The business cycle and copper mining in Chile

Fernando Fuentes and Carlos J. García

ABSTRACT

This article “endogenizes” the copper supply, incorporating demand for mining-sector inputs represented by other goods in the economy (specifically, intermediate goods) and also energy into a dynamic stochastic general equilibrium (DSGE) model for a sample of the 2003-2013 period. The model estimation reveals that a rise of 1% in the copper price leads to a 0.16% increase in gross domestic product (GDP) over five years. The main contribution of the study is to show that, if the mining sector is treated as integrated into the rest of the economy rather than being assumed to be an enclave, as it usually is, the effects of the copper price on the Chilean economy at least double.

KEYWORDS Business cycles, economic development, copper industry, mining, econometric models, Chile

JEL CLASSIFICATION E17, E27, E37, L72

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I
Introduction

The main purpose of this study is to measure the contribution of the mining sector to the Chilean business cycle by constructing and estimating a dynamic stochastic general equilibrium (DSGE) model[1] that explicitly includes the sector's connections with other production sectors.

In the first place, it should be noted that there is a huge literature of DSGE models for small open economies that analyse the effects on the economy of the price of a mining commodity on the assumption that the production (supply) of the commodity is exogenous. Examples of such studies include Dib (2008); Bems and De Carvalho Filho (2011); Bodenstein, Erceg and Guerrieri (2011); García, Restrepo and Tanner (2011); Lama and Medina (2012); Natal (2012), and García and González (2014). A similar perspective is also common in the DSGE models developed by a number of central banks, including those of Australia (Jääskelä and Nimark, 2008), Canada (Murchison and Rennison, 2006), New Zealand (Lees, 2009), Chile (Medina and Soto, 2007) and Spain (Andrés, Burriel and Estrada, 2006).

In models where production of the commodity is incorporated exogenously, its influence on the DSGE model is wholly confined to fluctuations in its price. There are two ways of modelling this price, as an exogenous shock (see, for example, García and González, 2014) or as a value endogenously determined by the structures representing the rest of the world in the model (Laxton and Pesenti, 2003). In the latter case, the whole international economy must be modelled, not just the country concerned, and as a result the first alternative has been more popular than the second in the literature of recent years.

As an alternative to what has been described, there has been little literature endogenizing the production of a mining commodity in a DSGE model. Two seminal articles are those of Gross and Hansen (2013) and Veroude (2012), who introduce elements of the vast literature on optimal extraction into a simple DSGE model that is calibrated but has no frictions and no external sector.[2] Both articles start by assuming a production function for ore extraction that depends on labour, capital K and ore reserves R. Thus, mining firms are subject to two constraints, capital formation and the depletion of ore reserves, which can be expanded by new finds of ore. However, the most salient point in these articles is that endogenizing production opens up the possibility of the mining sector drawing in resources from the wider economy. In other words, the mining sector ceases to be an "enclave" and is "integrated" with the other sectors of the economy, so that the effects of mining on the economy are multiplied.

This article synthesizes the two approaches. First, it takes a full DSGE model where the external sector and short-term nominal and real frictions are modelled. Second, it endogenizes supply in the production of copper, incorporating demand for mining-sector inputs in the rest of the economy. In addition, the model is estimated using Bayesian econometrics with a view to obtaining an empirical measure of the contribution of the mining sector to the Chilean economy over the last 10 years (quarterly information for 2003-2013), focusing the analysis on two key variables: gross domestic product (GDP) growth and the real exchange rate.

The present article is organized as follows: section II summarizes the correlation between mining and the business cycle, section III presents the DSGE model, section IV gives the results and section V presents the conclusions of the study.

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[1] Studies produced recently but with a different methodology from this article's include Aroca (2000), De Gregorio (2009) and Álvarez and Fuentes (2004), who analyse growth in the mining sector, linking it to Chile's comparative advantage in ore extraction. Other research has concentrated on the sectoral economic repercussions of mining. This is the case with Aroca (2000), Acevedo and others (2006) and COCHILCO (2013), where the elasticities of the mining sector relative to other economic sectors are calculated using an input-output matrix. Meller (2013) presents an econometric model that uses a reduced form equation to relate growth in the Chilean economy to mining activity. The results indicate that the more copper exports expand, the more the economy grows, a rebuttal, according to the study, of the hypothesis that the boom in the copper sector over the last decade might have caused Dutch disease.

[2] This literature sets out to identify the point up to which extraction of a non-renewable resource is optimal (see, for example, Bohn and Deacon, 2000).

II

The copper mining sector and the Chilean business cycle

This section presents evidence for the dynamic correlations between the mining sector and the business cycle in the Chilean economy. The sample used depended on the availability of data. Ideally, though, it was quarterly, covering the period from 2000 to 2013.

The correlation-type analysis indicated was chosen because: it can be used to examine the interaction between the mining sector and the business cycle in Chile over the last decade; it provides information additional to that yielded by the studies cited earlier about the impact of the mining sector on the economy; and, most importantly, it provides a way into the analysis to be carried out in estimating the DSGE model, with mining-sector output being incorporated endogenously.

The cross-correlations between the economic series representing the mining sector m (copper price, mining GDP or both) and the macroeconomic series y (GDP, consumption, real exchange rate, investment, etc.) are measured as follows:

$$r_{m,y}\left(l\right)=\frac{C_{m,y}\left(l\right)}{\sqrt{C_{m,m}\left(0\right)}\sqrt{C_{y,y}\left(0\right)}} \qquad l=0,+1,+2,\ldots \quad (1)$$

where:

$$C_{m,y}\left(l\right)=\sum_{t=1}^{T-l}\left(\left(m_i-\bar{m}\right)\left(y_{i+l}-\bar{y}\right)\right)\Big/T \qquad l=0,1,2,\ldots$$

$C_{m,y}$ (l) covariance between m and y.
$C_{m,m}$ (0) variance of m.
$C_{y,y}$ (0) variance of y.

What equation (1) can estimate is whether the variables representing the mining sector "anticipate" movements in the macroeconomic series, coincide with them or are simply unrelated. Thus, it is established that the mining variable m precedes the cycle of a macroeconomic variable by $T–l$ periods (quarters or years) if this correlation is significant (positive or negative) for $T–l>0$ (García, Jaramillo and Selaive, 2007). The statistical significance of a specific correlation, i.e., whether this correlation is different from zero, is measured by analysing whether the value of the correlation is or is not outside a confidence band of two standard deviations, represented by: $\pm 2\big/\sqrt{N}$, where N is the number of observations.

Table 1 measures the dynamic correlations between the copper price and macroeconomic aggregates: private consumption, private investment, exports and imports, all measured in real terms. All the variables were expressed in quarterly growth rates.[3] These correlations indicate that future consumption growth, GDP, investment and imports covary positively with present changes in the copper price. Nonetheless, it is important to stress that the analysis in this area only deals with comovement between variables and not causality. Thus, it is illustrative to confirm that the copper price weakly but positively "anticipates"[4] variables such as aggregate investment.

Conversely, total exports do not evince any kind of future comovement with the copper price. This is an important fact because not only is there no positive dynamic correlation, but there is no negative one, which would be indicative for example of symptoms of Dutch disease, i.e., a situation in which a very high copper price could be causing real exchange-rate appreciation and thereby undermining the competitiveness of the industrial sector.

Table 2 shows the results of dynamic correlations between the copper price and levels of GDP by branch of economic activity. This price covaries positively with the commerce sector in the first place, and then with the industrial sector, although it is important to note that the correlation with the industrial and commerce sectors does not necessarily indicate a positive causal influence from the mining sector, as there could also be a third variable or economic force (such as the international business cycle) that is affecting all the variables in the same direction. Lastly, there is no evidence of the copper price covarying either with construction or with agriculture.

[3] One alternative is to use the cyclical component of the decomposition carried out with the Hodrick-Prescott filter (García, Jaramillo and Selaive, 2007; Restrepo and Soto, 2006).

[4] Hereinafter, "weak" is to be understood as meaning that a correlation is statistically significant but very close to the confidence band.

TABLE 1

Dynamic correlations between the copper price and macroeconomic aggregates

Quarters	Gross domestic product (GDP)	Investment	Consumption	Imports	Exports
0	0.2937	0.1904	0.3835[a]	0.4512[a]	0.1554
1	0.3206[a]	0.4203[a]	0.3614[a]	0.5708[a]	0.1168
2	0.2073	0.3018	0.344[a]	0.375[a]	0.0982
3	0.0892	0.024	0.2043	-0.0009	0.1235
4	0.1085	0.067	0.1617	-0.116	-0.0797
5	0.1622	0.0108	0.0893	0.0291	0.1754
6	-0.1683	-0.0088	-0.1586	-0.0656	-0.1762
7	-0.116	0.1954	-0.0876	0.0458	-0.0793
8	0.0827	0.1532	-0.0661	0.0885	0.0465
9	0.0704	-0.0134	0.0109	-0.0995	0.0425
10	-0.0493	-0.0072	-0.1058	-0.135	-0.0886
11	-0.2165	-0.2155	-0.1847	-0.2669	-0.2138
12	-0.1457	-0.1611	-0.0875	-0.0769	-0.0872
13	-0.11	-0.079	-0.0837	-0.0323	0.0885
14	-0.1072	-0.0961	-0.011	-0.0107	0.0442
15	-0.0836	-0.2022	-0.0872	-0.0378	0.0141
16	-0.0427	0.0193	-0.0162	-0.0462	-0.1344

Source: Prepared by the authors, on the basis of the sources given in annex 2.

[a] Significant and greater than two standard errors.

TABLE 2

Dynamic correlations between the copper price and gross domestic product (GDP) by branch of economic activity

Quarters	Agriculture	Commerce	Industry	Construction	Transport
0	0.0541	0.4254[a]	0.3835[a]	0.2145	0.1253
1	0.2793	0.3213[a]	0.3614[a]	0.2398	0.2316
2	0.0023	0.2837[a]	0.344[a]	0.1318	0.3091[a]
3	-0.1391	0.2115	0.2043	0.0443	0.0914
4	0.0821	0.1765	0.1617	-0.0559	0.1263
5	0.2889	0.016	0.0893	0.1723	0.045
6	0.0356	-0.3144[a]	-0.1586	-0.0085	-0.3754[a]
7	-0.1641	0.01	-0.0876	0.2086	-0.2536
8	-0.0475	0.0411	-0.0661	0.1244	0.0651
9	-0.0109	0.0358	0.0109	0.0414	0.1082
10	0.0533	-0.1916	-0.1058	0.0219	0.0007
11	-0.1664	-0.1448	-0.1847	-0.1833	-0.2772[a]
12	-0.0656	-0.1104	-0.0875	-0.0954	-0.101
13	0.132	-0.1883	-0.0837	-0.1429	-0.1712
14	-0.097	-0.159	-0.011	-0.0557	-0.1168
15	-0.0181	-0.0456	-0.0872	-0.0481	-0.0861
16	-0.0533	0.0603	-0.0162	0.0004	0.0053

Source: Prepared by the authors.

