

Banco Central de Chile  
Documentos de Trabajo

Central Bank of Chile  
Working Papers

N° 640

Agosto 2011

**COPPER, THE REAL EXCHANGE RATE AND  
MACROECONOMIC FLUCTUATIONS IN CHILE**

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Documentos de Trabajo del Banco Central de Chile  
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## COPPER, THE REAL EXCHANGE RATE AND MACROECONOMIC FLUCTUATIONS IN CHILE

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### Abstract

This paper examines the impact of the copper price on macroeconomic performance in Chile. We explore particular features of the Chilean business cycle focusing on economic activity and the real exchange rate. We find that the Chilean economy has become increasingly resilient to copper price shocks in the last twenty-five years, and especially during this last decade. The evidence shows that output volatility has dramatically decreased over the last twenty years, and the contribution of copper price fluctuations to output volatility has also declined. Moreover, the real exchange rate has acted as a shock absorber, and although during the last decade its short-run volatility has increased, its long-run volatility has remained stable and more recently has slightly declined. The declining impact of copper prices on the business cycle is due to macroeconomic policies. The evidence shows that a flexible exchange rate, a rule-based fiscal policy, and a flexible inflation targeting regime play a central role in these results.

### Resumen

En este trabajo se examina el impacto del precio del cobre sobre el desempeño macroeconómico de Chile. Exploramos el ciclo económico chileno poniendo especial énfasis en la actividad económica y en el tipo de cambio real. Encontramos que, en los últimos 25 años, la economía chilena se ha vuelto cada vez más resiliente a *shocks* del precio del cobre, específicamente dicha resiliencia se ha hecho más evidente durante estos últimos 10 años. La evidencia muestra que la volatilidad del producto ha disminuido drásticamente en los últimos 20 años, y que a su vez la contribución de las fluctuaciones del precio del cobre sobre dicha volatilidad ha disminuido también. Más aun, el tipo de cambio real ha actuado como un amortiguador de *shocks*; si bien la volatilidad de corto plazo del tipo de cambio real ha aumentado, su volatilidad de largo plazo se ha mantenido estable e incluso ha mostrado una leve caída. El decreciente impacto del precio del cobre sobre el ciclo se debe a la política económica. La evidencia muestra que la política de tipo de cambio flexible, la política fiscal basada en una regla fiscal, y el régimen de metas de inflación juegan un rol central en estos resultados.

# 1 Introduction

Chile is rich in natural resources. The mining sector has been very important historically, and today Chile is the largest producer of copper in the world. But while Chile reaps the benefits of abundant copper, the metal also represents many challenges for macroeconomic management and long-term growth.

The abundance of natural resources has been an important area of discussion in development economics for a long time. A few decades ago it was thought that developing countries should move away from natural resources because of the declining price trend. This view was argued to support a development strategy based on import substitution. The facts have shown that this view was based on a wrong assumption. Nevertheless, the relationship between development and natural resources has again become a highly debated issue. A large body of research has examined the question of whether natural resources are a blessing or a curse from the point of view of economic growth.<sup>1</sup>

Natural resource abundance has also been discussed in the context of macroeconomic models of small open economies. The purpose of these development models has been to analyze the impact of commodity price fluctuations on the economy, in particular the business cycle and the composition of growth. An important question these models seek to answer is, What is the appropriate framework for monetary and fiscal policy in order to mitigate the potential costs of commodity price fluctuations?

This paper discusses the case of copper in Chile from the perspective of macroeconomic management. Although the long-run implications of Chile's abundance of copper for the country's economic growth are related to the impact of copper on the business cycle, because a volatile business cycle may reduce growth potential, our focus is on macroeconomic performance.<sup>2</sup> In particular, this paper shows that the fluctuations in copper prices have less impact than they used to have on aggregate fluctuations in Chile and that this is the result of the macroeconomic policy regime in place. Indeed, the stability that comes from being more resilient to the international environment should foster long-run economic growth.

The analysis in this paper finds that the Chilean economy is not excessively dependent on copper, as it may have been in the past. Moreover, the impact of copper on the economy has diminished over time thanks to macroeconomic policies.

