The structuralist theory of 'Dutch Disease': some numerical results

Pablo R. Liboreiro[1]

[1]School of Civil Engineering, Technical University of Madrid
Author's email: pablo.rodriguezl@upm.es

Abstract

Purpose — By means of a practical model, the paper discusses the structuralist theory of the so-called Dutch Disease, which is based on the existence of conflicting claims to product among distinct sectors in a situation of lagging supply of key intermediates

Methods — The model is for the Chilean economy and follows a Kaleckian 'fix-price/flex-price' structure, with 33 production sectors. Once calibrated and parameterized, the model can be solved numerically to estimate the effects of mining activities on other production sectors.

Findings — Some results follow from the numerical exercises. Mining-induced cost-push effects are biased against manufactures, while mining-induced demand effects are biased in favour of services. Therefore, high levels of mining activity led to a lower share of manufacturing in income as well as a lower volume of exports of non-mineral goods. However, it cannot in any case be taken for granted that mining will have crowding-out effects on manufacturing output.

Implication — The numerical exercises show a link between infrastructure services and mining-induced cost effects, which points to the crucial importance of infrastructure policy in mineral exporting countries. Results also show that the proposal for 'achieving economic diversification by restricting mining' – although tempting – may not work.

Originality — The present study contributes to the literature on Dutch Disease by illustrating the order of magnitude of mining-induced demand and cost effects. These competing effects have been postulated theoretically by structuralist scholars but have not to date been estimated in practical models.

Keywords: Dutch Disease, 'Flex-price/Fix-price' Model, Mining-induced Cost-Push Effects, Mining-induced Demand Effects.

JEL Classification Numbers: F41, O14, N56

Introduction

Among the most debated aspects of structural change in an open economy over the past 40 years has been the phenomenon known as 'Dutch Disease', where increases in mineral exports go hand-in-hand with declines in the diversification of the production structure. This phenomenon has in many cases been associated with advanced economies (minerals in Australia, natural gas in the Netherlands, oil in the United Kingdom and Norway), but signs of Dutch Disease have also been observed in developing countries (minerals in Chile and Mongolia, oil and gas in Russia and the Middle East). In fact, the effects of Dutch Disease are expected to impact more heavily on the economic performance of developing countries, it being commonly assumed that in order for countries to develop, they must succeed at broadening their skills and technologies, thereby moving beyond the production of a few primary goods to become competitive in a range of relatively advanced goods (Imbs & Wacziarg, 2003; Kuznets, 1964).

The 'mainstream' theory of Dutch Disease (Corden, 1984; Corden & Neary, 1982) explains the coexistence of increasing mineral exports and declining industries as resulting from adjustment mechanisms within a competitive full-employment economy in the face of 'productivity shocks'. Indeed, according to the orthodox approach, the expansion of mineral output at given world prices can be understood as a 'once-for-all' exogenous technical improvement in the mining sector. This is represented by a favourable shift in the mining production function, whose inputs are capital and labour. Capital is assumed to be a factor specific to each sector, whereas labour is considered mobile across all sectors and assumed to be fully employed at all times. Assuming that prices of traded goods are given exogenously while prices of non-traded goods will vary to clear the market, 'technical' improvements in the mining sector generate extra income. Part of this extra income is spent (via consumer spending) on non-traded goods, giving rise to an appreciation of the real exchange rate – i.e., an increase in the price of non-traded goods in relation to the price of traded goods. Furthermore, the increase in the marginal product of labour in the mining sector (as a result of a boom) and the increase in prices in the non-traded goods sector will together give rise to the movement of labour out of the manufacturing sector and into the mining and the non-traded goods sectors. According to the mainstream hypothesis, these two effects – the 'spending effect' and the 'resource movement effect' – represent the key mechanisms that explain Dutch Disease.

The main defect of this mainstream theory is that its predictions largely depend on the assumption of full employment of labour, since both the spending effect and the resource movement effect assume that real wages will vary, to clear the labour market. Thus, in countries where a large part of the labour force is underemployed, as in many developing and emerging-market countries, the possibility of Dutch Disease would be unlikely, since the labour supply is expected to be very elastic at a given real wage. Furthermore, the adjustment mechanisms predicted by mainstream theory act in the same deindustrializing direction, making it apparently difficult to find cases where Dutch Disease does not occur, even in the short run (Mien & Goujon, 2022; Nülle & Davis, 2018). Such contradictions have not gone unnoticed by neoclassical scholars, who have changed the theoretical emphasis from the resource movement effect to spending effects arising from a 'procyclicality' of fiscal policy in developing countries (Bruno & Sachs, 1982; Frankel, 2012; Sinnott et al., 2010). In fact, a good portion of recent mainstream studies on Dutch Disease focus more on the evaluation of 'fiscal rules' and the macroeconomic impact of fiscal policies than on adjustment mechanisms operating in a full-employment economy in the face of a productivity shock in the mining sector (Arezki & Ismail, 2013; Medas & Zakharova, 2009; Pegg, 2010; van der Ploeg, 2019). The role of mining in the economic structure here recedes into the background, while the main role in fostering the development of Dutch Disease is played by the government through its spending decisions.

The structuralist theory of Dutch Disease (Taylor, 1983, 1991) provides an alternative explanation to the mainstream, disregarding the assumption of full employment of labour (among other factors). This unorthodox approach is based on the existence of conflicting claims to an available product between sectors in a situation of lagging supply of key intermediates.[1] The issue is represented in terms of a 'flex-price/fix-price' model. Manufactures are assumed to be produced under imperfect competition, so that prices are fixed by relatively stable mark-ups over variable costs, thereby comprising a 'fix-price' sector. To the contrary, the production of import-substituting or non-importable intermediates such as energy, transport services, or other infrastructure are assumed to comprise a 'flex-price' sector in which greater production is associated with a higher price-cost ratio due to inflexibility of supply. These 'flex-price' goods are used as inputs and feed either mineral production or another 'fix-price' sector (such as manufacturing). Thus, when mineral output expands,

[1] The foundations of the structuralist theory of Dutch Disease, emphasizing the role of changing prices of non-traded goods in reaching macroeconomic equilibrium, can be traced to Sunkel (1958) and Kalecki (1954a). Its current formulation derives from Taylor (1983, 1991).

two effects are set in motion. On the one hand, greater intermediate demand will be generated, so that intermediate prices rise (to ration the inflexible supply) and thus engender cost-push price increases in manufacturing. This intermediate cost-push will reduce both consumption and export demand for manufacturing output. On the other hand, if mineral output expands, this will generate demand for manufacturing output, because a share of the export receipts from mining will be spent on consumer goods, and because some of the increased intermediate demand will go to purchasing manufactured goods. The final outcome for manufacturing output is unclear; depending on which effect is stronger, the output response can go either way.