[a] Significant and greater than two standard errors.

Table 3 uses annual data to show the dynamic correlations between the copper price and fiscal spending and revenue, expressed as percentages of GDP. As was to be expected, there is a contemporary correlation between the copper price and fiscal revenue from copper. One finding that stands out, though, is that changes in the copper price anticipate increases in the different fiscal expenditure items as shares of GDP. This outcome is consistent with a fiscal rule whereby copper revenues are to be spent over time (García, Jaramillo and Selaive, 2007) and not immediately.

Table 4 uses quarterly data to show dynamic correlations between the copper price and external-sector variables, measured as percentages of GDP (current account and foreign investment), together with dollar-denominated export growth rates. All the variables were measured in each year's dollars, including the current account and foreign investment, and then divided by GDP in dollars. The results indicate that the copper price anticipates foreign investment as a share of GDP by many periods. Furthermore, this price coincides in time with a current account surplus. Both findings are consistent with the fact that the higher copper prices of recent years have attracted foreign investment, and with the evidence that a good price enables a current account surplus to be achieved because of its effect on the trade balance.

TABLE 3

Dynamic correlations between the copper price and fiscal spending and revenue

Quarters	Personal spending	Transfers	Total spending	Tax revenue	Copper revenue
0	-0.2766	0.4325	-0.3055	0.5138	0.5714[a]
1	0.0615	0.5707[a]	0.0303	0.4515	0.2084
2	0.3703	0.681[a]	0.3645	0.1567	-0.0858
3	0.5482[a]	0.6368[a]	0.5444	-0.0019	-0.3263
4	0.5762[a]	0.5032	0.5389	0.1354	-0.4802
5	0.4447	0.2405	0.4037	0.0663	-0.4854
6	0.258	-0.0438	0.2174	0.0221	-0.3859

Source: Prepared by the authors.

[a] Significant and greater than two standard errors.

TABLE 4

Dynamic correlations between the copper price and external-sector variables

Quarters	Current account	Foreign investment	Industrial exports	Agricultural exports	Mining exports
0	0.5107[a]	0.5518[a]	0.677[a]	0.4815[a]	0.6292[a]
1	0.3196[a]	0.5276[a]	0.3476[a]	0.0394	0.0052
2	0.0751	0.5064[a]	0.0146	0.0709	-0.1842
3	-0.1319	0.4571[a]	-0.1035	-0.0123	-0.0632
4	-0.2508	0.4869[a]	0.078	0.1017	-0.1164
5	-0.2913	0.5075[a]	0.2427	-0.1207	0.161
6	-0.3237[a]	0.4959[a]	-0.0977	-0.2111	-0.0245
7	-0.3583[a]	0.5136[a]	0.0575	0.2176	0.0813
8	-0.3626[a]	0.468[a]	0.1426	0.1343	-0.0081
9	-0.3392[a]	0.4197[a]	-0.0059	0.0318	-0.0931
10	-0.2236	0.448[a]	-0.411	-0.3212	-0.2498
11	-0.0595	0.4058[a]	-0.2698	-0.0558	-0.1683
12	0.1303	0.353[a]	0.0791	-0.0697	0.037
13	0.2782	0.2565	0.0412	0.1024	0.1962
14	0.3507[a]	0.1469	-0.0011	0.1173	0.1062
15	0.3526[a]	0.0988	-0.0018	-0.0484	-0.1463
16	0.3228[a]	0.0646	-0.0298	0.0678	-0.0459

Source: Prepared by the authors.

Note: The current account and foreign investment are expressed as percentages of GDP and exports as quarterly growth rates. The copper price was expressed in different ways. The trend of the Hodrick-Prescott (HP) filter was used for the correlation with foreign investment, the cyclical part of the HP filter for the current account, and the quarterly growth rate for exports.

[a] Significant and greater than two standard errors.

As already mentioned, the positive dynamic correlation between the copper price and dollar-denominated agricultural and industrial export growth may be signalling that a third variable or economic force has pushed up (or down) not only the copper price, but exports of all kinds. In this context, it seems reasonable to assume that fluctuations in the international economy might be this third variable or force, represented first by the long growth cycle up until 2007, and then by the sharp contraction resulting from the international financial crisis that began in 2008 (and the subsequent recovery).

Table 5 shows the dynamic correlations between the copper price and labour-market and real exchange-rate (RER) variables. The results clearly indicate that the correlations between labour market variables and the copper price are statistically equal to zero or counterintuitive (the correlation with real wages is zero or negative). This evidence is in line with the weight of mining-sector employment in total employment. The mining sector is marginal, accounting for about 3%, a very small share by comparison with the major non-mining sectors of the economy (industry, commerce and construction), which between them account for almost 55% of total employment in the Chilean economy. Consequently, it is very likely that the mining sector does not have direct effects on employment, the unemployment rate and the evolution of real wages nationally.

Furthermore, as was to be expected, table 5 shows that there is a negative correlation between the copper price and the real exchange rate, although this comovement is very weak and strictly contemporary. This finding is consistent with systematic evidence in Chile and internationally that commodity prices do not predict exchange-rate fluctuations (Meese and Rogoff, 1983; Chen, Rogoff and Rossi, 2010; García, González and Moncado, 2013).

TABLE 5

Dynamic correlations between the copper price, labour market variables and the real exchange rate (RER)

Quarters	Unemployment rate	Employment	Real labour costs	Real pay	RER
0	0.1684	0.0221	0.0399	0.0685	-0.408
1	0.2077	0.1766	-0.3467[a]	-0.3344[a]	0.2214
2	0.1408	0.1346	-0.0801	-0.0833	0.1231
3	-0.0604	0.1187	0.0587	0.0758	0.0125
4	-0.1576	0.1195	0.0411	0.0647	0.0676
5	-0.1301	0.019	-0.1298	-0.1106	0.0051
6	-0.1019	-0.3123[a]	-0.0136	0.0188	-0.1419
7	-0.1259	-0.1416	0.0925	0.1247	-0.2438
8	-0.0846	0.213	-0.0766	-0.0586	0.0775
9	-0.0851	0.0155	-0.1327	-0.1324	0.1643
10	-0.077	-0.2929	-0.0592	-0.023	0.1641
11	-0.1502	-0.0561	0.074	0.099	-0.1046
12	-0.1709	0.2484	0.1139	0.1089	-0.0615
13	-0.0767	-0.054	-0.0062	0.0084	0.0022
14	-0.0058	-0.4331[a]	-0.0286	0.0174	-0.0297
15	-0.0102	0.0365	-0.0569	-0.0409	0.1145
16	0.0101	0.5146[a]	0.008	-0.0157	0.0151

Source: Prepared by the authors.

[a] Significant and greater than two standard errors.

In conclusion, the stylized facts in this section indicate a number of elements that need to be considered when the mining sector is modelled in a DSGE macro model:

- The copper price seems to be the key variable encapsulating the effects of the mining sector on the rest of the economy.
- The copper price anticipates changes in GDP, private investment, consumption and imports.
- This price also anticipates increases in fiscal spending, although this occurs three years after the increase in the copper price.
- The copper price also anticipates foreign investment.
- The mining sector does not greatly affect the labour market nationally. In this respect, the sector can be seen as an enclave with its own workforce concentrated in regions I, II, III and IV.
- The effects on the real exchange rate are negative, but there is no evidence that copper price variations anticipate changes in the real exchange rate.
- Although real exchange-rate appreciation could reduce the competitiveness of the non-mining export sector, the evidence found in this study does not indicate that mining activity is the explanation for major episodes of exchange-rate appreciation.

III

The macroeconomic model

This section presents the key modifications to the standard DSGE model (see, for example, García and González, 2014) that had to be made for the mining sector to be included appropriately.[5] The modifications were of two kinds. First, mining-sector output was modelled endogenously. Then, as a result of this change, a new channel of integration between this sector and the rest of the economy was added: demand for intermediate inputs. In this way, it can be demonstrated that, given the assumptions of the model used in the study, imported inputs turn into intermediate goods that meet the demand for consumption, investment by the intermediate sector itself and the government, and mining-sector investment. Conversely, the standard model only emphasizes the direct fiscal contribution of the mining sector, discounting profit remittances by mining firms of foreign origin.

Accordingly, the standard DSGE model was modified in two ways as set out below.

1. The mining sector

Unlike the standard DSGE model, this one assumed that copper production was not exogenous. On the contrary, it assumed that the production of copper QCU_t depended on labour L_t^{CU}, capital K_t^{CU} and energy E_t.

$$QCU_t = A_t^{CU} L_t^{CU\bar{\alpha}} K_t^{CU\bar{\beta}} E_t^{1-\bar{\alpha}-\bar{\beta}} \quad (2)$$

where A_t^{cu} represents the availability of ore; for example, longer haulage distances and lower ore grades. Thus, a drop in this variable also leads to a reduction in mining GDP unless production inputs are increased. In logarithmic terms, this variable is assumed to take the following form:

$$a_t = \left(rho\_A\_COPPER\right) a_{t-1} + \varepsilon_t^{EE} \quad (3)$$

The incorporation of these three inputs (L_t^{CU}, K_t^{CU} and E_t^{CU}) makes modelling the DSGE more difficult in a number of respects. A number of assumptions thus had to be made to simplify the modelling.

[5] Annex 1 details the equations of the model employed.

