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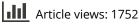
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#### ARTICLE

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# Sub-national economic effects of the resources sector in Chile

# **Rodrigo Valdes**

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#### ABSTRACT

The significant contributions of resource sectors to national economies are well known; however, information on sub-national impacts is much scarcer. Using Chile as a case study, this paper investigates how disturbances in the price of copper impact the economies where this mineral is produced. The proposed method combines estimates of long-term copper prices with a general equilibrium model to simulate the differential effects of copper price variations. The results suggest that price variations affect the design and implementation of public and private policies, at economic and business levels.

**ARTICLE HISTORY** 

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#### **KEYWORDS**

Prices; regional economies; resources sector; Chile

# 1. Introduction

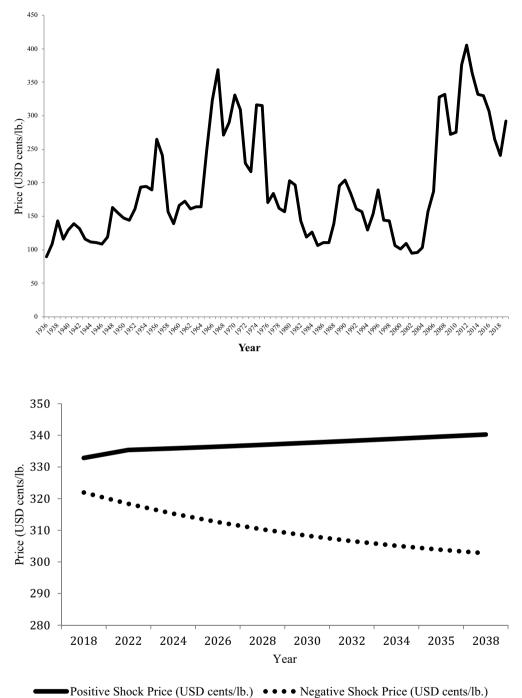
The copper sector differs from many other productive sectors in that it requires high amounts of initial investment compared to other businesses, its projects have long time horizons, and that it deals with an uncertain exhaustible resource (Marshall, Silva, & Meller, 2002). Large fluctuations in any of these variables affect mining performance, which can be transmitted to the rest of the economy through, e.g.,, tax collection, the exchange rate, and return on investment (Lagos, 1997). As a result, price fluctuations in natural resources and their effects on the economic performance of resource-rich countries have attracted significant academic interest in the field of resource economics (see Baffes & Savescu, 2014; Irwin, Sanders, & Merrin, 2009; Ruehle & Kulkarni, 2011; Tilton & Lagos, 2007). While previous studies have analyzed copper price variability, demand estimates, and production linkages, very few articles have discussed mining sectors' regional interrelationships - let alone price fluctuation effects on domestic, regional production economies in developing countries.

Historically, Chile's economic and social development has been tied to production and exports from copper mining. Particularly, the income generated in private and public sectors places Chile as the largest copper producer in the world (USGS, 2018). In 2017, exports of this mineral represented 59% of the total Chilean exports (Chilean Central Bank, 2018); from 1980 to 2013, mining activity accounted for 17.9% of the fiscal revenue and 27% of the total foreign investment and over the last 15 years, its share of national GDP averaged 8%-11%.

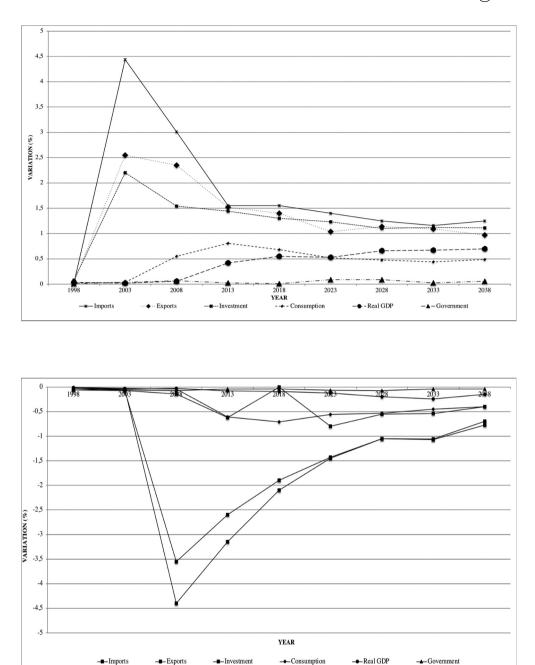
CONTACT Rodrigo Valdes 🖾 rodrigo.valdes@pucv.cl 🖃 Escuela de Negocios y Economía, Facultad de Ciencias Económicas y Administrativas, Pontificia Universidad Católica de Valparaíso, Avenida Brasil 2830, Piso 7, Valparaíso, Chile Supplemental material for this article can be accessed here.