According to the structuralist theory, the coexistence of a booming mining sector with a lagging manufacturing sector is not an unavoidable result of the expansion of mineral output; rather, it depends on the specific structure of an economy. Thus, in the event that the price responsiveness of both exports and imports is low, and a significant portion of the export receipts from mining are spent on manufactures, then the 'demand effect' will overpower the 'cost-push effect' and a booming mining sector will further imply a booming manufacturing sector. To the contrary, if trade elasticities are large and competition is strong between the mining and manufacturing sectors for the use of key intermediates, then the 'cost-push effect' will dominate, and a booming mining sector will lead to a lagging manufacturing sector. Furthermore, one effect or the other will be dominant depending on the macroeconomic adjustment mechanism to variations in mining output, which will depend largely on institutions and political economy.

The interest of the structuralist theory of Dutch Disease lies precisely in the framework that it provides for the discussion of alternative scenarios, depending on the parameters that characterize the structure of a given mineral-exporting economy. However, despite the interest of this approach, to date there have been very few studies to illustrate the roles that the mechanisms assumed by the theory actually play in a practical model. Studies have been carried out in which the effects of Dutch Disease are illustrated under an assumption of the adjustment mechanisms typical of a competitive full-employment economy (Bahar & Santos, 2018; Benjamin et al., 1989; Kayizzi-Mugerwa, 1991). In some studies, the impact of export revenues and exogenous foreign savings on domestic product, price level, and income distribution in import-dependent developing countries has been analysed with practical structuralist models (Davies et al., 1994; Gibson, 1985, 1990; Rattso & Torvik, 1998). Dutch Disease-type adjustments associated with improvements in the terms of trade have also been included in structuralist macroeconomic models (Serino, 2010). However, to the best of our knowledge, no studies have to date been carried out in which a practical model is employed for discussion of the hypothesis that Dutch disease can arise in a situation of conflicting claims to product in conditions of inflexible supply. This is precisely the aim of the present study.

The model described here is for the Chilean economy, although it can be easily adapted to another mineral-exporting economy. This is a multi-sector macro model that follows a Kaleckian structure in which it is assumed that two types of price formation can arise out of different conditions of supply (Kalecki, 1954b). Prices in sectors producing manufactures as well as consumer or business services are determined by costs: these are 'fix-price' sectors in which prices are set by a mark-up over variable costs. Prices in the agricultural sector and in sectors producing import-substituting intermediates and infrastructure services are determined by demand: these are 'flex-price' sectors in which greater domestic production implies a higher price-cost ratio. The mining sector is considered to be completely controlled from outside: both its supply and prices are exogenously given, while exports vary in order to clear the market.

The data needed to calibrate and parameterize the model are taken mainly from the OECD Input-Output Table (2018 release) for the Chilean economy in 2014; this is complemented with additional data from OECD Statistics. The Chilean model is described in section 1, which sets out the equations for the model. The criteria used to calibrate and parameterize the model based on available data appears in section 2. In section 3, a number of comparative static exercises conducted with the model are analysed, with parameters or exogenous variables to simulate alternative scenarios compatible with a decrease in mining output. The emphasis is on the role that alternative adjustment mechanisms can play in assessing whether mining generates crowding-out or crowding-in effects on manufacturing and services, depending on the magnitude of the 'demand' or 'cost-push' effects. Conclusions are summarized and some policy implications are discussed in section 4.

1. A macro model for Chile

The Chilean model is based on the notion that different sectors of the economy respond differently to changes in demand. Sectors producing raw materials, import-substituting intermediates (fuels, cements), infrastructure services (public utilities, transportation, communications), and construction and housing are considered 'flex-price' sectors, which implies a rising supply curve for domestic production of these goods. In contrast, sectors producing manufactures and business or consumer-oriented services are 'fix-price' sectors, where prices are determined by a mark-up over variable costs. Supply in the mining sector is considered exogenously given, and prices are governed by international markets, while exports vary to clear the market.

The model is built to be solved numerically using data from OECD Input-Output Tables (2918 release) and some additional data from Chile's national accounts. The model's equations appear in Table 1, and the variables and parameters are described in Table 2. The equations are set out in blocks, described below in succession.

Blocks I and II contain input-output balances. Block I sets demand for domestic production (to the left) equal to domestic supply for the 33 sectors, where demand for domestic production is comprised of domestic and foreign demand. Block II set that domestic use (to the left) is satisfied by both domestic production and imports. The entries in Blocks I and II correspond to the rows of an IOT, under the convention that base-period prices for sectoral outputs are all set to one. Sectoral domestic demand is made up of intermediate demand, household and government consumption, and investment, while sectoral supply consists of both domestic output and imports.

Because the supply of goods is made up of domestic output and imports, the average price at which each type of good is procured will be a weighted average between the price of domestic goods and the price of imported goods. This is what the equations in Block III express.

Block IV gives expressions for variable costs per unit of output. Costs per unit of output are made up of purchases of intermediates, including both domestic and imported goods and payments of wages to workers. Both intermediates and labour enter in fixed proportions in the production of each good.

Block V provides equations defining wage and profit incomes. Wage income in the first equation comes from production (including government activities) and emigrant remittances. The level of income from profits follows in the second equation, as the sum of sales revenue net of variable costs less government revenue from State-owned firms and royalties. Government interest payments are added and net interest payments abroad are subtracted to yield the final value of profit income.

Real wages are assumed to be exogenously given, so money wages are determined by the cost of living. Equations in Block VI reflect precisely this while defining the consumer price index.

Block VII contains equations for levels of consumer spending from wage and profit incomes. Here, gross income from Block V turns to disposable income, after taking into account corporate taxes and net transfers to workers. From disposable income, the level of consumer spending is obtained assuming constant savings ratios.

Sectoral consumption levels follow in Block VIII according to the set of demand equations known as the linear expenditure system. There are two sets of parameters for the linear expenditure system: base-levels of consumption of goods, which are assumed to be independent of income and prices, and marginal propensities to consume from incomes above the levels required to pay for the base-level procurements. The own-price and cross-price responsiveness of consumption as well as income responsiveness are summarized by these parameters.

Block IX specifies sectoral export levels for non-mineral goods assuming an essentially non-competitive world market. Moreover, imports are assumed to be proportional to domestic demand for domestic production, and the proportionality coefficient is assumed to depend on relative foreign and domestic prices, as described in Block X. In this way, traded domestic goods are considered imperfect substitutes for products sold in world markets.

Thus far, 267 equations have been described using 301 variables, and the 34 equations in Block XI serve to close the system. The first two equations in Block XI specify that the supply for mineral goods is fixed, and that the price of domestic mineral output is set by world markets. The following eight equations represent supply in 'flex-price' sectors as a rising function of the price-cost ratio. The remaining 24 equations specify that prices are determined by a mark-up over variable costs in 'fix-price' sectors.

To solve the system, it is useful to think in terms of excess demand functions. Specifically, according to equations in Blocks I to V and VII to X, sectoral domestic demand can be written as a linear system of equations that is a function of sectoral money wages and domestic prices. Taking into account equations from Blocks III, IV, X and XI, sectoral price levels for the 'fix-price' sectors can be written as a non-linear system that is a function of 'flex-prices' and money wages. An algorithm to solve the system therefore contains the following steps.