First, it was assumed that the mining sector used a mix of energy comprising fuel (oil) and electricity. The mining sector was assumed to be a price taker for both inputs.

$$E_t = OIL_t^{\delta} EE_t^{1-\delta} \quad (4)$$

where *OIL* is the fuel and EE_t is electricity. Thus, given a certain level of production and thence total energy (E_t), the demand for fuel and for electricity can be obtained separately from their prices. The electricity-sector model is simplified, and it is assumed that the mining sector cannot affect the electricity price. It is acknowledged that a more realistic (but also more complex) model would consider the possibility that the mining sector could affect the electricity price, and thence the cost of all production activities in the country, because of its relative size within the Chilean economy. It has been left for future research to spell out this additional channel from mining to the rest of the economy. In logarithmic terms, the electricity price is assumed to have the following form:

$$p_t^{EE} = \left(rho\_PEE\right) p_{t-1}^{EE} + \varepsilon_t^{EE} \quad (5)$$

Notwithstanding, to improve the fit of the DSGE model there were also assumed to be lags in the response of demand for both energy and all other inputs to their respective prices.[6]

Thus, demand for a generic input J, termed $input_{J,t}$, measured in log-linearized terms, depends positively on the level of output as defined by $output_t$, negatively on the real-terms price of the input as defined by $P_{J,t}$, and on a lag defined by $input_{J,t-1}$:

$$\begin{aligned} input_{J,t} = {} & MP\_input_J\_COPPER\left(output_t - p_{J,t}\right) \\ & + \left(1 - MP\_input_J\_COPPER\right) input_{J,t-1} \end{aligned} \quad (6)$$

[6] Berger, Caballero and Engel (2014) show that this functional form is equivalent to the assumption of a firm taking input procurement decisions in a lumpy fashion.

Secondly, copper-producing firms purchase capital from other firms in each period t. Although in point of fact some firms may also produce some of their own capital goods, this study assumes, purely for simplicity's sake, that these are separate firms.

For the same reason, it is also assumed that at the end of each period t copper-producing firms can resell the capital purchased from capital goods-producing firms.

Thus, the copper-producing firm's target function is:

$$\max_{\left\{K_{t+k}^{CU}, L_{t+k}^{CU}, E_{t+k}\right\}_{k=0}^{\infty}} \sum_{k=0}^{\infty} E_t \left\{ \Lambda_{t,t+k} \underbrace{\left(P_{t+k}^{CU} A_{t+k}^{CU} L_{t+k}^{CU\bar{\alpha}} K_{t+k}^{CU\bar{\beta}} E_{t+k}^{1-\bar{\alpha}-\bar{\beta}} + \left(1-\delta^{CU}\right) K_{t+k}^{CU} Q_{t+k}^{CU} \right)\left(1-t_t^u\right)}_{REVENUE} \right\}$$
$$- \sum_{k=0}^{\infty} E_0 \left\{ \Lambda_{t,t+k} \underbrace{\left(R_{F,t+k} Q_{t+k-1}^{CU} K_{t+k}^{CU} + W_{t+k}^{CU} L_{t+k}^{CU} + P_{t+k}^{E} E_{t+k} \right)\left(1-t_t^u\right)}_{COSTS} \right\} \tag{7}$$

where $\Lambda_{t,t+k}$ is the stochastic discount factor, δ^{CU} the depreciation rate, P_{t+k}^{CU} the copper price, W_{t+k}^{CU} wages in the sector, P_{t+k}^{E} the energy price (an index composed of the oil and electricity prices), Q_{t+k}^{CU} the price of capital, $R_{F,t+k}$ the return on capital and t_t^u taxes on profits. Equation (7) yields the demand for capital, labour and total energy.

Again, capital-producing firms buy used capital from intermediate goods-producing firms, repair depreciated capital and construct new capital, where I_t^{cu} is the new capital created. Then, the maximization problem of capital-producing firms is:

$$\max_{\left\{I_{t+k}^{CU}\right\}_{k=0}^{\infty}} \sum_{k=0}^{\infty} E_t \left\{ \Lambda_{t,t+k} \left(\left(Q_{t+k}^{CU}-1\right) I_{t+k}^{CU} - t_t^u Q_{t+k}^{CU} I_{t+k}^{CU} - f\left(\frac{I_{t+k}^{CU}}{I_{t+k-1}^{CU}} \right) I_{t+k}^{CU} \right) \right\} \tag{8}$$

where f is an increasing function that represents investment adjustment costs and $K_{t+k+1}^{CU} = \left(1-\delta^{CU}\right) K_{t+k}^{CU} + I_{t+k}^{CU}$. Equation (8) yields the supply of capital, which together with the demand for capital (equation (7)) can be used to determine the price of capital and the amount of capital available for the next period.

Third, as in the rest of the economy, there is assumed to be partial wage rigidity (in accordance with Calvo; see also by way of example the details in García and González, 2014). In other words, wages change exogenously over time as a result of two factors: the portion of wages adjusted directly because of changes in contracts (defined by *xi_w_COPPER*) and the portion of wages (defined by *index_w_COPPER*) that remain current but are adjusted for past inflation.

A labour supply can be derived from the modelling of wages. Thus, taking this assumption about wages and adding in the labour demand equation derived from equation (8) yields mining-sector employment and wages. Purely for simplicity's sake, it is assumed that the marginal utility of consumption by families working in the mining sector is equal to the marginal utility of all other families in the economy. This assumption is innocuous if it is considered that the mining labour market has only marginal effects on the aggregate labour market in the Chilean economy (see section II).

2. The mining sector and the general equilibrium of the economy

In standard DSGE models that take mining output as exogenous (see, for example, García and González, 2014), the only connection between the mining sector and the rest of the economy is expressed through the fiscal sector: a portion of copper GDP is set down directly as fiscal revenue, the rest as remittances abroad.

In the present study, conversely, a wider connection is allowed, as it is further assumed that the mining sector draws in goods from the rest of the economy, in addition to electricity. To illustrate this point, equation (9) represents the goods market equilibrium when mining output is assumed to be exogenous:

$$P_{m,t}Y_t = P_tC_t + P_tI_t + P_tG_t + P_tX_t \tag{9}$$

where I_t is investment in domestic or (non-commodity) intermediate goods, Y_t is output of these goods, C_t is household consumption, X_t is exports (external demand) and G_t is government spending on these goods.

By contrast, the present article assumes that mining-sector investment I_t^{cu} takes place in the domestic goods market:

$$P_{m,t}Y_t = \underbrace{P_tC_t + P_tI_t + P_tG_t}_{\text{REST OF THE ECONOMY}} + \underbrace{P_tX_t}_{\text{EXTERNAL SECTOR}} + \underbrace{P_tI_t^{cu}}_{\text{MINING}} \tag{10}$$

Although integration of the mining sector into the rest of the economy is an assumption of the model, this is based on the production structure of the Chilean economy. Table 6 shows the percentage of inputs that the copper mining sector draws from the wider economy; this was about 70% in 2008-2011, a figure obtained from the input-output matrix (Central Bank of Chile, 2013). While serving to simplify the analysis, though, this assumption produces limitations in the study, since assuming that the only connection between the mining sector and the rest of the economy is through investment-related purchases underestimates the ultimate impact of mining on the rest of the economy. It will be for future research to explore the wider connections between the copper sector and other sectors of the economy.

TABLE 6

Inputs produced by other sectors of the economy that are used for copper mining

Year	Percentage
2008	0.66
2009	0.69
2010	0.68
2011	0.73

Source: Prepared by the authors, on the basis of information from the Central Bank of Chile.

Lastly, once all the family and firm constraints have been aggregated, discounting the production of electricity for mining and considering that mining GDP (QCU_t) is wholly exported, the total constraint in the economy is obtained:

$$\begin{aligned} &\underbrace{P_tC_t + P_tI_t + P_tG_t + P_tI_t^{CU}}_{\text{SPENDING}} + \underbrace{P_tCAJ_t}_{\text{INVESTMENT ADJUSTMENT COSTS}} \leq \underbrace{P_{m,t}Y_t}_{\text{INTERMEDIATE GOODS PRODUCTION}} \\ &\underbrace{- SX_tM_t - SX_tP_t^{OIL}OIL_t - SX_tP_t^{OIL}OIL_t^{CU}}_{\text{INPUT AND FUEL IMPORTS}} \\ &\underbrace{+ SX_t\frac{B_{t+1}^*}{\tilde{R}_t^*} - SX_tB_t^*}_{\text{CHANGE IN EXTERNAL DEBT}} + \underbrace{\Gamma\left(SX_tP_t^{cu}QCU_t\right)}_{\text{COPPER REVENUES}} \end{aligned} \tag{11}$$

where SX_t is the nominal exchange rate, P_t^{OIL} the oil price, M_t imports of inputs for the production of intermediate goods, B_t^* the external debt, $\tilde{R}_t^*$ the external interest rate adjusted for the risk premium and CAJ_t the total (i.e., both mining and non-mining) investment adjustment costs.

In sum, spending in the economy, including investment adjustment costs, must be financed from the output of intermediate goods, net of imports of both intermediate goods inputs and fuel (including the portion for copper), plus the change in external financing (changes in external debt) and copper revenue (copper's contribution to GDP minus remittances abroad).

IV
Model estimation and main results

This section will show the details of the results of the estimations and simulations serving to measure not only the impact of copper mining on the rest of the economy but also the way this sector in particular is affected by key variables such as the copper price, the electricity price and wages.

The exercises carried out are of three kinds. First, we analyse how a shock of 1% in the copper price affects the macroeconomic variables of the Chilean economy (mining-sector elasticity). Second, we measure the contribution of different economic shocks to variance in GDP growth, including the copper price and the availability of ore. Lastly, we examine what impact the copper price would have on the rest of the economy if mining were an enclave, i.e., if this sector were not integrated into the rest of the economy and thus did not draw in intermediate goods from it.

1. Results of the estimation using the DSGE model[7]

The DSGE macro model is estimated using Bayesian econometrics, meaning that the distribution of the parameter needs to be established using prior values, after which standard econometric techniques (maximum likelihood) and repetitions (simulation) are used to obtain the distributions of the final or posterior estimates. The prior values of the parameters estimated were taken from the traditional macro model literature (see García and González, 2014; and García, González and Moncado, 2013).[8] Two independent estimations were carried out with a large number of repetitions to ensure quality, and the distribution of the parameters was found to converge on similar values in both (see figure A.3.1 of annex 3).

There were two parts to the macro model estimation strategy, one where the parameters relating to the stationary state were calibrated, and one where only the parameters relating to the model dynamic were estimated (i.e., the way the model converges on the stationary state after a shock).