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<sup>1</sup>Interestingly, most of this research has been based on the impact of natural resource abundance on economic growth, without taking into account that although it may slow down growth transitorily, the increase in income makes it welfare improving (Bravo-Ortega and De Gregorio, 2006). For a classical reference on the economic consequences of natural resources abundance (see Sachs and Warner (1999)). For the role of institutions and human capital on overcoming the resource curse see Robinson, Torvik, and Verdier (2006) and Bravo-Ortega and De Gregorio (2006), respectively.

<sup>2</sup>During the last 25 years Chile has enjoyed its highest rate of economic growth ever, and hence the proposition that copper may be detrimental for economic growth is easily dismissed. For further discussion, see De Gregorio (2009).

A recurrent concern during periods of rising commodity prices is the so-called Dutch Disease, which has short- and long-term implications. The concern has been about the impact on economic performance of the exchange rate appreciation that comes with a commodity price boom. During the last decade, copper prices reached both their highest and lowest values since the Great Depression. Despite this volatility, and other severe international shocks, real exchange rate fluctuations have been more moderate than what would have been expected in the past.<sup>3</sup>

The reduction in Chile's output volatility since the 1990s and 2000s has been previously documented in De Gregorio et al. (2008) and Larraín and Parro (2008). The first of these papers shows that indeed volatility has decreased and this has been the result of the macroeconomic policies implemented in the last decade. However, the study's estimations do not allow one to separate the different components, that is, the fiscal, monetary, and exchange-rate policies applied during this period. The second paper performs regressions for volatility controlling for a dummy since the fiscal rule based on a target for the structural budget was implemented together with an index of exchange rate intervention. The authors attribute about 60 percent of the decline in volatility to the fiscal rule and the flexibility of the exchange rate. In contrast to that previous research the focus of this paper is on the changing, and diminishing, contribution that copper price fluctuations make to economic performance.

Carrying out an integrated assessment of the different factors reducing output volatility, in particular the role of copper price fluctuations, would require a full model describing channels through which the external conditions transmit to the domestic economy. However, such a task is beyond the purpose of this paper, and with current models it would be very difficult to undertake since the comparison would have to be made with policy regimes that are particularly difficult to formalize. We use a general equilibrium model for the last decade in the last section, but that model cannot be used for previous periods. This is mainly because pre-2000 macroeconomic policies had many features that are complex to model, such as the exchange rate band, capital controls and a monetary policy based on setting an indexed interest rate. On the fiscal side there was fiscal prudence but no explicit rule. For this reason, we use a more eclectic approach to focus on the impact of copper prices on Chile's business cycle. First, we review the evidence on fiscal policy. Then we examine the determinants of both output volatility and real exchange rate (RER). The evidence of this paper shows that indeed the output response to copper has declined and that the RER has played a shock absorber role since the inflation target regime and the floating exchange rate policy were adopted. In addition, long-run RER volatility has recently declined slightly despite sharp copper price fluctuations.

This paper proceeds with a brief discussion of the importance of copper in Chile, the third section discusses fiscal policy and the fourth section presents evidence on copper price fluctuations and the business cycle. It is shown that output volatility in Chile

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<sup>3</sup>For recent discussion on exchange rate and Dutch disease see Magud and Sosa (2010).

has declined substantially since the early 1990s. Both the volatility and the response of the economy to copper have declined further in the last decade, which has featured a flexible inflation target and a floating exchange rate. The application of these policies has benefited from a predictable fiscal rule. The fifth section of the paper presents evidence on the long-run RER dynamics. We show that after permanent terms-of-trade shock, the RER stabilized at its long-term value more quickly during the period after 1999, that is, after the implementation of the flexible exchange regime. Moreover, the effects of terms-of-trade shocks have been less persistent during the latter period. The sixth section of this paper presents evidence that nominal exchange rate and short-run RER volatilities have increased. However, long run RER volatility has remained stable. In fact, nominal exchange rate and RER have played a shock absorber role in the Chilean economy since the implementation of the fully flexible exchange regime. The last section of the paper simulates the effects of a copper price shock on the Chilean economy using a standard dynamic stochastic general equilibrium model estimated under different policy rules. The paper closes with some concluding remarks.