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In the above context, this paper examines the impact of copper price volatility at the sub-national level, analyzing Chile's economic growth as a relationship between the mining sector and regional economies. The paper is organized as follows: Section two presents existing forecasting and long-term adjustment methods for international



commodity prices; Section three describes copper price formation mechanisms among international markets; Section four reviews the importance of copper mining in Chile; Sections five and six show the estimation strategy; and Section seven presents the results and discussions. The final section concludes.

# 2. International price of commodities: forecasting and long-term adjustments

Copper price forecasting directly influences decisions in public and private mining sectors. Therefore, its methods directly affect tax revenues depending on the type of shock, short- or long-term prices, and the duration of adjustments (Ruehle & Kulkarni, 2011). Different price projection approaches have been developed in the copper sector, in general or otherwise. For example, Issler et al. (2014) combined forecast techniques to predict monthly and quarterly commodity prices using the 1965 to 2008 IMF International Financial Statistics (IFS) database; Gargano and Timmermann (2014) subjected datasets of financial and macroeconomic predictors - e.g., industrial production, unemployment, inflation, the Australian Dollar, the Indian Rupee, and open interest in futures markets - to univariate and multivariate regressions to predict returns on CRB commodity sub-indices (industrials, metals, fats/oils, foods, textiles, etc.); Chen, Rogoff, and Rossi (2010) forecasted quarterly changes in commodity price indexes using mixed-frequency data (daily exchange rates and equity data from 1984 to 2010), finding that equity price indexes can have a predictive power similar to exchange rates; and similarly - Rapach et al. (2013) found that information on U.S. stock prices broadly forecast stock returns in other international markets.

In spite of the above advances, there has been limited development of methodological approaches to study effects of price variations on domestic and international economies. However, some sectoral studies do exist. For example, Marshall et al. (2002) – in their analysis of long-term price as a function of copper consumption growth rate, future production, and profitability established for mining projects – found evidence of heterogeneous effects at the domestic level and demonstrated that long-term variations have a direct influence on the investment strategies of copper companies; Cuddington and Jerrett (2008) used band-pass filters to extract particular cyclical components from copper price series data, and found that high and low price rally cycles may inform public budgetary adjustments; and finally, Tang (2012) proposed a reduced-form model of the stochastic long-run mean as a separate factor in order to explore the mean reversion of copper price, to generate long-term budgets for public and private agents, and to inform investment decisions.

Unlike the methodological proposal of this article, however, most of the above pricing models lack non-structural explanatory variables (i.e., investment, production capacity, inventories and demand determinants) for the effects of copper price volatility over a longer period of time. My approach innovates first, by incorporating long-term trends and short-term volatility to control for asymmetric responses to positive and negative shocks in copper prices and second, by implementing general equilibrium models to analyze sectoral interrelationships of the mining sector and the effects of price fluctuations on the economy.

# 3. The formation of copper prices

As depicted in Figure 1, international copper prices have experienced a general downward trend over time, with clearly distinguishable periods. From 1936 to 1970s, strong price fluctuations were attributable to the Great Depression and the oil crisis; in the early 1970s, prices rose sharply and then began a steady fall to their historic lows in the early 2000s. All these variations show changes in the average prices of each cycle, and therefore influence the long-term price.

Scholars have tried diverse approaches to gain further insight into this process of copper price formation. Of these, Wets and Rios (2015) blended short-term and long-term processes into a multidimensional model using several indexes. These authors examined various channels of copper price formation, and discerned some economic interdependence. The analysis in this paper builds on that approach, including asymmetric responses to positive and negative shocks on long-term copper prices, and provides novel insight into the economic implications for local economies.