The calibration replicated the long-term equilibrium or stationary state of the Chilean economy, measured by ratios such as consumption to GDP, investment to GDP or government spending to GDP. In the calibration process, it is crucial to obtain values for the parameters of the mining-sector output function (equation (2)).[9] These parameters represent the share of each of the inputs in copper production. To calibrate these parameters, use was made of information from the Chilean Copper Commission (COCHILCO), the National Energy Commission (CNE) and the Central Bank of Chile. The results of the calibration are shown in table 7, with the shares of capital (51%) and labour (39%) being predominant in copper output. Of the total energy used by the sector (10%), electricity makes up the bulk with 70% (see the bottom of table 7).[10]

In summary, calibrating the DSGE model produces the following stationary state or long-term equilibrium for the Chilean economy, which is consistent with the information available from the Central Bank of Chile (see table 8).

TABLE 7

Share of inputs and energy types employed in copper production

Parameter	Share
Labour	0.39
Capital	0.51
Energy	0.1
Parameter	Share
Fuel	0.3
Electricity	0.7

Source: Prepared by the authors, on the basis of information from the Chilean Copper Commission (COCHILCO), the National Energy Commission (CNE) and the Central Bank of Chile.

[7] Annex 2 presents the data employed.

[8] The subsequent posterior values were obtained using the Metropolis-Hastings algorithm based on a Markov chain of 20,000 repetitions to construct the estimated distribution of the (subsequent) parameters. Estimations with 100,000 repetitions yielded similar results.

[9] Annex 3 presents the parameters for the rest of the economy.

[10] Annex 4 presents the details of the calibration of the Cobb-Douglas functions for the mining sector.

TABLE 8

Stationary state of the DSGE model

Stationary state	Ratio to gross domestic product (GDP)
Consumption	0.64
Intermediate investment	0.19
Copper investment	0.06
Government spending	0.10
Intermediate exports	0.27
Imported inputs	0.41
Imported fuel	0.03
Copper GDP	0.17
Tax burden	0.18

Source: Prepared by the authors, on the basis of the dynamic stochastic general equilibrium (DSGE) model.

The parameters associated with the impact of copper mining[11] on the economy will now be evaluated (see table 9). First, the standard deviations of the shocks affecting the sector will be observed. Here, the greatest volatility derives from the prices of copper itself and oil, both at around 16% (oil is a major input in copper production). It transpires that these two variables represent the most volatile shocks facing the Chilean economy in absolute terms, according to the DSGE model estimation (see annex 3). Next comes the effect of the electricity price and of the shock represented by the availability of the material (copper); these are more moderate, being comparable to other shocks affecting the economy, at around 6% (see annex 3).

Next, as explained with equation (6), the parameters (MP) measure the short-term sensitivity of demand for each input to activity and prices in the mining sector. As can be seen in table 9, all the MP parameters are well below 0.5, which indicates a high degree of inertia in the copper mining sector where procurement of new inputs is concerned. Within a quarter, in other words, the decision to acquire an input is heavily influenced by the decision taken in the previous period, and the adjustment process (meaning the time taken to fully change an input demand decision because of a change in prices and output) lasts an average of five quarters.[12]

Where wages in the mining sector are concerned, the model shows these remaining rigid for about three quarters,[13] and they present a level of indexation to past inflation of about 1.[14] This finding is in line with those obtained in estimating the dynamic of wages in the rest of the economy (see annex 3).

[11] With regard to the estimates of the parameters determining the dynamic of the macro model, many of the values estimated are found to be in line with the values found by other studies (García and González, 2014; and García, González and Moncado, 2013). Annex 3 presents detailed estimates of all the parameters in the macro model.

[12] 3.9 quarters = 1/(1-0.74), where 0.74 is the average lag of the parameters (1 - MP).

[13] 2.65 quarters = 1/(1-xi_w_COPPER) = 1/(1-0.62), where xi_w_COPPER measures the average likelihood of nominal wages remaining rigid in the copper sector.

[14] index_w_COPPER = 0.9, where index_w_COPPER is the inflationary inertia of nominal wages.

TABLE 9

Parameters relating to the impact of copper mining on the economy

Parameter	Prior (mean)	Posterior (mean)	Confidence interval 90%		Prior distribution	Prior standard deviation
MP_EE_EN_COPPER	0.5	0.2564	0.1317	0.3676	beta	0.1
MP_EN_COPPER	0.5	0.1423	0.0555	0.2258	beta	0.1
MP_L_COPPER	0.5	0.0848	0.051	0.1188	beta	0.1
MP_K_COPPER	0.5	0.5461	0.4031	0.6778	beta	0.1
index_w_COPPER	0.9	0.9046	0.8335	0.9712	beta	0.05
xi_w_COPPER	0.67	0.6216	0.5705	0.6813	beta	0.05
rho_Oil	0.9	0.8655	0.7959	0.9337	beta	0.05
rho_Pcu	0.9	0.8623	0.8377	0.8915	beta	0.05
rho_A_COPPER	0.9	0.9045	0.8917	0.9168	beta	0.01
rho_PEE	0.5	0.8518	0.8016	0.9022	beta	0.1
Standard deviation:						
Copper price	16.53	16.627	15.8637	17.4668	invg2	0.5
Oil price	16.07	16.2808	15.608	17.0067	invg2	0.5
Mining wage price	0.9	0.5559	0.4213	0.6845	invg2	0.5
Electricity price	6.84	6.9106	6.2696	7.6251	invg2	0.5
A^{cu}	3.59	7.2804	5.834	8.6681	invg2	0.5

Source: Prepared by the authors, on the basis of the dynamic stochastic general equilibrium (DSGE) model.

Lastly, all the shocks affecting this sector have a high level of persistence (rho parameters), exceeding 0.8.

2. The elasticity of the copper mining sector

To measure the impact of the mining sector on the Chilean economy, the decision was taken to analyse the effect over time (quarters) of a 1% copper price shock on all the variables in that economy, assuming that no other shock was affecting it. This way of quantifying impact is known as an impulse-response function (IRF).

The information will be presented using a (quarterly) chart to set out the way the copper price affects the rest of the economy, i.e., the history behind a change in the copper price. The chart comprises subcharts showing the evolution of the different macroeconomic variables after a 1% copper price shock over the quarters. For the variables to be compared, all the subcharts have the same dimensions on the vertical axis.

Then, a table will give a precise summary of the impact of the copper price on the main macroeconomic variables over the years. Given that the DSGE model is linear and was estimated using percentage change data (log differences multiplied by 100), the numbers in the table can be interpreted as elasticities. Thus, they have to be multiplied by 10 to find out what effect a 10% increase in the copper price would have. With this method, it is easy to quantify any impact on the Chilean economy of a change in the copper price.

Figure 1 shows the impulse responses in the economy to a 1% shock in the copper price. This shock is clearly expansionary, i.e., it leads to increased growth in GDP, investment, electricity use, employment and wages in the mining sector. The way this spreads through the Chilean economy is as follows, confirming the correlations analysis presented at the beginning of this paper.

There is a direct expansionary effect on GDP, since mining GDP is part of this, averaging a share of 17% in recent years. There is a lesser increase in consumption and a rise in mining-sector demand for intermediate goods, driving an increase in imported inputs and employment in non-copper sectors (these sectors' wages remain practically unchanged). All this contributes to an expansion in overall GDP beyond the increase in mining GDP alone.

Government spending rises moderately, as the fiscal rule is assumed to be operating in the DSGE model.

Inflation rises marginally because of the increased activity level, causing the central bank to raise interest rates slightly, which has two effects: (i) the real exchange rate appreciates, so that non-copper exports fall, and (ii) non-copper investment falls, although total investment (i.e., including that in the mining sector) rises.

It can be seen that a marginal rise in the interest rate has significant effects on the real exchange rate and investment in other production activities, since these variables in the DSGE model do not depend on the current level of the interest rate alone but on the whole path of this

FIGURE 1

Effect of the copper price on the Chilean economy

(All variables measured as growth rates)

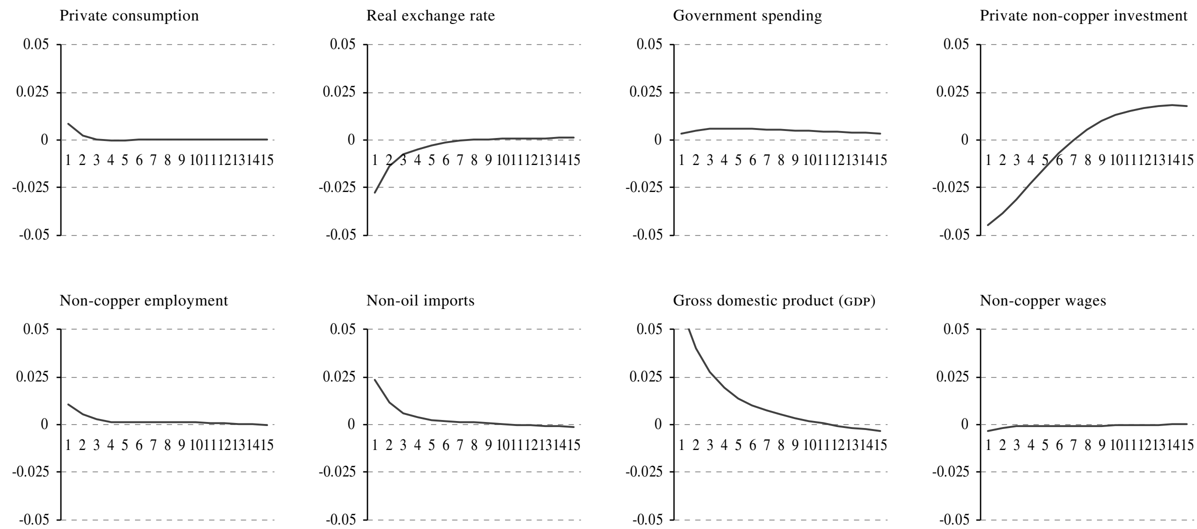
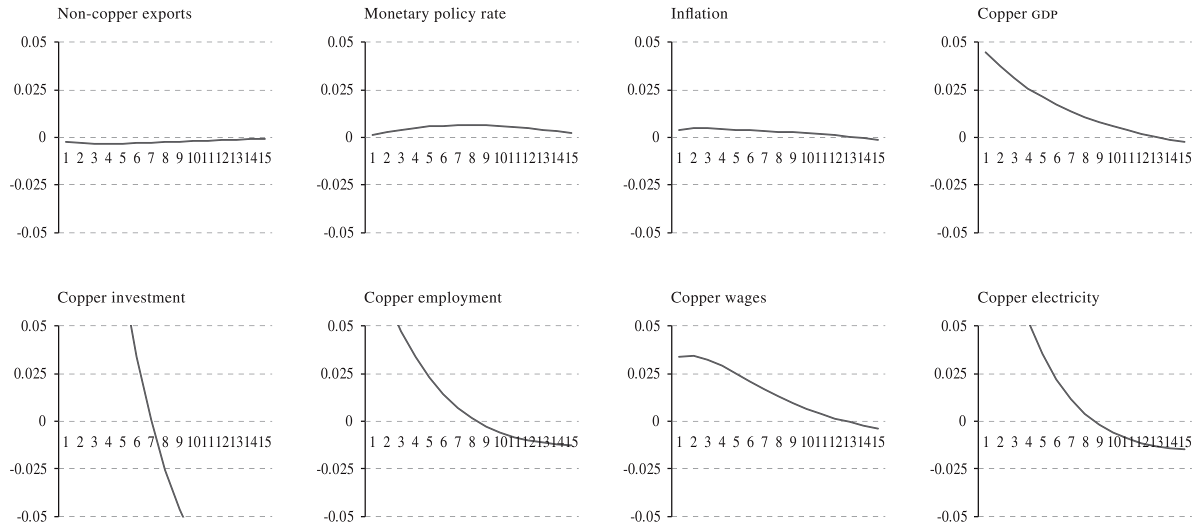


Figure 1 (concluded)



Source: Prepared by the authors, on the basis of the dynamic stochastic general equilibrium (DSGE) model.

variable (long-term interest rate). The accumulation of higher marginal rates over a prolonged period ultimately reduces these two variables in the early periods.