1. Guess trial money wages.
2. Guess trial prices for the 'flex-price' sectors.
3. From equations in Blocks III, IV, X and XI, calculate sectoral price levels of the 'fix-price' sectors using the trial values of 'flex-price' sector prices and money wages.
4. Using the trial values of prices and wages, calculate sectoral demand from the linear system of equations arising from equations in Blocks I to V and VII to X.
5. Calculate sectoral excess demand by comparing demand for domestic production with domestic supply, as specified by the closure rules of Block XI. If sectoral excess demand is equal to zero for three significant figures, finish. If not, decrease (increase) mineral exports if the excess demand for the mining sector is positive (negative), and increase (decrease) prices if the excess demand for the 'flex-price' sectors is positive (negative); then return to step 2.
6. Using the expressions from Block VI, check whether real wages that result from solving the model are equal to benchmark real wages for three significant figures. If so, finish. If not, increase (decrease) money wages if the difference is negative (positive) and return to step 2.

When this solution procedure is complete, all sectors can be considered to be in supply-demand equilibrium and, as a consequence, savings must equal investment. This derived relationship appears in Block XIV. Blocks XII to XIII contain derived relationships for macro balance, defining foreign and government current accounts, respectively.

Block XII gives the level of foreign savings – or the deficit in the external current account – in Chilean peso prices. Because taxes or subsidies on imports and exports are not included in the model specification, the trade deficit (imports minus exports) is measured at internal prices.

In Block XIII appear the equations for the government current account. The first equation of Block XII specifies a simple rule according to which government profits are determined as a constant fraction of sectoral profits. This relationship is important in a mineral-exporting economy, because some share of the mining sector's surplus often goes to the government in the form of mining taxes or royalties (in addition to the income that the government obtains from State-administered sectors). All of this is represented here as a constant share in sectoral profits. The second equation of Block XII states that government revenue is made up of indirect taxes, corporate taxes, and some share of sectoral profits. Government expenditure consists of purchases of goods and services and net transfer payments.

The savings-investment balance of Block XIV is of standard form. Savings to the left of the equal sign derives from workers, capitalists, the government current account, and foreign savings. Investment on the right includes capital formation.

Table 1. Equations for the Mineral-Exporting Economy Model

I. Demand-Supply Balances by Sector	
$D_i + E_i = X_i$	$i = 1, \ldots, 33$
II. Domestic Use by Sector	
$\sum_{j=1}^{33} a_{ij} X_j + C_i + I_i + G_i = D_i + M_i$	$i = 1, \ldots, 33$
III. Composite Price Equations	
$Q_i = \dfrac{P_i + eP_i^* M_i / D_i}{1 + M_i / D_i}$	$i = 1, \ldots, 33$
IV. Equations for Variable Costs	
$B_j = \sum_{i=1}^{33} a_{ij} Q_i + b_j w_j$	$j = 1, \ldots, 33$
V. Generation of Income Flows	
$Y_W = \sum_{j=1}^{33} b_j w_j X_j + eRE^*$	
$Y_Z = \sum_{j=1}^{33} \left[\left(\dfrac{P_j}{(1 + t_j)} - B_j \right) X_j - GR_j \right] + GINT - eFINT^*$	
VI. Money Wage Setting	
$w_j = \omega_j CPI$	$j = 1, \ldots, 3$
$CPI = \sum_{i=1}^{33} Q_i \left(\dfrac{Q_i C_i}{D} \right)$	
VII. Consumption from Income Flows	
$D = (1 - s_W)(Y_W + TR) + (1 - s_Z)(1 - t_z) Y_Z$	
VIII. Sectoral Consumption Functions	
$C_i = \theta_i + \dfrac{m_i}{Q_i} \left(D - \sum_{i=1}^{33} Q_i \theta_i \right)$	$i = 1, \ldots, 33$
IX. Sectoral Export Functions	
$E_i = \bar{E}_i \left(\dfrac{P_i}{eR_i^*} \right)^{-\epsilon_i}$	$i = 2, \ldots, 33$
X. Sectoral Import Functions	
$\dfrac{M_i}{D_i} = \dfrac{\overline{M}_i}{D_i} \left(\dfrac{P_i}{eP_i^*} \right)^{\mu_i}$	$i = 1, \ldots, 33$
XI. Model Closure	

$$X_1 = \bar{X}_1$$

$$P_1 = eR_1^*$$

$$X_i = X_i^o \left(\frac{P_i/B_i}{P_i^o/B_i^o}\right)^{\sigma_i} \qquad i = 2,3,4,19,20,21,22,23$$

$$P_i = (1+t_i)(1+z_i)B_i \qquad i = 5,\dots,18,24,\dots,33$$

XII. Foreign Savings

$$S^{For} = \sum_{i=1}^{33} eP_i^* M_i + eFINT^* - eR^* - \sum_{i=1}^{33} P_i E_i$$

XIII. Government Savings

$$GR_i = \frac{\phi_j}{1-\phi_j}\left[\left(\frac{P_j}{(1+t_j)} - \sum_{i=1}^{33}\left(a_{ij}Q_i - b_j w_j\right)\right)X_j\right]$$

$$S^{Gob} = \sum_{i=}^{33} \frac{t_i P_i}{1+t_i} X_i + t_z Y_Z + \sum_{i=1}^{33} GR_i - \sum_{i=1}^{33} Q_i G_i - TR - GINT$$

XIV. Savings-Investment Balance

$$s_W Y_W + s_Z(1-t_Z)Y_Z + S^{Gob} + S^{For} = \sum_{i=1}^{33} Q_i I_i$$

Table 2. Symbols for the Mineral-Exporting Economy Model

I. Sectors

Raw materials
1. Mining and quarrying
2. Agriculture, forestry, and fishing

Import-substituting intermediates
3. Coke and fuels
4. Non-metallic mineral products

Manufactures
5. Food products, beverages, and tobacco
6. Textiles, wearing apparel, leather and related products
7. Wood and products of wood and cork
8. Paper products and printing
9. Chemicals and pharmaceutical products
10. Rubber and plastic products
11. Basic metals
12. Fabricated metal products
13. Computer, electronic, and optical products
14. Electrical equipment
15. Machinery and equipment
16. Motor vehicles, trailers, and semi-trailers
17. Other transport equipment

Infrastructure services
19. Electricity, gas, water supply, sewage, waste, and remediation services
20. Transportation and storage
21. Telecommunications

Construction and housing
22. Construction
23. Real estate activities

Services
24. Wholesale, retail trade, and repair of motor vehicles
25. Accommodation and food services
26. Publishing, audiovisual and broadcasting activities
27. IT and other information services
28. Financial and insurance activities
29. Business sector services other than financial, insurance, and real estate activities
30. Public administration, defence, and compulsory social security
31. Education
32. Human health and social work