Indeed, to this last point, although it is widely accepted that resource sectors make a significant contribution to national and state economies, information about how they impact regional economies is much scarcer. In addressing this gap, this paper pioneers the analysis of regional effects by exploring how copper price fluctuations and sources affect the economies of the major Chilean copper-producing regions.

# 4. The Chilean copper mining sector

Copper mining is the most economically significant productive sector in Chile: between 2008 and 2018, it was responsible for 59.1% of the total exports, 18.1% of share of total investment, and from US\$39.1 to US\$51.1 billion in net public revenues (Corporacion Chilena del Cobre (COCHILCO), 2018). Table 1 presents Chilean copper mining value added in terms of exports, direct foreign investment, and revenue shares.

In terms of regional importance, mining cycles have had an enormous impact on the evolution, localization, and industry changes of economic activity in Chile. Because the copper cycle is geographically dispersed and capital-intensive (Badia-Miró & Yañez, 2015), multinational corporations dominate activities in the primary mining regions of Tarapaca (Region I), Antofagasta (Region II), Atacama (Region III), Coquimbo (Region IV), Valparaiso (Region V), and Libertador General Bernardo O'Higgins (Region VI). In 2016, large-scale operations - conducted by 19 private companies and the National Copper Corporation of Chile (hereafter, CODELCO) - accounted for about 6.5 million metric tons (Mt), or 95.2% of the total; medium-scale, by 22 private companies, 5% to 6% of the annual copper production; and sundry small-scale operations, for about 2% (Corporacion Chilena del Cobre (COCHILCO), 2018). Antofagasta, the leading copperproducing region, has accounted for between 53% and 65% of the national production every year since at least 2004 (National Geology and Mining Service, 2017; hereafter, SERNAGEOMIN). In 2018, the top copper-producing companies accounted for 77% of the total production: Minera Escondida Ltda. - which holds the leading private copper mine, Escondida – produced 1.1 million Mt of copper, or 19.2% of the national total; and the subsequent eight, 59%, divided between public endeavors (Chuquicamata, Andina Division, El Teniente, and Radomiro Tomic) and private companies (Los Bronces, Los Pelambres, Candelaria, and Collahuasi) (Corporacion Chilena del Cobre (COCHILCO), 2018).

# 5. Methodology

To approach the complexity of these interrelations, and considering market mechanisms and price volatility, I propose a two-stage method. The first step is to forecast long-term copper prices and compare them with those forecasted by the Chilean Public Expert Committee. Briefly, prices published by the Public Expert Committee - created to guarantee an independent structural balance process and to assess medium-term projections in the public structural budget – are estimated by consulting rounds with a panel of 16 experts, each of whom are asked for average price estimates over the next 10 years (excluding the lowest and highest estimates). This study, in contrast, simulates variations in long-term prices with the Wets and Rios approach (Wets & Rios, 2015) over a 20-year horizon for each year in question. Indeed, the Wets and Rios approach for estimating long-term copper prices was chosen for this study because it, first, explicitly differentiates short- and long-term regimes; second, includes market information in the price estimations framework; and third, may be extended to incorporate any number of indexes. Generally, this process presents a reversion to an unobservable long-term marginal cost that follows a trend, notwithstanding random fluctuations in both level and time (1). The specification for i = 1, ..., n is as follows:

$$y_{i}^{t} = v_{i}(1 - e^{-u_{i}t}) + y_{i}^{0}exp\left[-\left(u_{i} + \frac{1}{2}\sum_{j=1}^{J}b_{ij}^{2}\right)(t - t_{0}) + \left(\sum_{j=1}^{J}b_{ij}\left(w_{j}^{t} - w_{j}^{t0}\right)\right)\right]$$
(1)

and at  $t_0 = 0$ ,

$$y_{i}^{t} = v_{i}(1 - e^{-u_{i}t}) + y_{i}^{t0}exp\left[-\left(u_{i} + \frac{1}{2}\sum_{j=1}^{J}b_{ij}^{2}\right)t + \left(\sum_{j=1}^{J}b_{ij}\left(w_{j}^{t}\right)\right)\right]$$
(2)

where *t* and *t*<sub>0</sub> are the present and future periods, respectively;  $y_i^0$  is the present value of index i (given);  $u_i$  and  $b_{ij}$  are constants that need to be estimated;  $y^t = (y_i^t - y_n^t)$  is the state of the system at time t;  $w_j$ , j = 1, ..., J are independent (standard) Wiener processes;  $v_i$  is an index to which  $y_i^t$  reverts in the long term; and  $u_i$  is the "speed" at which  $y_i^t$  reverts to  $v_i$ .