To provide a clearer picture of all this, table 10 shows the growth values for the different macroeconomic variables resulting from a 1% copper price shock. Table 10 is constructed from the same information as figure 1, but summarizes the information in annual terms. It details the evolution of the economy until five years after the shock, while also giving cumulative results for 1, 5 and 10 years. The main changes observed are as follows.

TABLE 10

Impact of a 1% copper price increase

Year	C	E	G	NCI	NCE	NOM	GDP	W	X	R	PI	CGDP	CI	CE	CW	EE
1	0.011	-0.054	0.020	-0.137	0.020	0.045	0.147	-0.007	-0.012	0.013	0.019	0.140	0.911	0.229	0.130	0.381
2	0.000	-0.004	0.023	-0.016	0.004	0.007	0.036	-0.002	-0.012	0.025	0.014	0.063	0.083	0.046	0.076	0.073
3	0.001	0.003	0.019	0.055	0.004	0.001	0.006	-0.002	-0.007	0.023	0.008	0.020	-0.267	-0.027	0.022	-0.028
4	0.001	0.005	0.015	0.072	0.000	-0.004	-0.011	0.001	-0.004	0.011	-0.003	-0.007	-0.364	-0.048	-0.011	-0.057
5	0.001	0.006	0.011	0.062	-0.003	-0.006	-0.019	0.004	-0.001	-0.007	-0.017	-0.023	-0.331	-0.048	-0.027	-0.060
Cumulative																
1	0.011	-0.054	0.020	-0.137	0.020	0.045	0.147	-0.007	-0.012	0.013	0.019	0.140	0.911	0.229	0.130	0.381
5	0.015	-0.044	0.088	0.035	0.026	0.042	0.159	-0.006	-0.036	0.064	0.021	0.192	0.027	0.151	0.191	0.307
10	0.020	-0.022	0.112	0.093	-0.002	0.023	0.043	0.024	-0.023	-0.176	-0.209	0.016	-0.452	0.005	0.050	0.068

C	Private consumption	X	Non-copper exports
E	Real exchange rate	R	Monetary policy rate
G	Government spending	PI	Inflation
NCI	Private non-copper investment	CGDP	Copper GDP
NCE	Non-copper employment	CI	Copper investment
NOM	Non-oil imports	CE	Copper employment
GDP	Gross domestic product	CW	Copper real wages
W	Non-copper real wages	EE	Copper electricity

Source: Prepared by the authors, on the basis of the dynamic stochastic general equilibrium (DSGE) model.

A 1% rise in the copper price causes GDP to grow by up to 0.16% five years on from the shock. Thus, mining elasticity in the event of a rise in the copper price is 0.16 = (0.16%/1%) in five years.

The past experience of the Chilean economy has been of persistent quarterly increases in the copper price over time. The calculations carried out in this study using the DSGE model indicate that the impact of this on GDP has been quantitatively large: if this quarterly growth in the copper price continued for 4, 8, 12 and 16 quarters, cumulative GDP would grow by 0.67%, 1.41%, 2.18% and 2.89%, respectively.[15]

Given that the copper price shows large standard deviations (up to 16%), a positive fluctuation of this size would equate to almost two points of growth in five years (2.54% = 16*0,16).

Growth in copper investment easily offsets the drop in non-copper investment the first year. Because inflation falls, though, the central bank also cuts the interest rate, so that investment partially recovers in other sectors.

Although consumption rises by 0.015% in five years, the main macro aggregate that rises is government spending (0.088%).

The rising copper price is undoubtedly associated with real exchange-rate appreciation. This amounts to 0.044%, which reduces non-copper exports by 0.036% in five years. During this period, however, employment in other sectors rises by up to 0.026% in five years.

3. The contribution of the copper mining sector to growth volatility

The variance of the growth observed in 2003-2013 is broken down into the macroeconomic shocks of the DSGE model with a view to measuring the contribution of the copper mining sector to growth volatility. The strength of this analysis, then, is that it consider all shocks together, allowing a clearer picture to be formed of the importance of mining, and the copper price in particular, in comparison with other elements that are also drivers of the business cycle in the Chilean economy.

By construction, these shocks must add up to 100% of growth variance in the Chilean economy in the period defined. Consequently, a great variety of shocks studied by the literature on economic fluctuations in open economies (monetary, fiscal, production, terms of trade, risk premium, etc.) were included in the DSGE model so that the fluctuations observed in the Chilean economy were not left to be explained by just a few kinds of shock. Due to the great persistence of the shocks affecting the economy, furthermore, the growth variance decomposition was analysed from 1 quarter to 20 quarters.

The approach described puts into perspective the effect of the copper price not only on GDP growth but also on one of the key variables in the Chilean economy, the real exchange rate. Indeed, the previous section clearly showed that a rise in the copper price causes the real exchange rate to strengthen, and thus non-copper exports to fall. An important question arises for the 2003-2013 period, though: was the copper price a fundamental determinant of the evolution of the real exchange rate, or did other shocks drive this variable?

Table 11 shows a key element in the country's economy: external factors are almost as important in explaining the business cycle as productivity. Among these factors, the copper price by itself accounted for about 5.8% of GDP variance in 2003-2013 and was the largest factor, ahead of the risk premium and far ahead of external activity (the weighted growth of the United States, Europe and Japan), external interest rates and the oil price.

Furthermore, table 12 indicates that the copper price has a very marginal influence on fluctuations in the real exchange rate. Conversely, the risk premium for the exchange rate itself and productivity shocks account for almost 60% of the fluctuation in this variable. Consequently, it can be said that although a higher copper price leads to real-term appreciation of the Chilean peso, exchange-rate fluctuations in the 2003-2013 period were associated with other shocks more connected with financial and production factors.[16]

[15] Annex 5 presents the details of this calculation.

[16] García and González (2014) find that this also holds true for other economies with a large mining sector, such as Australia.

TABLE 11

Decomposition of variance in GDP growth

(Percentages)

GDP growth	Quarters				
Shock	1	4	8	16	20
Consumption	15.4	25.1	21.0	20.8	20.7
Monetary policy interest rate	13.5	8.7	8.5	8.4	8.3
Government spending	4.5	3.5	2.8	2.8	2.7
Risk premium	2.8	2.4	2.0	2.0	2.0
Wage	46.8	33.3	32.9	32.7	32.7
External interest rate	0.3	0.5	0.5	0.6	0.6
External gross domestic product (GDP)	0.5	0.4	0.5	0.6	0.6
Copper price	6.0	5.8	5.0	4.9	5.0
Oil price	0.4	0.5	0.6	0.7	0.7
Productivity	0.8	14.8	22.0	22.5	22.6
Copper availability	0.6	0.5	0.4	0.4	0.4
Other	8.4	4.6	3.7	3.6	3.6
Mining (copper price + availability)	6.7	6.3	5.4	5.4	5.4
External factors	10.0	9.6	8.7	8.9	8.9

Source: Prepared by the authors, on the basis of the dynamic stochastic general equilibrium (DSGE) model.

TABLE 12

Percentage decomposition of variance in the bilateral real exchange rate with the United States

Changes in the real exchange rate	Quarters				
Shock	1	4	8	16	20
Consumption	10.5	14.6	14.1	14.1	14.1
Monetary policy interest rate	4.0	3.5	3.6	3.6	3.6
Government spending	0.0	0.0	0.0	0.0	0.0
Risk premium	23.2	26.6	25.6	25.5	25.5
Wage	15.2	13.3	13.6	13.6	13.6
External interest rate	9.5	8.6	8.7	8.7	8.7
External gross domestic product (GDP)	1.9	1.6	1.6	1.6	1.6
Copper price	0.4	0.0	0.0	0.0	0.0
Oil price	0.1	0.2	0.2	0.2	0.2
Productivity	35.2	31.1	32.3	32.2	32.2
Copper availability	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.4	0.4	0.4	0.4
Mining (copper price + availability)	0.4	0.0	0.0	0.0	0.0
External factors	23.2	26.6	25.6	25.5	25.5

Source: Prepared by the authors, on the basis of the dynamic stochastic general equilibrium (DSGE) model.

4. Integration versus enclave

It is important to quantify just how important to all the results presented hitherto is the key assumption that the copper mining industry is integrated with or connected to the rest of the Chilean economy via demand for intermediate inputs.

In order for the effect of this assumption on the model results to be quantified, these are compared with the results obtained using the alternative assumption that mining behaves like an "enclave", i.e., that its contribution to the economy is confined to contributing to fiscal revenues, whether directly via the Chilean National Copper Corporation (CODELCO), the country's State copper producer, or through profit taxes.