18. Other manufacturing; repair and installation of machinery and equipment	33. Arts, entertainment, and recreation
II. Endogenous variables	
X_i	Sectoral output levels, $i = 1, \dots, 33$
D_i	Sectoral domestic demand for domestic production, $i = 1, \dots, 33$
P_i	Sectoral price levels, $i = 1, \dots, 33$
Q_i	Composite price levels, $i = 1, \dots, 33$
B_i	Variable costs per unit of output, $i = 1, \dots, 33$
Y_W	Wage income
Y_Z	Profit income
w_i	Sectoral money wages, $i = 1, \dots, 33$
CPI	Consumer price index
D	Consumption spending
C_i	Sectoral levels of consumer demand, $i = 1, \dots, 33$
E_i	Sectoral exports, $i = 1, \dots, 33$
M_i	Sectoral imports, $i = 1, \dots, 33$
S^{For}	Current account deficit
S^{Gob}	Government budget surplus
III. Exogenous variables	
I_i	Sectoral level of investment demand, $i = 1, \dots, 35$
G_i	Sectoral level of government demand, $i = 1, \dots, 35$
$\bar{X}_1$	Fixed mineral output level
P_i^*	Dollar border price of imports, $i = 1, \dots, 35$
R_i^*	World dollar price of competing exports, $i = 1, \dots, 35$
RE^*	Remittances (in dollars)
$FINT^*$	Interest payments abroad (in dollars)
t_i	Indirect tax rates, $i = 1, \dots, 35$
t_Z	Tax rate on profit income
z_i	Mark-up rates, $i = 11, \dots, 20, 25, \dots 35$
ω_i	Sectoral real wage rates, $i = 1, \dots, 35$
ϕ_i	Sectoral government profit share, $i = 1, \dots, 35$
TR	Net transfer payments
e	Exchange rate
IV. Parameters	
a_{ij}	Sectoral input-output coefficients, $i, j = 1, \dots, 35$
b_i	Sectoral labour-output ratios, $i = 1, \dots, 35$
m_i	Marginal propensity to consume from profit income, $i = 1, \dots, 35$
θ_i	Floor-level consumption from profit income, $i = 1, \dots, 35$
s_W	Savings ratio from wage income
s_Z	Savings ratio from profit income
$\bar{E}_i$	Constants in the export functions, $i = 2, \dots, 35$
$\overline{M_\iota / D_\iota}$	Constants in the import functions, $i = 1, \dots, 35$
ϵ_i	Price elasticity of export demand, $i = 1, \dots, 35$
μ_i	Trade substitution elasticity, $i = 1, \dots, 35$

σ_i	Elasticity in the supply-response function, $i = 2,3,4,\ldots,10,21,\ldots,24$
V. Initial values	
P_i^o	Base-year sectoral prices, $i = 1,\ldots,35$
B_i^o	Base-year sectoral variable costs, $i = 1,\ldots,35$
X_i^o	Base-year sectoral output levels, $i = 1,\ldots,35$

2. Calibration and parametrization

In order to obtain plausible figures by numerically solving the model, data were considered provided by the OECD database for the Chilean economy for the year 2014. The primary sources of data are: the OECD Input-Output Tables (2018 release), employment data from the STAN Industrial Analysis series, and data from the OECD National Accounts series, including detailed fiscal data from the Details of Tax Revenue–Chile and Government Deficit-Surplus series. Taking into account the need for consistency in the accounting identities of the model, the exogenous variables and parameters listed in part III and part IV of Table 2 were estimated. Observations on their calculation follow.

1. If base-year domestic prices P_i^o, world dollar prices P_i^*, R_i^*, and the nominal exchange rate e are set equal to 1, then sectoral levels of investment demand I_i, government demand G_i, base-year levels of sectoral output X_i^o, and the constants in the export and import functions $\bar{E}_i$, $\overline{M_i/D_i}$, are obtained directly from the IOT.
2. Sectoral wage rates ω_i can be obtained by dividing the sectoral compensation of employees shown in the IOT by the number of employees in the STAN series. The difference between sectoral persons engaged and sectoral employees yields the sectoral number of proprietors. To estimate the income that proprietors obtain as workers, the same wage paid to employees is imputed to them. In this way, gross operating surplus is free of mixed income so that its figure is closer to corporate profits.
3. Once the IOT is completed with sectoral levels of persons engaged, the input-output coefficients a_{ij} and the labour-output coefficients b_j follow directly by division of intersectoral flows and sectoral employment by gross output of the sectors. Mark-up rates z_j and indirect tax rates t_j follow by calculating the variable costs per unit of output.
4. The parameters of the linear expenditure system m_i, θ_i are computed from sectoral budget shares $\phi_i = P_i C_i / D$, which follow directly from the IOT and from the income elasticities of consumer demand η_i estimated by Muhammad et al. (2011) for several countries (including Chile) and eight categories of goods (food, clothing, housing, house furnishing, health, transport and communications, recreation, education, and other goods). Thus, taking care that Engel's aggregation condition is met, the marginal budget shares are calculated from:
$$m_i = \eta_i \phi_i$$
And the floor-levels of sectoral consumption:
$$\theta_i = (D/P_i)[\phi_i - m_i \sigma^C]$$
Where σ^C is the supernumerary income ratio, which indicates the importance of price substitution in consumer demand. In the present case, it is assumed to be $\sigma^C = 1/2$.
5. To estimate the components of the balance of payments, it is assumed that the current account deficit as it appears in OECD national accounts should coincide with the figure assumed in the model for the base year when measured as a percentage of GDP. Then, considering the value of the trade balance that results from the IOT, remittances and net interest payments are obtained as residuals.
6. To estimate the ingredients of fiscal policy, it is also necessary to match data from the IOT with data from national accounts. The IOT figures show indirect taxes net of subsidies and

government consumption expenditure. The tax rate on profit income can be estimated from corporate tax income figures in national account series. The government's share of mining profits can be estimated from mining taxes and mining patents data. The value of government interest payments can also be inferred from national account series. Finally, net transfer payments are obtained as a residual, so that the value of the assumed government current account (not including capital expenditures) matches the value that appears in national accounts.

7. Regarding the values of the savings ratios for wage and profit income, no specific estimates are available. The stylized fact is that the consumption share from labour incomes usually runs between 90 and 100 percent. If we set $s_W = 0.95$, consumption expenditure from wage income can be calculated directly, and consumption from profit income is obtained as a residual.
8. To find plausible ranges of trade elasticities μ_i and ϵ_i, some stylized facts of the Chilean economy are considered. First, price elasticities of export demand for manufactures seem to be higher than elasticities for raw materials; moreover, it seems that $\epsilon_i \leq 3.0$ in every case (Imbs & Mejean, 2017; Moguillansky, 2016). Second, given the low responsiveness of imports to prices in the case of Chilean (Monfort, 2008), trade substitution elasticities must be assumed in the inelastic range for many goods. In fact, the higher the ratio of sectoral imports to domestic use, the lower the expected trade substitution elasticities.
9. Plausible ranges can also be found for the elasticities in the supply-response function σ_i. In the case of modern, capitalist agriculture, as is prevalent in Chile, the elasticity of supply can be assumed to be in the range $\sigma = 0.3 - 1.0$ (Mundlak, 2001; Rao, 1989). The supply-response function of public utilities and fuels in the particular case of Chile must be assumed to be inelastic; indeed, inflexibility in the supply of energy and water is a structural characteristic of the Chilean economy (Aitken et al., 2016; Serra, 2022). Thus, it is plausible to assume that the elasticity in the supply of these goods is in the same range as that of agricultural goods. It is possible that housing, non-mineral products, and telecommunications may also be found in this inelastic range due to both a lack of idle capacity and institutional constraints. Supply of construction and transportation services may be more elastic ($\sigma = 0.6 - 2.0$), given that these are more labour-intensive activities.