Next, in the second of the two stages, the study implements a general equilibrium model to simulate positive and negative differential effects of copper price variations (10% increase and decrease, respectively) and their effects at sub-national level. Adapted from the OECD model (Beghin, Dessus, Roland-Holst, & van der Mensbrugghe, 1996), the base model represents Chile in 74 economic sectors, uses capital and labor as primary productive factors, and takes assumptions of capital as putty or semi-putty, full availability of labor (which grows at an exogenous rate for the period of analysis), and full availability of mining reserves. The model specifications include labor and incomegroups differentiation, trade partners, and specified productive factors (O'Ryan, de Miguel, & Miller, 2003). The dynamic structure of the model allows for the inclusion of adjustment costs when capital is released from one sector to another. Exogenous costs are given by disinvestment and related elasticities, obtained from the international literature. Investment in each sector – mainly represented as relative returns between installed capital and capital to be installed – may take intersectoral capital as immobile or

fully mobile, as depends on long- or short-term vision. The closing equation of the model – a balance of payments considering net exports, foreign savings, factor payments, and transfers to and from households and government – ensures adherence to Walras' law. The model framework takes as main indices: productive sectors or activities

(i,j); types of work, or occupational categories (l); household income groups, expressed in quintiles (h); public spending categories (g);

final demand spending categories

(f); trade partners (r); and different types of pollutants (p). The production structure is modeled by nested functions for constant elasticity of substitution and constant elasticity of transformation (CES/CET). If constant returns to scale and minimized costs are assumed, each sector produces:

$$\min PKEL_i KEL_i + PND_i ND_i \tag{3}$$

s.t.

$$XP_{i} = \left[\alpha_{\text{KELi}} KEL_{i}^{\sigma_{i}^{\text{P}}} + \alpha_{\text{NDi}} ND_{i}^{\sigma_{i}^{\text{P}}}\right]^{1/\sigma_{i}^{\text{P}}}$$
(4)

where KEL is a composite good of capital, energy, and labor; PKEL is the price of KEL; ND is a composite good of no-energy intermediate inputs; PND is the price of ND; XP is total ouput;  $\alpha$  is the share of input/factor use; and  $\sigma$  is the substitution elasticity.

Households use their income for consumption and savings, modeled by an Extended Linear Expenditure System (ELES) utility function which also incorporates minimum subsistence consumption independently from the level of income. This is given by:

$$\max \mathbf{U} = \sum_{i=1}^{n} p_i \ln(C_i - \theta_i) + \mathbf{p}_s \ln\left(\frac{S}{CPI}\right),\tag{5}$$

subject to

$$\sum_{i=1}^{n} PC_i Ci_i + S = YD$$
(6)

and

$$\sum_{i=1}^{n} p_i + p_s = 1$$
(7)

where U stands for consumer utility;  $C_i$  is the consumption of good i;  $\theta_i$  is subsistence consumption; S, savings; CPI, the price of savings; and p, the marginal propensity to consume each good or to save. Finally, the different types of taxes and transfers in public finances are directly defined in the model as taxes on labor (differentiated by occupational category), firms, and income (differentiated by quintile).

In order to analyze the impact of copper price variations on regional economies, the paper proposes a social accounting matrix (SAM). This SAM includes only the copperproducing regions of Chile, and will serve as the basis for adapting the previously described general equilibrium model to these regions. This matrix departs from the methodological approaches developed by Riffo, Becerra, Acevedo, Morgado, and Villegas (2006), Rojas (2009), and Mardones (2012), and instead opts for the Top-Down method as proposed by Thorbecke (2000). Overall, this evaluation instrument solves many limitations by more realistically representing regional economies by incorporating market and price mechanisms in the assignment of resources.