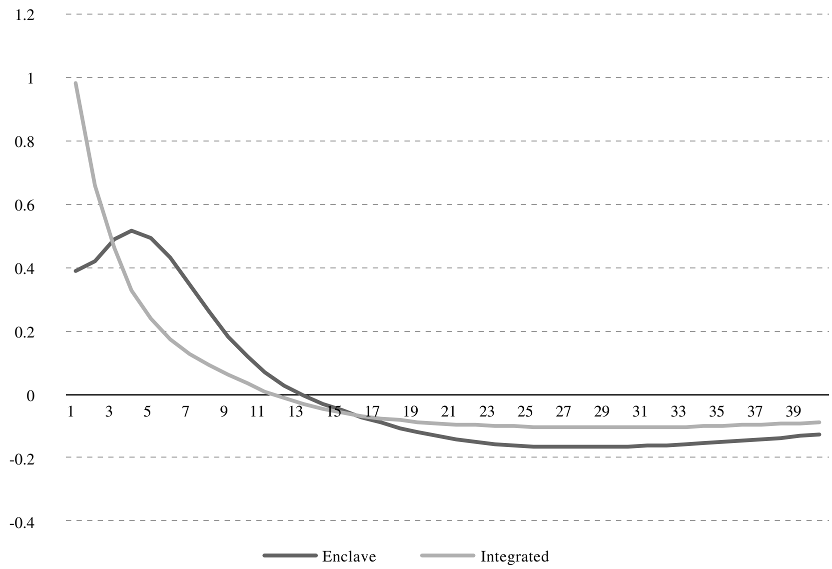
Figure 2 illustrates the importance of properly modelling the integration of mining into the rest of the economy and not just considering the sector's fiscal effects. If the DSGE model had treated the mining sector as an enclave unintegrated into the rest of the economy, the effects on GDP growth would have had to be divided by almost 2.5 (0.98/0.39).

It is worth clarifying that the distinction between integration and enclave was of basic importance in identifying the impacts of the copper price on the economy. From the point of view of the model as a whole, the improvements yielded by this distinction proved marginal. In other words, the fit (as measured by the Bayesian factors) is very much the same in both models. Nonetheless, it is important to stress that this is a common problem in the estimation of DSGE models, i.e., the sample properties are not sufficient to discriminate between different models. Del Negro and Schorfheide (2008) argue that the solution to this identification problem is to look for microeconomic evidence that enables the value of the parameters concerned to be fixed. In the present case in particular, there is a fairly obvious connection between the copper sector and the rest of the economy. Going by the information in the input-output matrices since 2008 (see table 6), the copper sector systematically draws a substantial proportion of its inputs from the rest of the economy.

FIGURE 2

Effect on gross domestic product (GDP) growth of one standard deviation in the copper price

(Enclave versus integrated)



Source: Prepared by the authors, on the basis of the dynamic stochastic general equilibrium (DSGE) model.

V
Conclusions

When modelling the importance of copper mining in the Chilean economy, it is vital to recognize the connections this sector has with the rest of the economy as well as the resources it generates for the Government of Chile.

Thus, while the sector's chief contribution is via the copper price, it is important to realize that its output depends on inputs largely supplied by the rest of the economy. Thus, copper price increases will activate a range of demand that will positively affect many other sectors in the economy.

In quantitative terms, a 1% rise in the copper price leads to a cumulative GDP increase of 0.16% in five years. When continuous increases in the copper price as seen in the past decade were modelled, the results were quantitatively important in explaining the upsurge of growth in the economy over those years.

Lastly, although copper price increases are associated with real exchange-rate appreciation, there is no evidence that the copper price accounted for the variance in the exchange rate in 2003-2013. In fact, this variable is driven mainly by risk premium and productivity shocks.

ANNEXES

ANNEX 1

The DSGE model

The DSGE model used generally accords with what is proposed by Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2003 and 2007). In addition to oil and copper, however, it also incorporates electricity as a production input.

Households

There is a continuum of families of unitary size, indexed by $i \in [0,1]$. There are two types of families in the model: one portion (1 - λ_c) are "Ricardian" families with access to the capital market, while another portion λ_c are restricted families whose income comes entirely from earnings. The preferences of Ricardian families are given by (A1.1), where C_t^o is consumption and L_t^o is the family's supply of labour.

The coefficient $\sigma > 0$ measures risk aversion and ρ_L the disutility of working; the inverse of this parameter is also the inverse of the elasticity of hours worked to the real wage; h measures the formation of habits to capture the dynamic of consumption.

$$\max_{\left\{C_{t+k}^o(i), L_{t+k}^o(i), B_{t+k}^o(i), B_{t+k}^{o^*}(i)\right\}_{k=0}^{\infty}} E_t \sum_{k=0}^{\infty} \beta^k \left(\frac{\left(C_{t+k}^o(i) - hC_{t+k-1}^o(i)\right)^{1-\sigma}}{1-\sigma} - \frac{L_{t+k}^o(i)^{1+\rho_L}}{1+\rho_L} \right) \tag{A1.1}$$

The budgetary constraint on unrestricted families (explained in detail in section III) is given by:

$$\begin{aligned}(1+t_{t+k}^c)P_{t+k}C_{t+k}^o(i) &\le (1-t_{t+k}^W)W_{t+k}(i)L_{t+k}^o(i)\\ &+B_{t+k}^o(i) - SX_{t+k}B_{t+k}^{o^*}(i) + D_{t+k}^o - R_{t+k}^{-1}B_{t+k+1}^o(i)\\ &+\left(\Phi\left(\frac{B_{t+k+1}^{o^*}}{PIB_{t+k}}\right)R_{t+k}^*\right)^{-1} B_{t+k+1}^{o^*}(i)\end{aligned} \tag{A1.2}$$

where t_t^W is income tax, t_t^C the consumption tax, W_t wages, SX_t the nominal exchange rate, B_t^o domestic debt stocks, $B_t^{o^*}$ the external debt stock, D_t^o dividends, R_t the domestic interest rate and R_t^* the external interest rate. Restricted families are subject to the following budgetary constraint (free of income taxes):

$$(1+t_c)P_tC_t^R(i) = W_t(i)L_t^R(i) \tag{A1.3}$$

Financial intermediaries

Financial intermediaries lend funds S_{jt} obtained from families to non-financial firms. These funds come from their own wealth N_{jt} and funds obtained from families B_{jt}.

$$Q_tS_{jt} = N_{jt} + B_{jt} \tag{A1.4}$$

Financial wealth evolves via the spread between the market rate R_{Ft+1}, for producers of capital, and the monetary policy rate R_{t+1}, which is also the effective interest rate for families.

$$N_{jt+1} = \left(R_{Ft+1} - R_{t+1}\right)Q_tS_{jt} + R_{t+1}N_{jt} \tag{A1.5}$$

Financial intermediaries' goal is to maximize their expected wealth, given by:

$$V_{jt} = \max_{\left\{N_{jt+k+1}\right\}_{k=0}^{\infty}} E_0 \sum_{k=0}^{\infty} (1-\theta)\theta^k \Lambda_{t,t+k+1}\left[\left(R_{Ft+1+k} - R_{t+1+k}\right)Q_{t+k}S_{jt+k} + R_{t+1+k}N_{jt+k}\right] \tag{A1.6}$$

Gertler and Karadi (2011) introduce moral hazard into problem (A1.6), showing that in the aggregate:

$$Q_t S_t = \phi_t N_t \tag{A1.7}$$

Equation (A1.7) indicates that the total availability of private credit is intermediaries' wealth multiplied by a factor ø, which indicates their degree of leverage.

Intermediate goods firms

Intermediate goods firms use capital K_t, labour L_t and imported goods M_t to produce intermediate goods Y_t. At the end of period t, intermediate goods-producing firms purchase capital K_{t+1} for use in production in the following period. Once the production process is over, firms have the option of selling the capital. To acquire the resources needed to fund capital purchases, firms hand over S_t entitlements equal to the number of units of capital acquired K_{t+1} and the price of each entitlement is Q_t. In other words, $Q_t K_{t+1}$ is the value of the capital acquired and $Q_t S_t$ the value of the entitlements against capital. Then the following must be satisfied:

$$Q_t K_{t+1} = Q_t S_t \tag{A1.8}$$

In each period or at each time t, the firm produces Y_t using capital, labour and imported goods. Let A_t be total factor productivity. Then, output is given by:

$$Y_t = A_t K_t^{\beta} L_t^{\alpha} M_t^{1-\alpha-\beta} \tag{A1.9}$$

Let $P_{m,t+k}$ be the price of the intermediate good. Given that the firm's decision is taken at the end of period t, the maximization problem for the firm producing intermediate goods is:

$$\begin{aligned}\max_{\{K_{t+k}(j),L_{t+k}(j),M_{t+k}(j)\}_{k=0}^{\infty}} & \sum_{k=0}^{\infty} \Lambda_{t,t+k} E_t\left\{\left(P_{m,t+k}Y_{t+k}(j)+(1-\delta)K_{t+k}(j)Q_{t+k}\right)\left(1-t_{t+k}^{u}\right)\right\} \\ & -\sum_{k=0}^{\infty} \Lambda_{t,t+k} E_t\left\{\left(R_{F,t+k}Q_{t+k-1}K_{t+k}(j)+W_{t+k}L_{t+k}(j)+SX_{t+k}M_{t+k}(j)\right)\left(1-t_{t+k}^{u}\right)\right\}\end{aligned} \tag{A1.10}$$

Taxes on these firms' profits t_t^u do not affect the demand for inputs and nor do they have fiscal effects, given the assumption of perfect competition in the production of these goods, which means zero profits.

The coefficient $\sigma > 0$ measures risk aversion and ρ_L measures the disutility of working; the inverse of this parameter is also the inverse of the elasticity of hours worked to the real wage, while h measures the formation of habit to capture the dynamic of consumption. To better model the dynamic of consumption, expected earnings were aggregated ad hoc in the Euler equation for optimizers.