Key exogenous variables and parameters from these manipulations and hypotheses appear in Table 3.

Table 3. Main Parameters of the Model

Generation of Income			
$eRE^*/Y_W = 0.0112$		$GINT/Y_Z = 0.0177$	$eFINT^*/Y_Z = -0.1203$
$\phi_3 = 0.073$		$\phi_{32} = 1.0$	$\phi_j = 0 \;\; j \neq 3, 32$
Uses of Income			
$s_W = 0.0500$	$s_Z = 0.5476$	$TR/Y_W = 0.0186$	$t_Z = 0.1234$
Income and Trade Elasticities			
Sector	η_i	ϵ_i	μ_i
2	0.66	$1.00 - 2.00$	$0.75 - 2.25$
3	1.12	-	$0.75 - 2.25$
4	-	-	$0.75 - 2.25$
5	0.66	$1.00 - 2.00$	$0.75 - 2.25$
6	0.93	$1.50 - 3.00$	$0.33 - 1.00$
7	-	$1.00 - 2.00$	$0.75 - 2.25$

8	-	1.00 − 2.00	0.75 − 2.25
9	1.27	1.50 − 3.00	0.33 − 1.00
10	-	1.50 − 3.00	0.33 − 1.00
11	-	1.50 − 3.00	0.33 − 1.00
12	-	1.50 − 3.00	0.25 − 0.75
13	1.28	1.50 − 3.00	0.25 − 0.75
14	1.01	1.50 − 3.00	0.25 − 0.75
15	-	1.50 − 3.00	0.25 − 0.75
16	1.12	1.50 − 3.00	0.25 − 0.75
17	-	1.50 − 3.00	0.25 − 0.75
18	1.01	1.50 − 3.00	0.25 − 0.75
19	1.03	-	-
20	1.12	1.00 − 2.00	0.75 − 2.25
21	1.12	-	-
22	-	-	-
23	1.03	-	-
24	0.97	1.00 − 2.00	0.75 − 2.25
25	1.38	1.00 − 2.00	0.75 − 2.25
26	1.38	-	-
27	-	1.00 − 2.00	0.75 − 2.25
28	1.28	1.00 − 2.00	0.75 − 2.25
29	1.03	1.00 − 2.00	0.75 − 2.25
30	-	-	-
31	0.89	-	-
32	1.27	-	-
33	1.38	-	-

3. Numerical results

In this section, trial variations in parameters and data are described for the Chile model in order to estimate the effects of mining activities on other sectors of the economy, considering the effects on quantities, prices, and the distribution of income. The experiments are implemented via time-independent, static perturbations of the parameters around their base-run values, with the aim of estimating the impact of a 25% decrease in mining output. The simulated scenarios recreate the successive coupling of different phenomena that may accompany a variation in mining output.

1. Scenario 1 recreates the situation in which mining output decreases but prices remain constant.
2. In scenario 2, prices respond to the decrease in mining output according to the supply conditions of each productive sector and intersectoral linkages, but money wages remain fixed.

Both scenario 1 and scenario 2 assume that money wages, the exchange rate, and the level of investment remain constant in the face of a decline in mining activities. Scenarios 3 to 5 deal with alternative adjustments that could occur in the event of such a shock.

3. In scenario 3, real wages adjust to maintain both foreign savings (in dollars) and the level of investment at pre-shock levels.
4. In scenario 4, real wages and the level of investment remain fixed, so that foreign savings is the factor that adjusts to the shock.
5. In scenario 5, investment is cut so as not to require more foreign savings (in dollars) than before the shock in a context of fixed real wages.

Table 4 summarizes the main features of alternative simulated scenarios. These scenarios can be seen as a hypothetical development of events. First, mining output falls as a result of mine depletion, stricter environmental legislation, or a corporate decision to maintain copper prices. This shock is initially adjusted without changes in domestic prices, but after some time the prices vary to clear the market in 'flex-price' sectors, thereby changing the price structure due to cost-push effect in 'fix-price' sectors. During that same rough period of time (or perhaps slightly longer if the government intervenes in the foreign exchange market, which is not common in Chile), the exchange rate depreciates due to the unwillingness of foreign actors to lend more dollars. This depreciation of the currency initially translates into a deterioration in the terms of trade and an improvement in the external balance, while wages do not react. After some time, workers begin to demand higher wages until they recover the lost purchasing power. The conflict between capitalists and workers again increases the external current account deficit; if it is not possible for the country to borrow more dollars, the government will have to cut investment to avoid a cumulative inflationary process with the peso in free-fall in the forex market.

The effect of mining activities on the rest of the economy can only be evaluated by comparing the initial situation with a stable final situation. Thus, if we consider that Chilean workers are willing to accept cuts in their real wages in a context of balance-of-payments constraints, then scenario 3 represents a plausible description of the Chilean economy with less mining activity. If we assume that real wages are fairly firm and that Chile can draw on more foreign savings, scenario 4 may be a stable end-result. Finally, if we consider that real wages are sticky, limits on foreign borrowing are strong, and the government or central bank acts to avoid inflationary situations, then scenario 5 represents a better description of this hypothetical situation. It is possible that the real alternative description of the Chilean economy would fall somewhere between scenario 3 and scenario 5 – or it may be that in the event of such a shock, no stable final situation is likely.

Table 4. Alternative Simulated Scenarios

		Scenario
	Base run	0
	Only mineral output decreases, prices remain constant	1
	Mineral output decreases and prices vary	2
Decreased	Real wage adjustment (foreign saving and investment fixed)	3
mineral output	Foreign saving adjustment (real wages and investment fixed)	4
coupled with	Investment adjustment (real wages and foreign saving fixed)	5

Figure 1 shows how the system responds to a 25% decrease in mineral output depending on the assumed macroeconomic scenario and taking into account the uncertainty implicit in the values of trade and supply elasticities. From these numerical results, some observations follow.

After mining output declines by 25% and before prices respond to subsequent variations in sectoral demand, manufacturing output decreases by 3% while service output decreases by 5% (Figure 1.A, S1). That is to say, mining-induced demand is biased toward services, because mineral extraction largely requires infrastructure and business services, many manufactured intermediates are imported, and mining-induced consumption from wages and profits is biased toward services. The fall in mining output also leads to a 97% increase in the current account deficit in dollars (Figure 1.C, S1), so that the share of savings from foreign sources increases from 13% to 26%, while the share from domestic sources decreases (Figure 1.E, S1). As regards income distribution, a decrease in mining output of 25% during a time interval in which prices remain constant implies a decrease in the share of mining income from 12% to 10% and an increase in the share of wages from 58% to 59% (Figure 1.F, S1).