## 2 Copper in the Chilean Economy

Chile has become increasingly important in the world copper market. Since the late 1960s the Chilean economy has increased its share of global production, to somewhat more than a third (Figure 1).

The share that mining represents both in Chile's GDP and in its exports has also been historically large. In the late nineteenth century, Chile was an important producer of nitrates, an industry that collapsed some decades later when cheaper synthetic nitrate was created. Then copper started taking off. The mining sector's share in total GDP declined substantially in the middle of the last century but, unsurprisingly, it has fluctuated with the price of copper since then. Those copper prices have experienced sharp fluctuations. The previous period of very high prices was in the mid 1960s. The price of copper declined sharply in the early 1990s only to again reach new historical highs since (Figure 2).

Figure 3 shows the share of the mining industry in GDP measured at both current prices (A) and constant 2003 prices (B). With the low prices of the early 2000s, the share of mining in nominal GDP was slightly above 5 percent, but with the most recent very high prices this share rose above 20 percent in 2006-07. Measured at 2003 prices, this share has slightly declined to 6.7 percent of GDP in 2009.

Given the size of the Chilean mining sector, there has been serious concern about the implications of volatile copper prices for economic activity. Indeed the Chilean economy saw significant growth when copper prices were high (Figures 2 and 4). During the period of high copper prices in 1979-80, the economy grew at 8.1 on an annual basis. Similarly, during the boom of 1988-89 growth was 8.9 percent, and in 1995 it was 10.6

percent. However, during the most recent copper-price boom, which started in late 2005, the economy grew more moderately. Indeed, in 2006-07, before the Great Recession, the economy grew at an annual rate of 4.6 percent. At the same time, the reaction of the economy to lower copper prices has also moderated. Before 2000, the Chilean economy generally went into recessions when the copper price collapsed. However, in the three years from 2000 to 2002, when the copper price dropped to its minimum triennial real price since the Great Depression, the economy grew at 3.3 percent. This is very suggestive evidence that the Chilean economy has become much more resilient to copper price fluctuations.

Before discussing in more detail the decline in volatility of output, we would like to discuss qualitatively the direct channels through which copper prices affect the economy. What we would like to show is that, in principle, there is no reason to believe that the business cycle should be affected significantly by copper price movements.

First, the mining sector accounts for only about 1.5 percent of total employment, down from 2.6 percent in the early 1980s. This is direct employment, but in the north of Chile, where most mining production takes place, a large fraction of economic activity is linked directly or indirectly to mining. However, the share of the total population living in the mining regions is only about 7 percent. This fact shows that the direct effect of copper activity is limited. This contrasts with agricultural commodities which, where abundant, represent a larger fraction of GDP and employment.

Second, about two thirds of copper production is owned by foreign companies.<sup>4</sup> The rest is produced by a state-owned company, CODELCO. Overall, when including taxes paid by foreign investors, about half of the income from copper is foreign, and the rest is public, in the form of profits from CODELCO and tax revenues. But as is well known, fiscal policy in Chile operates under a rule that sets expenditure on the basis of long-term copper prices, so the fiscal impact of high copper prices is dampened significantly by the fiscal rule.<sup>5</sup>

Of course, in a Ricardian world, whether the income is public or private would be immaterial. However, the evidence on Ricardian equivalence is limited, in particular in a developing economy such as Chile where a large fraction of people are without full access to credit markets (Céspedes, Gali, and Fornero, 2010). Anyway, the country becomes richer with a higher copper price, and this should have some impact on private demand. However, it is difficult to imagine given the improvements in the Chilean policy framework that the effects are of such a magnitude as to induce recession when

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<sup>4</sup>There are important Chilean investors in some mining companies, but they are incorporated as foreign companies. There are also some small- and medium-sized companies that are owned by Chilean residents, but they make up a small fraction of copper production.