Capital-producing firms

Capital-producing firms purchase capital from intermediate goods-producing firms, repair depreciated capital and construct new capital with the repaired capital. If we define I_t as investment, the maximization problem for capital-producing firms is:

$$\max_{\{I_{t+k}\}_{k=0}^{\infty}} \sum_{k=0}^{\infty} \Lambda_{t,t+k} E_t\left\{\left((Q_{t+k}-1)I_{t+k} - t_{t+k}^{u} Q_{t+k} I_{t+k} - f\left(\frac{I_{t+k}}{I_{t+k-1}}\right) I_{t+k}\right)\right\} \tag{A1.11}$$

In other words, the capital goods-producing firm obtains a profit for investing in each period of $(Q_t - 1)I_t$, minus adjustment costs $f(I_t / I_{t-1})$. Lastly, *tu* are taxes on undistributed profits. The law of capital movement is given by:

$$K_{t+1+k} = (1-\delta)K_{t+k} + I_{t+k} \tag{A1.12}$$

Retail firms

The final product Y_t is obtained using a constant elasticity of substitution (CES) function to aggregate the output of intermediate firms. This is assumed to be done by other firms, called retailers, which simply package the output of intermediate goods:

$$Y_t = \left(\int_0^1 Y_{ft}^{\frac{\varepsilon-1}{\varepsilon}} df \right)^{\frac{\varepsilon}{\varepsilon-1}} \quad (A1.13)$$

As in Christiano, Eichenbaum and Evans (2005), retail firms operate in conditions of Calvo pricing and partial indexation. Then, the maximization problem for a retailer j is given by:

$$\max_{\{P_t^*(j)\}_{k=0}^{\infty}} \sum_{k=0}^{\infty} \theta^k E_t \left\{ \Lambda_{t,t+k} Y_{t+k}(j) \left(P_t^*(j) \prod_{l=1}^{k} \left(\pi_{t+l-1}^{k} \right)^{\delta_D} - MC_{t+k} \right) \right\}$$
$$s.a. \quad Y_{t+k}(j) \le \left(\frac{P_t^*(j)}{P_{t+k}} \right)^{-\varepsilon_D} Y_{t+k} \quad (A1.14)$$

where MC_{t+k} are the marginal costs of the retail firm. In particular, a firm is willing to adjust its prices with probability $(1 - \theta)$ in each period. Between these periods, the firm is willing to partially index its price (i.e., $\delta_D \in [0,1]$) to the past inflation rate. With these assumptions, the price level evolves in accordance with:

$$P_t = \left((1-\theta) \left(P_t^* \right)^{\frac{1}{1-\varepsilon}} + \theta \left(\pi_{t-1}^{\delta_D} P_{t-1} \right)^{\frac{1}{1-\varepsilon}} \right)^{1-\varepsilon} \quad (A1.15)$$

The final product used by consumers and firms is assumed to be a combination between Y_t and imports of oil for transport $TOIL_t$.

Monetary policy

Monetary policy follows a Taylor rule that responds to changes in output, inflation and the exchange rate.

$$R_t^* = \overline{R} \left(\left(\frac{\Pi_{t+1}}{\overline{\Pi}} \right)^{\phi_\pi} \left(\frac{GDP_t}{\overline{GDP}} \right)^{\phi_y} \left(\frac{E_t}{\overline{E}} \right)^{\zeta_e^1} \left(\frac{E_t}{E_{t-1}} \right)^{\zeta_e^2} \right) e^{u_t^R} \quad (A1.16)$$

$$R_t = \left(R_{t-1} \right)^{\Omega_R} \left(R_t^* \right)^{1-\Omega_R} \quad (A1.17)$$

where $\overline{R}$ is the natural rate, Π_t is total inflation, $\overline{\Pi}$ is the inflation target, $\overline{GDP}$ is potential GDP, E_t is the real exchange rate, $\overline{E}$ is the equilibrium real exchange rate and u_t^R is a monetary shock. In estimating equations (A1.16) and (A1.17), GDP excluding natural resources (i.e., the copper sector) was used.

Non-mining exports

In the model, exports X_t are assumed to depend on the real exchange rate E_t and international economic activity GDP^*_t and to present a degree of inertia Ω. Then,

$$X_t = \left(E_t \right)^{-\eta^*} GDP_t^* \quad (A1.18)$$

$$X_t = \left(X_{t-1} \right)^{\Omega} \left(X_t \right)^{1-\Omega} \quad (A1.19)$$

Country risk

To close the model, the further assumption is made, as in Schmitt-Grohé and Uribe (2003), that country risk depends on external debt as follows:

$$SX_t \left(\Phi \left(\frac{B_{t+1}^*}{GDP_t} \right) R_t^* \right)^{-1} \quad (A1.20)$$

The resource constraint, copper output and government spending

The fiscal rule establishes that spending depends on structural revenue IT, plus an adjustment for excess of public debt. In other words, if this debt is consistent with its long-run value B^{G^*}, then the value of fiscal spending is equal to structural revenue IT.

$$P_t G_t = \left(\frac{B_t^{G^*}}{B^{G^*}} \right)^{-\phi^G} IT \quad (A1.21)$$

The government budgetary constraint, which includes all tax revenues plus copper transfers $\gamma^{cu} SX_t P_t^{cu} QCU_t$, is:

$$t_t^c P_t C_t + t_t^u P_t I_t + t_t^u P_t I_t^{cu} + t_t^W W_t N_t + \left(R_t\right)^{-1} B_{t+1}^G + \gamma^{cu} SX_t P_t^{cu} QCU_t = B_t^G + P_t G_t \quad \text{(A1.22)}$$

where B_t^G is government debt and γ^{cu} is the percentage of total copper exports by value made by the government (CODELCO).

ANNEX 2

Data used

The study sample is quarterly, from January 2003 to April 2013.

(i) *Macroeconomic data*

Macroeconomic information was taken from the website of the Central Bank of Chile:

http://si3.bcentral.cl/Siete/secure/cuadros/home.aspx.

(ii) *Mining-sector data*

Copper GDP:

Central Bank of Chile (quarterly figures for 2003-2013, spliced with reference series from 2008). (Data available online):

http://si3.bcentral.cl/Siete/secure/cuadros/home.aspx.

Mining investment

Obtained from COCHILCO, Inversión de la Gran Minería del Cobre, *Anuario*, using annual figures from 2003 to 2013 measured in each year's dollars multiplied by the exchange rate and divided by an investment deflator to give a value in real terms. (Data available online):

http://www.cochilco.cl/estadisticas/anuario.asp.

Obtained from the Central Bank of Chile: gross fixed capital formation (GFCF), using annual figures from 2003 to 2013 measured in each year's dollars multiplied by the exchange rate and divided by an investment deflator to give a value in real terms. (Data available online):

http://si3.bcentral.cl/Siete/secure/cuadros/home.aspx.

This information was used to calculate mining investment as a share of total investment each year.

In any year, the mining investment share is assumed to rise in a linear fashion to its annual share.

Central Bank of Chile: gross fixed capital formation (GFCF), taking quarterly figures from 2003 to 2013 spliced with reference series from 2008. (Data available online):

http://si3.bcentral.cl/Siete/secure/cuadros/home.aspx.

Mining employment

National Institute of Statistics (INE), employment by category, mining and quarrying, 2010-2013. (Data available online):

http://www.ine.cl/canales/chile_estadistico/mercado_del_trabajo/empleo/series_estadisticas/nuevas_empalmadas/series_fecha.php.

INE, employment by catgory, mining and quarrying, 2010-2013. (Data available online):

http://www.ine.cl/canales/chile_estadistico/mercado_del_trabajo/nene/series_trimestrales_2011.php.

The series were then spliced and converted into quarterly figures (Microsoft Excel ©) and seasonally adjusted using the EViews 8 Census X-13 © software.

Mining pay

Nominal pay index, mining and quarrying, ine, with the series obtained from two series: (i) spliced historical series from 1993 to 2007 (base January 2006 = 100), and (ii) reference series with annual base 2009 = 100. (Data available online):

http://www.ine.cl/canales/chile_estadistico/mercado_del_trabajo/remuneraciones/series_estadisticas/nuevo_series_estadisticas.php.

The series is monthly and was converted to quarterly figures (Microsoft Excel ©) and seasonally adjusted using the EViews 8 Census X-13 © software.

Electricity

COCHILCO, Consumo Nacional de la Energía en la Minería del Cobre, *Anuario*, taking the 2003-2013 annual average in terajoules (TJ). (Data available online):

http://www.cochilco.cl/estadisticas/energia.asp.

The series was converted into GWh (1 GWh»0.28 TJ). (Data available online):

http://www.lngplants.com/conversiontables.html.

National Energy Commission (CNE), gross generation in the Central Interconnected System (SIC)-Interconnected System of the Norte Grande (SING) (annual average in GWh). (Data available online):

http://www.cne.cl/estadisticas/energia/electricidad.

This information was used to calculate mining electricity consumption as a share of total national consumption each year.

CNE, gross generation SIC-SING (monthly average in GWh). This was converted into quarterly figures (Microsoft Excel ©) and seasonally adjusted using the EViews 8 Census X-13 © software. (Data available online):

http://www.cne.cl/estadisticas/energia/electricidad.

Within any year, the mining share of electricity consumption is assumed to rise in a linear fashion to its annual share.

The energy price

The energy price relevant to mining is constructed by taking a weighted average of the price in the SIC and the SING.

The weights used are the percentage of mining GDP in regions I and II for SING (0.6) and the percentage of mining GDP in regions III, IV, V and VI for SIC (0.4). Regional information is only available for 2010-2012, however.

The pricing details are as follows:

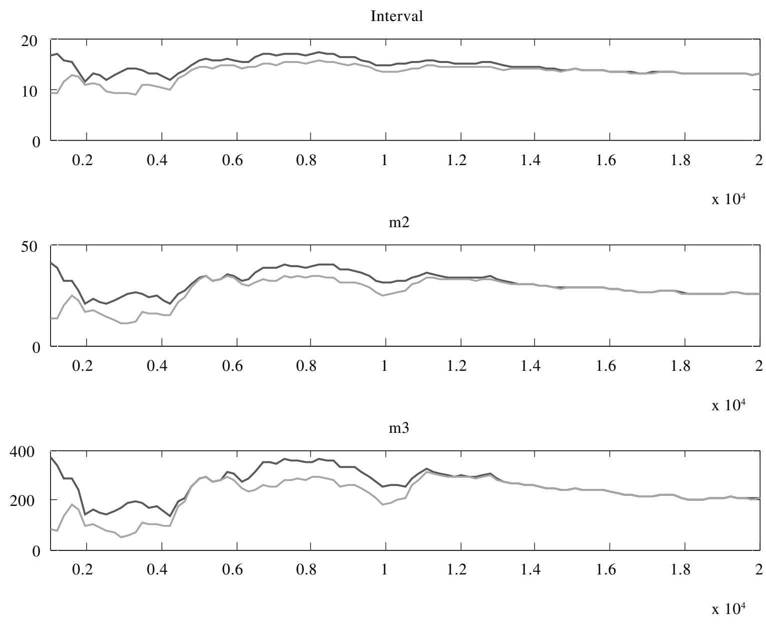
- From the third quarter of 2006 to the fourth quarter of 2013, use is made of the average market price in pesos/kwh for customers not subject to price regulation, as published by the National Energy Commission. Since published prices are four-month averages, the figure used for any quarter was the simple average of the two four-month periods that included the three months of the quarter concerned (for the third quarter of 2006, for example, a simple average of the two four-month periods June 2006-September 2006 and July 2006-October 2006 was taken).
- For the period from the first quarter of 2000 to the second quarter of 2006, use was made of the data calculated by Synex, as employed in the study "Impacto macroeconómico del retraso en las inversiones de generación eléctrica en Chile" (Agurto and others, 2013).