Once prices have responded to changes in demand, a series of effects are set in motion that depend on the assumed elasticities. Thus, if the price responsiveness of exports is greater, manufacturing output increases until reaching a point near pre-shock levels (Figure 1.A, S2). This restorative effect is due to the fact that manufacturing sectors are now taking advantage of the lower prices of 'flex-price' intermediates (as much as 10% lower) to gain share in world markets. This effect and the relative inelasticity of supply explain why agricultural output recovers its pre-shock level once prices vary. In fact, agricultural exports increase by 1-3% and manufacturing exports by 2-4%. A similar restorative effect does not occur with services output, regardless of the elasticities assumed (Figure 1.A, S2). The reasoning here is that services do not use intermediates such as fuels or infrastructure services as intensively as agriculture and manufacturing, so the former do not benefit as much from lower prices. All these changes in prices and quantities give rise to changes in the distribution of income. Specifically, all sectors increase their share of income except mining and non-traded intermediates. The share of manufacturing in income rises from 10% to 11%. Moreover, real wages increase by 2% to 3% and the share of wages in income grows from 58% to 61% at the expense of profits. Thus, it is observed that at a constant exchange rate and constant money wages, mining activities generate some 'forced saving' and crowding-in effects on services.

Despite the increase in non-mineral exports, the external current account deficit in dollars is well above its pre-shock level (Figure 1.C, S2). If foreign investors are not willing to lend the country more dollars, then the peso will depreciate. The amount by which the peso must be depreciated to restore the pre-shock level of external deficit depends greatly on the elasticities of trade and supply: in the simulations, this ranges from 20% to 100% (Figure 1.C, S3). If money wages do not respond to devaluation, then real wages are cut by 8% to 26% (Figure 1.D, S3). This real depreciation naturally leads to a decline in the terms of trade for all sectors and especially for non-traded intermediates and services. Real depreciation greatly stimulates manufacturing output (Figure 1.A, S3) thanks to the increase in exports (Figure 1.C, S3). In fact, manufacturing output is 10% to 12% higher than before the shock, thanks to the good performance of exports. The output of services also increases, but by less, barely recovering the pre-shock level (Figure 1.A, S3), because although service exports also increase strongly (more than manufacturing exports), the contractionary effects of real depreciation on consumption prevent better performance. Naturally, this is a process of forced savings to correct the external imbalance, so that the share of savings from profits and government grows at the expense of wages (Figure 1.E, S3), and the share of wages in income plummets while the share of profits soars (Figure 1.F, S3). In turn, the share in income of export-oriented sectors (agriculture, mining, manufacturing) grows, while the share of services decreases, due to changes in quantities, relative prices, and income distribution (Figure 1.D, S3).

The situation of forced thrift and real depreciation may not last long: at some point, workers may muster sufficient power to recover pre-shock real wages, and foreign investors may allow the country to increase its external debt. In such a case, the terms of trade will improve with respect to the case of real-wage devaluation until they reach a point below the pre-shock level. Specifically, the respective terms of trade for agriculture, manufacturing, and services are 1-6%, 3-8%, and 5-10% lower than before the shock (Figure 1.B, S4). Real wages have here recovered their pre-shock level, but dollar wages are 5-10% lower (Figure 1.F, S4) because with less mining activity, the terms of trade for non-traded intermediates and for construction and housing, respectively, will be 6-15% and 5-12% below pre-shock levels; thus, it is possible to achieve lower dollar domestic prices with the same level of real wages. Lower dollar prices allow agricultural, manufacturing, and service exports to be greater than before the shock. This drives agricultural and manufacturing output slightly higher (0-1% and 0-3%, respectively), but it is not enough to prevent services output from falling by 2-4% (Figure 1.A, S4). Forced savings at the expense of wages comes to an end: the share of wages in income grows at the expense of profits (Figure 1.F, S4), and the shares of agriculture, manufacturing, and services are above their pre-shock levels at the expense of mining and non-traded intermediates (Figure 1.D, S4). All this is possible thanks to an increase in recourse to foreign savings 65% to 86% above the pre-shock level (figure 1.C, S4).

Finally, it is possible that resorting to increased foreign savings proves little more than a temporary palliative, and that balance-of-payments constraints will eventually reappear. Here two alternative scenarios can take place: either the peso depreciates again, and the external balance is temporarily corrected until real wages recover pre-shock levels, so that the country moves between scenarios 3 and 4 in a cumulative inflationary process; or the government intervenes to reduce aggregate demand. One possible and quite common recourse is to cut investment demand through contractionary monetary policy or budget cuts: this is scenario 5. According to the parameters of the Chile model, investment would have to be cut by 15-20% to reach pre-shock levels of real wages and foreign savings. In this scenario, agricultural output could be as much as 1% higher than before the shock, but manufacturing and services output could fall by as much as 3% and 9%, respectively (Figure 1.A, S5). In this depressive context, the terms of trade decrease further; in fact, it is possible to achieve the same real wage with a dollar wage 6-11% below the pre-shock level (Figure 1.F, S5). This naturally implies a greater volume of exports: 6-10% higher than the pre-shock level in the case of agriculture, 11-16% higher in the case of manufacturing, and 10-15% higher in the case of services (Figure 1.C, S5). The lower levels of dollar domestic prices, investment, and output explain that the share of savings deriving from abroad will increase, and that the share coming from the government will decrease compared to pre-shock levels (Figure 1.E, S5). The share of mining in income is more or less the same as before the shock, and the shares of agriculture, manufacturing, and services grow at the cost of lower shares for non-traded intermediates, construction, and housing (Figure 1.D, S5). The share of wages in income grows by 2% (Figure 1.F, S5) but, apart from this, the result is not very promising: stabilization policy may foster deindustrialization. When rigid real wages, balance-of-payments constraints, and an aversion to inflation come together, it is not evident that mining will have a crowding-out effect on manufacturing.

Consideration of families of parameters and alternative scenarios allows us to identify two sources of uncertainty when estimating the impact of mining activities on other sectors of the economy. An important source of uncertainty is the value of trade and supply elasticities, as illustrated in the relative thickness of the shaded areas in Figure 1. This source of uncertainty has already been noted in the structuralist literature on Dutch Disease (Taylor, 1983, 1991). Another important source of uncertainty is the macroeconomic closure – that is, the level of real wages, investment, and foreign savings compatible with the absence of mining activities. Usually, this element has been ignored, but judging by the differences between scenarios 3 to 5 displayed in Figure 1, it represents a source of uncertainty even greater than the value of trade and supply elasticities. When assessing the impact of mining activities on other sectors of the economy, as well as the possibility of Dutch Disease, it is necessary to take all these sources of uncertainty into account.