# 6. Data

Data on yearly series of international real copper prices were obtained from the United States Geological Survey and the Copper Chilean Commission. The simulation strategy showed effects across all copper-producing regions: Tarapaca (Region I), Antofagasta (Region II), Atacama (Region III), Coquimbo (Region IV), Valparaiso (Region V), and Libertador General Bernardo O'Higgins (Region VI). These effects are incorporated into the CGE model via the social accounting matrix (SAM) provided by the Chilean Central Bank (2018). Secondary data from macroeconomic variables for each sub-national sector, as well as trade information, were obtained from diverse private and public institutions (COCHILCO, Chilean Central Bank, and SERNAGEOMIN, among others).

# 7. Results and discussion

# 7.1. Price forecasting and comparison

The Wets and Rios approach (Wets & Rios, 2015) requires that the series trend is stable (stationary), i.e., has no unit root and may thus be estimated along a trend. Determined by Elliott, Rothenberg, and Stock (1996) applied to the whole sample, the unit root hypothesis was rejected (see Table 2), and so future prices may be estimated through a mean reversion procedure as defined by the approach.

Figure 2 shows simulations under the Wets and Rios approach. The results for price elasticity show that a 10% negative shock in 2018 leads to an initial -2.81 % decrease in price, dropping to 14.05% after 20 years. Overall, while price dynamics associated with a negative shock are far more pronounced, the average suggests that an initial shock is temporary and prices return to an average trend.

Under this model, rates of return with respect to long-term price dynamics are relatively homogeneous, allowing for more stable forecasts of long-term time horizons (see Table 3).

Next, Table 4 shows the price forecasts from the Chilean expert committee through 2028.

Under the scenario of mainly negative transitory shock, the Wets and Rios approach (Wets & Rios, 2015) reasonably predicts the prices projected by the panel of experts, as seen in the last column of Table 4. Projecting this particular scenario yields two main hypotheses for effects in copper-producing regions. First, a fall in the price of copper generates a depreciation of the local currency, which mostly compensates a copper sector downturn, benefitting productive regions – as discussed in Bravo–Ortega and De Gregorio (2006). Second, a downward price projection in copper would appear to generate a distributive effect, due to improved relative income of the lowest quintiles. However, the capital-intensive producing regions are negatively affected by the contraction of this sector and subsequent reallocation of capital to other, more intensive

unskilled labor use sectors. As a result, workers in the copper industries with a high degree of training will be affected in the medium and long term by a relative drop in wages. According to Medina and Soto (2007), an initial effect of increased revenues arises because the wages of unskilled workers remain constant in the short term and fall less in the short- and medium-term than do wages of skilled workers. This is mainly because the downturn in the copper sector is offset by an increase in other productive sectors, primarily those that are more intensive in unskilled labor.

# 7.2. Simulation results

The two scenarios simulated – based on the general equilibrium model described above. Since the short-term variation of price has already been shown to modify the long-term price,<sup>1</sup> we develop an analysis of the effects on mining regions with respect to copper price volatility, sectors, and agents. In order to best isolate the effect of price volatility, royalty costs are not incorporated. Table 5 shows international copper prices used in Simulations.

# 8. Positive differential effects

The positive cycle generates an international price increase of copper, which leads to an average drop of 0.42% in the real exchange rate for the horizon under study, and therefore a net increase in imports. The transmission mechanisms of this shock are explained by an increase in the profitability of the mining sector, increasing levels of investment, production, and exports in producing regions. The price increase is transmitted by the relationship between domestic and foreign prices, generating an appreciation of international prices (Aroca, 2001). This appreciation affects the exchange rates, contributing a slight reduction in imports and an increase in copper exports. In this sense, an increase in the price of copper will have a positive effect on the real GDP, the level of savings, and the tax income in producing regions. On the other hand, the fall in exports for non-cupric sectors is mainly explained by a fall in the real exchange rate, which, as discussed by Rolf et al. (2011), is due to the increase of international copper prices, which generates an increase in the production of the mineral. Due to this, the copper sector captures resources from other sectors, which diminishes their respective levels of supply. Figure 3 shows the differential effects of the positive copper price cycle for producing regions for each variable incorporated in the general equilibrium model.

From a macroeconomic point of view, when international copper prices increase, the real GDP increases over time toward nearly 0.68% on average. Imports and exports increase in the first years of a shock, where the increase in imports is almost double that the prices return to their tendency over the of exports, as longterm; however, this increase diminishes and both growth rates start to converge. Investments increase on average around 1.3% during the entire analysis horizon of the simulation, although at its greatest impact, at 2.0%, during the first period of price shock. In addition, consumption increases by 0.68% on average during the course of the simulation.