ANNEX 3

Convergence and parameters estimated for the DSGE model

FIGURE A.3.1

Convergence and stability of parameters



Source: Prepared by the authors, on the basis of the dynamic stochastic general equilibrium (DSGE) model.

TABLE A.3.1

Parameters estimated for the DSGE model

Parameter	Prior	Posterior	90% confidence interval		Prior distribution	Standard deviation
sigma	2	1.7726	1.6361	1.8897	gamma	0.1
h	0.3	0.2638	0.2018	0.3359	beta	0.05
rho_L	1	1.1488	1.0025	1.2985	gamma	0.1
rho_G	0.9	0.9119	0.8497	0.9793	beta	0.05
rho_A	0.9	0.931	0.9051	0.9535	beta	0.05
rho_Rstart	0.9	0.6335	0.5437	0.7146	beta	0.05
rho_Ystart	0.9	0.974	0.9651	0.9827	beta	0.05
rho_Oil	0.9	0.8655	0.7959	0.9337	beta	0.05
rho_Pcu	0.9	0.8623	0.8377	0.8915	beta	0.05
rho_GD	0.1	0.0098	0.0083	0.0111	beta	0.05
index	0.906	0.8815	0.8013	0.9641	beta	0.05
xi	0.804	0.8173	0.8024	0.8298	beta	0.01
index_w	0.9	0.6731	0.5775	0.785	beta	0.05
xi_w	0.67	0.8961	0.8802	0.9136	beta	0.05
beta1	0.8	0.7961	0.7821	0.8106	gamma	0.01
beta2	0.1	0.0999	0.0987	0.1013	beta	0.001
rho_R	0.92	0.9201	0.906	0.9325	beta	0.01
rho_inf	2	1.9894	1.8261	2.1729	beta	0.1
rho_y	0.5	0.5758	0.456	0.7018	beta	0.1
rho_e1	0.3	0.2655	0.1338	0.3943	beta	0.2
rho_e2	0.3	0.0811	0.0001	0.1715	beta	0.2
rho_E	0.3	0.3015	0.2848	0.3198	beta	0.01
MP_M	0.5	0.3838	0.281	0.4713	beta	0.1
MP_L	0.5	0.1662	0.1344	0.193	beta	0.1
MP_K	0.5	0.5271	0.3736	0.6914	beta	0.1
theta_TOIL	0.5	0.4599	0.2992	0.6423	beta	0.1
theta_L	0.5	0.8001	0.7209	0.8725	beta	0.1
theta_K	0.5	0.5046	0.3333	0.6619	beta	0.1
theta_M	0.5	0.5602	0.419	0.688	beta	0.1
MP_TOIL	0.1	0.0694	0.0103	0.1306	beta	0.05
MP_G	0.5	0.5863	0.5159	0.6519	beta	0.05
trend_GDP	1.1	1.2909	1.2053	1.3755	gamma	0.1
trend_Oil	2.42	2.4448	2.3135	2.5874	gamma	0.1
trend_Pcu	3.28	3.2443	3.0929	3.3895	gamma	0.1
trend_GDPstar	1.22	1.2056	1.0516	1.3425	gamma	0.1
trend_L	0.71	0.5789	0.4701	0.6934	gamma	0.1
trend_E	0.5	0.112	0.0006	0.228	unif	0.2887
constant_R	0.99	0.9837	0.828	1.1513	gamma	0.1
constant_PI	0.75	0.7538	0.6067	0.8976	gamma	0.1
constant_Rstar	0.5	0.3869	0.0004	0.728	unif	0.2887
rho_PEE	0.5	0.8518	0.8016	0.9022	beta	0.1
MP_EE_EN_COPPER	0.5	0.2564	0.1317	0.3676	beta	0.1
index_w_COPPER	0.9	0.9046	0.8335	0.9712	beta	0.05
xi_w_COPPER	0.67	0.6216	0.5705	0.6813	beta	0.05
MP_EN_COPPER	0.5	0.1423	0.0555	0.2258	beta	0.1
MP_L_COPPER	0.5	0.0848	0.051	0.1188	beta	0.1
MP_K_COPPER	0.5	0.5461	0.4031	0.6778	beta	0.1
rho_A_COPPER	0.9	0.9045	0.8917	0.9168	beta	0.01
trend_GDP_COPPER	0.1	0.1039	0.09	0.1187	gamma	0.01
trend_PEE	0.64	0.6381	0.4976	0.7886	gamma	0.1

Source: Prepared by the authors, on the basis of the dynamic stochastic general equilibrium (DSGE) model.

TABLE A.3.2

Standard deviations of the shocks estimated in the DSGE model

Standard deviation of shocks	Prior	Posterior	90% confidence interval		Prior distribution	Standard deviation
Err_C	1.08	0.4898	0.3557	0.6311	invg2	0.5
Err_E	3.56	5.1476	4.5078	5.7673	invg2	0.5
Err_G	1.72	1.1	0.9047	1.2844	invg2	0.5
Err_M	4.78	4.5151	3.9697	5.1656	invg2	0.5
Err_Oil	16.07	16.2808	15.608	17.0067	invg2	0.5
Err_Pcu	16.53	16.627	15.8637	17.4668	invg2	0.5
Err_GDP	1.16	1.8313	1.3863	2.2744	invg2	0.5
Err_Q	9.76	9.7315	8.9636	10.7295	invg2	0.5
Err_W	0.87	0.4109	0.3251	0.4877	invg2	0.5
Err_X	5.03	5.1674	4.5989	5.7607	invg2	0.5
Err_Ystart	2.81	3.31	2.662	3.9391	invg2	0.5
Err_R	0.48	0.2178	0.1732	0.2618	invg2	0.5
Err_PI	0.96	0.7168	0.5913	0.8459	invg2	0.5
Err_Rstart	0.89	0.9244	0.7517	1.0735	invg2	0.5
Err_QCU	3.59	3.7614	3.2334	4.2889	invg2	0.5
Err_COPPER_I	6.46	6.4473	5.8375	7.0691	invg2	0.5
Err_I	4.6	4.4445	3.9205	4.93	invg2	0.5
Err_L_COPPER	1.4	4.4021	3.7446	5.0181	invg2	0.5
Err_L	0.81	1.5259	1.2768	1.753	invg2	0.5
Err_COPPER_W	0.9	0.5559	0.4213	0.6845	invg2	0.5
Err_EE_COPPER	4.34	5.1935	4.3792	5.8902	invg2	0.5
Err_PEE	6.84	6.9106	6.2696	7.6251	invg2	0.5
Err_A	1.16	0.7197	0.5738	0.8635	invg2	0.5
Err_A_COPPER	3.59	7.2804	5.834	8.6681	invg2	0.5

Source: Prepared by the authors, on the basis of the dynamic stochastic general equilibrium (DSGE) model.

ANNEX 4

Calibration of Cobb-Douglas functions in the mining sector

The functions represented by copper production are as follows:

$$QCU_t = A_t^{CU} L_t^{CU\tilde{\alpha}} K_t^{CU\tilde{\beta}} E_t^{1-\tilde{\alpha}-\tilde{\beta}}$$

$$E_t = OIL_t^{\delta} EE_t^{1-\delta}$$

$\tilde{\beta}$ is estimated as follows: first the average ratio between copper mining investment and mining GDP is taken, then the share of $\tilde{\beta}$ is calculated by:

$$\tilde{\beta} = share = \left(r + \delta^{cu}\right)\frac{K^{cu}}{QCU}$$

$$= \left(0.02368 + 0.02\right) * 0.23 = 0.51$$

The interest rate is calculated by assuming a subjective discount rate of 0.9865, plus a differential of 1%. The depreciation rate γ^{cu} is assumed to be 2% a quarter, the same as the depreciation rate for the rest of the economy, which in turn was set at that level to give reasonable values for the stationary state (consumption over GDP, investment over GDP and others).

In the case of energy, use is made of the average annual electricity and fuel consumption figures in terajoules (TJ) published by COCHILCO. Then, annual consumption is transformed into barrels of oil equivalent (dividing by 5.75/1,000) and GWh (multiplying by 0.28), since peso prices exist for these units (the price of a barrel of oil is multiplied by the observed exchange rate to give the peso price).

The total values for each energy type are calculated by multiplying prices by the number of barrels and GWh, respectively. Then the respective shares are obtained by dividing the annual values by copper GDP in each year's pesos. Thus, the average of the shares for 2003-2013 is calculated. In summary, total energy represents 10% of copper GDP, with fuel accounting for 3% and electricity for 7%, so that 30% of the total energy bill is for fuel and 70% for electricity.

The labour share is obtained as a residual, once the capital and energy share has been calculated (1 - 0.51 - 0.1 = 0.39).

ANNEX 5

One characteristic of the copper price is that it has had long periods of growth, rising at an average quarterly rate of 12% from 2003 to 2006, for example. Accordingly, table A.5.1 shows cumulative GDP growth if the copper price increases continuously by 1% a quarter over different time horizons.

TABLE A.5.1

Cumulative GDP growth with continuous increases of 1% in the copper price

Years	Quarters in which the copper price rises by 1%															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0.12	0.21	0.29	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
2	0.15	0.29	0.42	0.55	0.67	0.77	0.85	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
3	0.15	0.30	0.45	0.60	0.75	0.89	1.03	1.15	1.27	1.37	1.45	1.50	1.50	1.50	1.50	1.50
4	0.14	0.28	0.42	0.57	0.72	0.87	1.02	1.17	1.32	1.46	1.60	1.73	1.85	1.95	2.03	2.08
5	0.12	0.24	0.37	0.51	0.65	0.79	0.93	1.08	1.23	1.38	1.53	1.69	1.83	1.98	2.12	2.25

Source: Prepared by the authors, on the basis of the dynamic stochastic general equilibrium (DSGE) model.

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