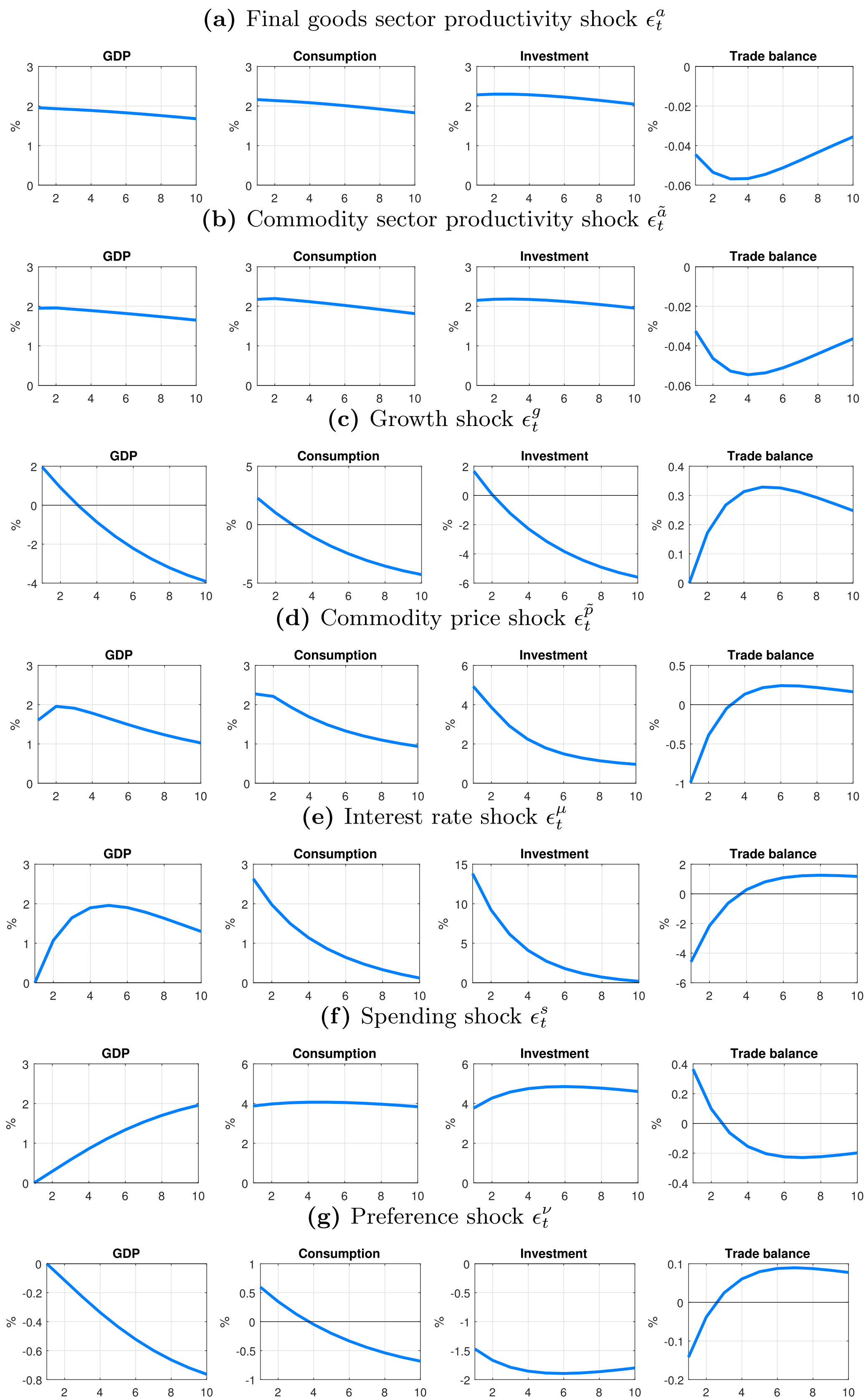

Fig. 9. Impulse response functions to different shocks.
Note: All shocks have been re-scaled to give the same maximum GDP growth response as the commodity price shock in the body of the paper.