<sup>&</sup>lt;sup>1</sup>Long term Price understood as 20-year future average.

Considering the above results, this simulation suggests the presence of Dutch disease in regional copper-producing economies due to increased copper sector exports and the corresponding fall of the real exchange rate, which affects exchange rates in other sectors. These results are further exacerbated, since the copper sector has few down-stream productive capabilities with other sectors that could have otherwise taken advantage of growth in this sector (Phelps, Atienza, & Arias, 2015).

# 9. Negative differential effects

Faced with a fall in international prices, the copper sector achieves less investment, diminishes its level of production, and sees fewer exports as a corollary. On average, during negative cycle, the real GDP falls by 0.67%; consumption by 0.62%; investment diminishes by about 1.54%; and exports and imports fall by 2.0 and 2.3%, respectively. There is a drop of 0.43%, on average, in the real exchange rate for the horizon under study. Figure 4 shows the differential effects of the negative copper price cycle among producing regions for each variable incorporated in the general equilibrium model.

When comparing positive and negative scenarios, it is clear that the regional economic variables present similar responses to both positive and negative price shocks. However, a negative shock in copper prices is 0.28% more contractive on exports than the contrasting positive shock on such increase. This is consistent with the results from other studies (Halada, Shimada, & Ijima, 2008) that have shown an analogous positive difference between inverse price shock comparisons, although in terms of aggregate consumption. In terms of real GDP, there is a greater contraction under a negative cycle due mainly to disinvestment costs. According to Brewster (2009), this happens because these types of cycles encourage the movement of capital toward more profitable sectors, which is an overall additional inefficiency in the economy. The increased real exchange rate mostly favors non-copper exports while import sectors would suffer. Furthermore, this phenomenon would favor local production through a scenario of substituting imports for intermediate consumption.

# 10. Conclusions

The focus of this study was on copper price volatility, and their sub-national impacts in Chile. The estimation strategy consists of two stages: first, an estimation of long-term copper prices using the Wets and Rios approach (Wets & Rios, 2015) and second, a general equilibrium model to simulate the differential effects of copper price cycles at sub-national level.

The estimates show that the Wets and Rios model yields more homogeneous price projections than those made by the Chilean government. Because the government projection is the basis for quantifying fiscal budgets, projecting negative price ranges or prices that are very resilient to international influence may have significant negative economic effects on regional economies, in which a sharp fall in government and business savings directly affects production via investment and result in a fall in total exports and a drop in sectorial investments. This further confirms that fiscal revenues – generated by copper sales – mostly benefit from the trade cycle term multiplier in regional economies.

In terms of price simulations, the paper concludes that, under a transitional scenario of an international price increase in copper, and without any policy change, there is a Dutch disease-type phenomenon that manifests in the short term and negatively affects exporting sectors. These results are exacerbated thanks to the copper sector lacking down-stream production in other sectors that would otherwise have taken advantage of this growth. On the other hand, a reduction in the international price of copper (also without any policy changes) produces contraction effects in the economy related to the inability of regional copper sectors to divest their capital under lost profitability and related to an increase in real exchange rate, which favors an increase in local production in a scenario of substituting imports for intermediate consumption. In both cases, the effects of a positive price cycle were shown not to compensate for the losses of a negative cycle.

In this sense, and from a political point of view, it is necessary to allocate funds that originate in a positive cycle towards compensating for the greater losses to come under a scenario of lower prices. Indeed, a policy designed for more balanced growth would nurture the relationship between household consumption and private investment (Ebert & La Menza, 2015). Rising household income and consumption would generate product innovation; private investment would lead to rising labor productivity in non-mining tradable and non-tradable goods sectors, which would, in turn, raise wages and further fuel domestic demand.

Finally, my approach allows policymakers (and others) to disentangle the relationships between price dynamics, shocks, and effects on regional economies. This would allow new approaches to policies in support of copper-producing regions to be developed in the future. For example, a recent article (Paredes, Soto, & Fleming, 2017) discusses wage compensations for commuting mining workers who live in a different region than where they work. Overall, policies may compensate for economic losses generated under a negative price cycle in producing regions.

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# **Disclosure statement**

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