Despite these uncertainties, a few results appear to be more or less robust. Mining activities seem to have positive effects on the terms of trade and, therefore, negative effects on exports of agricultural goods, manufactures, and traded services. This is the case even when assuming that real wages do not adjust to changes in mining output, and for the entire range of assumed trade and supply elasticities (Figure 1.C). It also seems that the share of mining in income grows at the expense of agriculture and 'fix-price' manufactures, and that mining causes the shares of non-traded intermediates, construction, and housing to increase somewhat (Figure 1.D). This is due to the effects induced by mining activities on prices and to some crowding-in on construction and housing. If Dutch Disease is understood as the coexistence of booming extractive sectors and lagging manufacturing exports and income share, then it seems that in the Chilean case, Dutch Disease is indeed present: the high level of mining activity has crowding-out effects on manufacturing exports and on the share of manufacturing in income. Thus, Chile's 'premature deindustrialization', when defined by a too-low share of manufacturing in income (Rodrik, 2016), may be a consequence of too much mining.

However, Dutch Disease properly means that mining activities drive down manufacturing output, but this is not so clear in the case of Chile, where uncertainty plays a significant role.

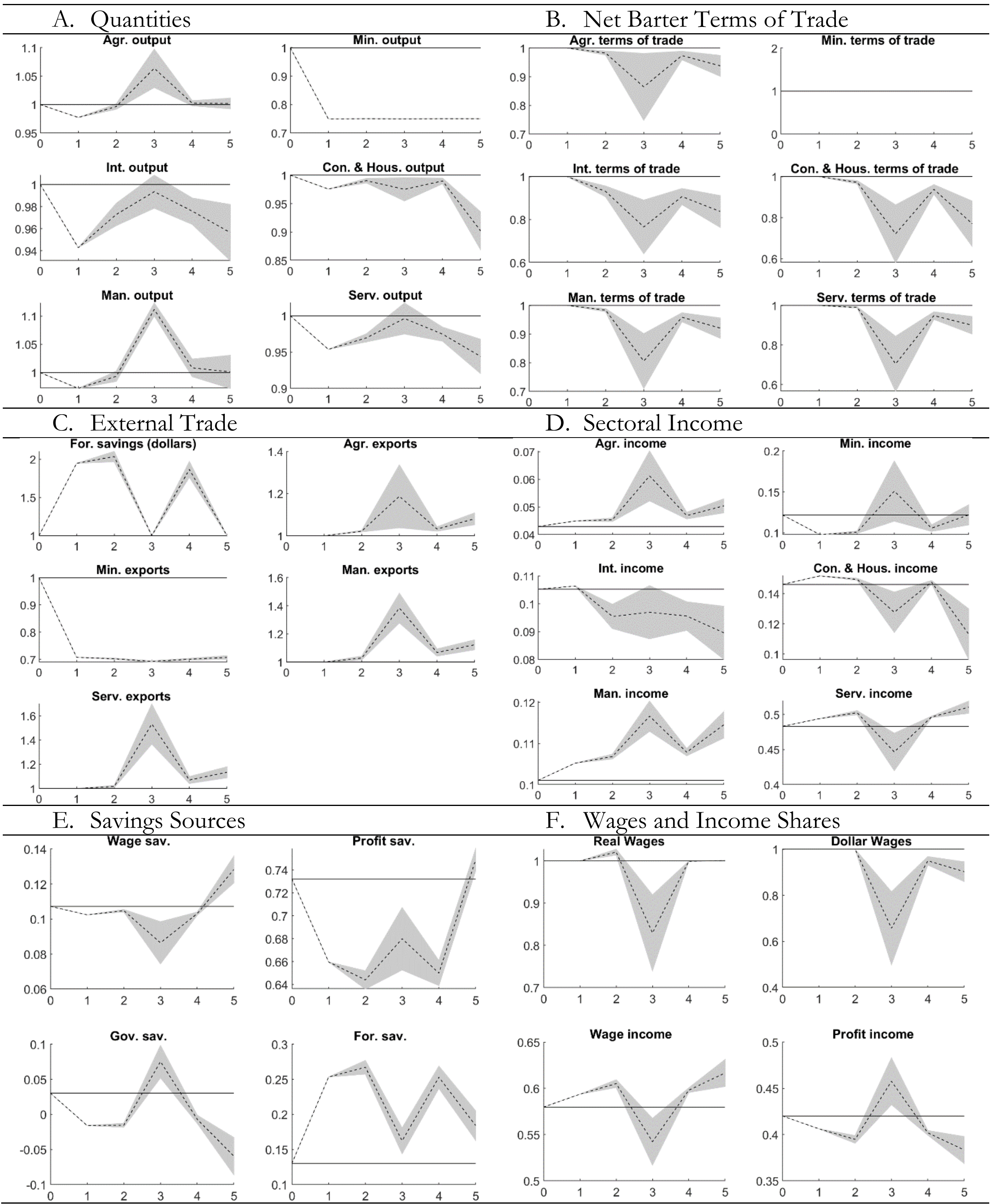
Particularly important is the uncertainty inherent in the most plausible macroeconomic scenario. Specifically, mining activities lead to crowding-out of manufacturing only in a case in which real wages or foreign savings are adjusted to changes in mining production. If both these factors are inflexible, then reduced mining activity can lead to less manufacturing output, since domestic demand will be reduced and exports may not be sufficiently price-responsive for a higher sales volume abroad to offset a lower sales volume at home.

Crowding-out or crowding-in effects by mining on other sectors ultimately have to do with the demand that mining activities generate, whether directly or indirectly. On the one hand, mining activities generate greater intermediate demand, leading to increases in prices of intermediates whose supply is inflexible and thereby giving rise to cost-push price increases in 'fix-price' sectors. These cost-push effects can reduce consumption and export demand (and eventually real wages). On the other hand, more mining activity increases the size of the market for other sectors, since some share of the demand for intermediates goes to the purchase of manufactures and services and, in addition, greater mining activity also implies greater payrolls and profits. Alternative simulated scenarios can be understood from these 'demand' and 'cost-push' effects. In scenario 3, in which adjustment occurs in real wages, manufacturing output increases, because its costs decrease in a twofold way (intermediate prices and wages), and this compensates for the decreases in mining and consumer demand. In scenario 4, manufacturing output can also increase above pre-shock levels; although real wages remain constant, non-traded intermediates become sufficiently cheap to gain market share. In scenario 5, mining has an additional induced effect on investment demand that is large enough to offset lower industrial costs.

An interesting aspect to this description, different from the neoclassical perspective, is that because two effects are competing, there is no inevitable result: much depends on the path taken by the macroeconomic adjustment to the shock, which depends in turn on institutions and political economy. Furthermore, the structuralist theory provides additional information on Dutch Disease, allowing for estimation of both the 'demand' and 'cost-push' effects of mining activities on other sectors for a given value of real wages, foreign savings, or domestic investment. Specifically, 'demand' effects come from changes in sectoral output at constant prices, while 'cost-push' effects result from changes in output when prices of non-traded intermediates vary to clear the market. Although demand and cost effects are different in magnitude depending on the scenario considered, it is interesting to estimate these for a case in which real wages and investment demand are fixed and foreign savings are accommodated to changes in mining output. That is what Figure 2 depicts. From this, some observations follow.