Table 8
Posterior estimates of parameters.

Parameter	Prior mean	Posterior mean	90% HPD interval	
ξ	0.199	0.2212	0.1550	0.2876
ψ	2.8	3.2057	2.5050	3.8984
ρ_a	0.5	0.8277	0.7494	0.9092
$\rho_{\tilde{a}}$	0.5	0.5887	0.2827	0.8980
ρ_g	0.5	0.5244	0.3199	0.7299
ρ_ν	0.5	0.8687	0.8382	0.8996
ρ_s	0.5	0.6440	0.5075	0.7832
ρ_μ	0.5	0.9199	0.8743	0.9693
$\rho^1_{\tilde{p}}$	0.8	0.8060	0.6840	0.9388
$-\rho^2_{\tilde{p}}$	0.15	0.1278	0.0105	0.2298
σ_a	0.10	0.0295	0.0231	0.0360
$\sigma_{\tilde{a}}$	0.10	0.0525	0.0242	0.0810
σ_g	0.10	0.0261	0.0193	0.0327
σ_ν	0.10	0.4582	0.4145	0.5000
σ_s	0.10	0.1876	0.1659	0.2089
σ_μ	0.10	0.0547	0.0410	0.0683
$\sigma_{\tilde{p}}$	0.10	0.1765	0.0876	0.2652

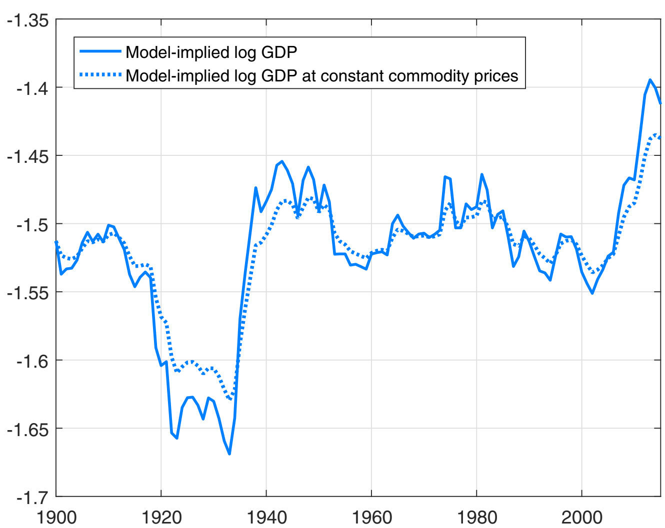

Fig. 10. Simulated GDP under different price measurement.
Note: The blue solid line shows the economy's GDP, computed as in Eq. (19), when feeding in commodity prices and holding all other disturbances constant. The dotted line repeats the same exercise but computes GDP at the steady state relative price of commodities, that is, $\tilde{p}_t = \tilde{p}$.

Appendix E. Interest rate premia and commodity prices: simple formal illustration

Suppose there is a borrower who borrows amount D_t. With probability λ she is able to repay in full. With probability $1-\lambda$ only a repayment smaller than the borrowed amount D_t can be made. This repayment is a fraction ϕ of commodity output $\tilde{p}_t\tilde{y}_t$ (equivalently, $\tilde{p}_t\tilde{y}_t$ can be thought of as collateral which the lender can seize when full repayment is not possible). The presence of a risk-neutral lender who herself can obtain funds at the risk-free rate r^* and who faces perfect competition, will result in the following zero profit condition:

$$(1+r^*)D_t = \lambda(1+r_t)D_t + (1-\lambda)\phi\tilde{p}_t\tilde{y}_t, \tag{1}$$

which can be rearranged to

$$r_t = \frac{1+r^*}{\lambda} - \frac{1-\lambda}{\lambda D_t}\phi\tilde{p}_t\tilde{y}_t - 1. \tag{2}$$

As can be seen from Eq. (2), an increase in $\tilde{p}_t$ reduces the interest rate r_t, ceteris paribus. This is the key assumption of our model we aim to rationalize with the above illustration. Furthermore, and also consistent with our formulation in Eq. (9), r_t is increasing in the level of debt D_t.

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