<sup>5</sup>The copper price that enters on the fiscal rule formula corresponds to the expected copper price from  $t + 1$  to  $t + 10$ . Therefore, there is some impact, while very limited, of current prices on the current fiscal budget since forecasts tend to be highly persistent. In fact, Magendzo (2010) estimates that only 10% of the last year's copper price changes are incorporated into the long-term copper price used in the fiscal rule.

the copper price falls and acute booms when it rises, as was historically observed in Chile.<sup>6</sup> For more discussion on the public finance channel, we review the role of fiscal policy in the next section.

### 3 Fiscal Policy and Copper

It can be argued that the fiscal rule, which was launched in 2000, is what has produced the greater resilience of Chile's economy to copper prices. Indeed, the introduction of the fiscal rule was a big step toward institutionalizing prudent fiscal policy, although fiscal prudence had been in place for a long time already. When introduced, the fiscal rule established the target of a structural surplus of 1 percent of GDP. The structural surplus is estimated using a cyclical adjustment for revenues and a long-term copper price. The parameters for both variables are established by two expert committees. In particular, for copper prices the experts are asked to forecast the average price for the next 10 years, and this is the price used to compute the structural revenues from copper.

For 2007, the rule moved transitorily to a target of 0.5 percent surplus of GDP, then in 2008 to a 0 percent balance, and it was changed to a deficit of -1 percent during the 2009 recession. The current administration has announced that it will return to a structural deficit of -1 percent by the end of its term, in 2014, amid the needs of reconstruction stemming from the earthquake of 2010.

The introduction of the fiscal rule was a very important development in macroeconomic management. It provides a predictable path for fiscal policy. Monetary policy in the context of an inflation target is greatly benefited by this rule. The models that are used to forecast inflation for the policy horizon of two years take this rule into account, and without the rule much weaker assumptions would have to be made in order to forecast inflation throughout the entire policy horizon and beyond. The adoption of this explicit rule has also contributed to eliminating the uncertainty induced by fiscal revenues linked with copper price fluctuations. Therefore, it is difficult to separate the effects of the fiscal rule from the effects of the inflation target regime, because the latter has been positively influenced by the predictability and transparency of fiscal policy.

The fiscal rule also played an important role in the run-up of copper prices in the last years, in particular before the subprime crisis developed. Indeed, with a copper price

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<sup>6</sup>Calvo and Mendoza (1999) and Spilimbergo (1999) both report a high sensitivity of the business cycle in Chile to the copper price. However, their samples do not include the sharp drop of the early 2000s and the later high rise, with moderate output fluctuations. Moreover, Calvo and Mendoza (1999) focus more on inflation, and their estimations for terms of trade use the price of copper divided by the price of oil, with the former also having important effects on the economy. In turn, Caballero (2002) argues that sensitivity to the business cycle to copper prices is due to the fact that copper is used as collateral for foreign borrowing. This channel could have been relevant when Chile had limited access to international financing.



averaging US\$3.4 per pound in 2006-07, the fiscal surplus was on average 8.2 percent of GDP. It is difficult to fathom how a windfall of such magnitude could have been saved without the rule. This allowed Chile to accumulate a sovereign wealth fund that reached 19.5 percent of GDP in 2008,<sup>7</sup> while gross public debt was 5.2 percent that same year. The government became a net creditor to the rest of the world (Figure 5), which allowed Chile to implement one of the largest fiscal expansions (relative to the size of the economy) in the world during the Great Recession. Toward 2010 the government's net creditor position declined, since it used part of its sovereign wealth fund to finance the fiscal expansion.

However, to attribute a major stabilization effect solely to the introduction of the fiscal rule would be questionable. Indeed, Chile had run a prudent fiscal policy since the mid 1980s. Figure 6 shows that from the mid 1980s to the Asian crisis in the late 1990s, Chile had an effective fiscal surplus every year; although in the late 1980s there was a deficit in structural terms. The structural surplus had been very stable until the Asian crisis, when it did become negative, and then again when it became negative during the Great Recession. A countercyclical fiscal policy is expected to reduce a structural balance during recessions and to increase it during expansions, so most of the time the fiscal policy was fairly acyclical, except in the two recessionary periods of the last 25 years.