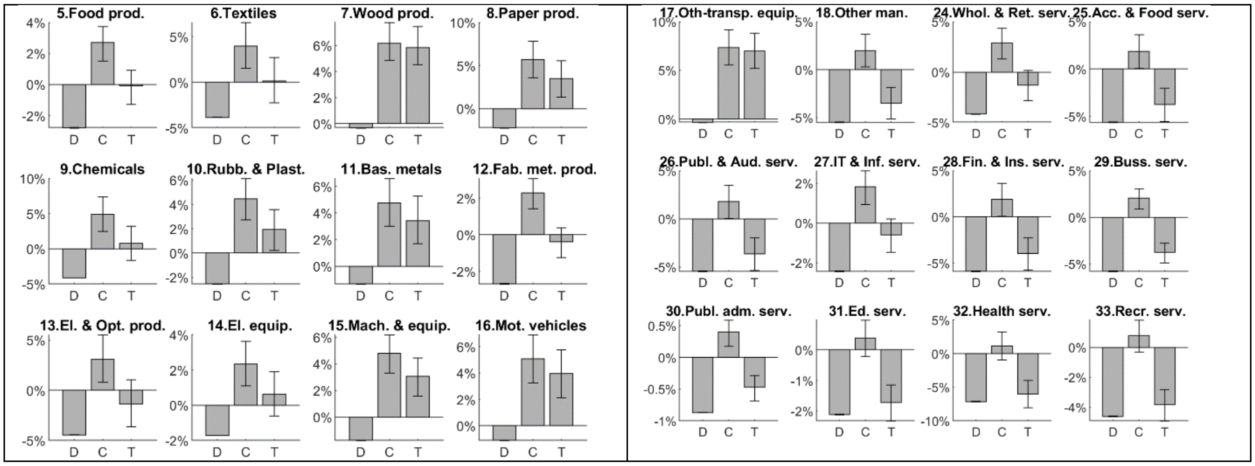
First, it is observed that the demand and cost-push effects of variations in mining output affect all sectors, although not all are affected equally. Specifically, demand effects are most felt by sectors oriented to personal consumption (such as health, accommodation, publishing, textiles) and some producer goods (such a chemicals, electronic machinery, business services). On the other hand, cost effects are most strongly experienced by heavy industry sectors (such as wood, paper, chemicals, rubbers and plastics, basic metals, machinery) and some manufacturing sectors oriented to personal consumption (such as textiles or food). Here a bias is observed: mining enlarges the size of the market (mainly for services) while transferring the cost of greater use of scarce intermediates to manufacturing. This explains why when the effects are netted, lower mining activity seems to have only positive effects on output in manufacturing sectors. This further explains why, in all the simulated scenarios, manufacturing output decreases less than services output.

Figure 1. Effects on Prices and Quantities of a 25% Decrease in Mineral Output



Notes: numbers on the y-axis denote alternative simulated scenarios (see Table 4).

Figure 2. Demand and Cost-Push Effects in 'Fix-price' Sectors of a 25% Decrease in Mineral Output for a Given Level of Real Wages



Notes: letters on the x-axis denote: D for mining-induced demand effects; C for cost-push effects; T for total effects

4. Conclusions

The foregoing numerical exercise shows in the context of a practical model how mining activities can generate crowding-out or crowding-in effects in other industries when different sectors make simultaneous claims to product in a situation of lagging supply by key intermediates.

The simulations presented here remain tentative approximations, given uncertainties around the true values of the elasticities of trade and supply and the various alternative macroeconomic scenarios. Plausible ranges of trade elasticities have been assumed, taking into account the available econometric studies, which have an aggregated focus; actual sectoral trade elasticities could conceivably be outside the considered range in many cases. Furthermore, the classification of sectors into 'flex-price' and 'fix-price' is likewise tentative and derives from considerations that are more qualitative than quantitative. The real values of the elasticity in the supply-response function of different sectors remain largely unknown. Many sectors whose supply has been assumed to be flexible may not be so, due to unnoticed institutional or capacity constraints. In addition, the model leaves out considerable detail regarding the Chilean economy – different demand patterns depending on the income level, differences between the formal and informal sectors – that may be relevant to the evaluation of alternative adjustment mechanisms. All of this means that estimated margins of error (already large) could be even greater.

Despite all this uncertainty, at least two conclusions from the present study can be considered more or less robust.

First, the simulations show that if a few sectors producing intermediates experience relatively inelastic supply, this can be sufficient cause to drive the mining-induced cost-push effects on other sectors to be as significant as the demand effects. These cost-push effects appear to be biased against manufacturing, while the demand effects are biased in favour of services. Thus, it can be expected that in a context of lagging intermediate supply, a high level of mining activity will lead to a lower volume of non-mineral exports and a lower share of manufacturing in income. This will be the case even when the supply of labour is so elastic that mining activities have negligible effects on real wages.

Second, although the mining-induced cost-push effects on manufacturing seem to be of the same order as the demand effects, it cannot in any case be taken for granted that mining will have crowding-out effects on manufacturing output as a whole. Specifically, the ability of mining to increase the size of the market for other sectors must not be underestimated, especially when considering a case in which there are constraints on foreign savings and real wages. In such a case, unless high price responsiveness of manufacturing exports coincides with low elasticity in the supply-response of non-traded intermediates, the possibility that lower mining activity will lead to lower manufacturing output cannot be ruled out.

Two policy implications follow from these two conclusions.

The first is almost trivial: a mineral-exporting country should put special emphasis on its infrastructure policy. Indeed, what the foregoing exercise shows is that, should a country neglect just a couple of key infrastructure services, that could be enough to make the cost of mining very high for that country. The link between infrastructures and mining-induced cost-push effects suggests that some phenomena observed in mineral-exporting developing countries – such as congestion in the transport, electricity, or water infrastructures (Bonfatti & Poelhekke, 2017; Kosenius & Horne, 2016; Mancini & Sala, 2018; Rioux et al., 2016; Schoderer et al., 2020; Silvia et al., 2021) – could have a greater effect than what is usually considered in terms of the output of other traded sectors. Mining uses infrastructure services very intensively, and only a significant investment effort can prevent cost effects from appearing in one way or another. In fact, in light of this relationship, the coincidence in Chile during the 1990s of expanding mining activity, increasing non-mineral exports, and high investment efforts in infrastructure makes sense. Mainstream opinion has generally explained this as investment being the result of savings generated by cost restraint due to fiscal rules, although in fact the causality may be the opposite.

The second, less obvious policy implication is that, while tempting, the proposal of 'achieving economic diversification by restricting mining' may not work. In fact, in the case of Chile (and other mineral exporting countries), mining activities play a very important role in balancing external accounts. Given the limited responsiveness of trade to changes in the prices of manufactures, the achievement of greater manufacturing output in a context of lower mining activity can be a painful process that implies either lower real wages or greater recourse to foreign savings. Due to structural constraints, both alternatives are not always feasible. Furthermore, when there are constraints on both foreign savings and real wages, it is very likely that in a context of lower mining activity, investment spending will be cut. This may imply a less elastic supply of key capital-intensive non-traded intermediates in the future, which would make the mining-induced cost effects even greater. Thus, the cure can end up aggravating the disease.

Acknowledgements

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