To look more closely at the cyclical properties of fiscal policy, Figures 7 and 8 present correlations of the cyclical component of government expenditure with the cyclical components of output and copper prices, respectively. Although the correlation-for ten and twenty-year rolling windows-between the cyclical components of GDP and government expenditure is not stable, its value started declining to negative magnitudes around the early 1990s. On average, for the 1990s, the correlation decreases to half of its historical value. Despite a positive co-movement toward 1997 – 98, since the second half of the 1980s the correlation shows a downward slopping trend. It is worth mentioning the dramatic decrease during the last years of the sample-close to  $-0.8$  for the period between 2001 to 2010-, this is mainly associated with the fiscal expansion during the global crisis. As Frankel et al. (2011) highlight, Chile has successfully implemented a countercyclical fiscal policy since it has been able to overcome the historical procyclicality. For the period 2000 – 09 these authors find a negative correlation close to  $-0.7$ , which contrasts with the 0.3 correlation found for the period 1960 – 99.

During the 1990s there was no explicit rule for fiscal policy, despite the fact that the policy generated surpluses almost every year. In order to contain a large expansion of government expenditure, especially during the transition from the military regime to democracy, the budget was designed with an implicit commitment to expand government expenditure no more than the expected growth in output. This may have induced some moderate procyclicality in government expenditure.

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<sup>7</sup>Two funds were created: the reserve fund for pensions and the economic and social stabilization fund. We refer to both as the sovereign wealth fund. There are also two additional, smaller funds, the oil stabilization fund and the infrastructure fund.

What is interesting about this evidence is the negative correlation between government expenditure and copper prices. This evidence implies that fiscal policy leans against the wind regarding copper prices (Figure 8). In moments of rising copper prices, fiscal expenditure tends to slow down. This negative-or zero-correlation has been in the data even for periods previous to the 1980s, although to a lesser extent. In 1985, a copper stabilization fund was introduced in the context of an IMF program implemented after the debt crisis. Historically, the negative correlation was oscillating -from a long run perspective- between values from  $-0.4$  to  $-0.2$  until the early nineties, and then it became increasingly negative with the run-up of the copper price to its current record levels.

The existing empirical evidence showing the fiscal rule's strong stabilization effect is based on a comparison with a counterfactual exercise of a balanced-budget rule. Indeed, if there were a balanced budget rule the business cycle would be substantially more volatile (as shown in Medina and Soto, 2007a, and Céspedes, Gali, and Fornero, 2010). However, the counterfactual has never been the actual framework used for fiscal policy, and it is at odds with the negative correlation between copper prices and government expenditure.

Other evidence has used a dummy to separate the periods with the rule from those without the rule (Larraín and Parro, 2008), but the evidence on fiscal prudence reported here shows that there was no significant break in the actual behavior of fiscal policy in the early years of this century. Indeed, by that time there were also important changes in monetary policy. A full inflation target was introduced, monetary policy became instrumented with the nominal interest rate, the capital account was open, and the exchange rate was allowed to float. There were important changes in the whole macroeconomic regime.

Overall, despite a historically conservative fiscal policy, the budget rule of the 2000s was central to avoid an extreme expansion associated with soaring copper prices. Fiscal revenues were, on average, 21 percent of GDP during 2000 – 04 and went up to 26 percent, on average, in 2007 – 08. At the same time, the average contribution of CODELCO to fiscal revenues was only 5 percent during 2000 – 04, rising to 19 percent in 2007 – 08. In this latter period, the contribution of private copper companies was 12 percent of total revenues. Thus, copper accounted for almost a third of total revenues. Contrary to the experience almost a hundred years ago, when most taxes were replaced by the windfall of nitrates, fiscal responsibility was reinforced with the fiscal rule applied in the last decade.

## 4 Economic Fluctuations and the Copper Cycle

The copper price was historically an important driver of the business cycle in Chile, although its effects have changed over time. It is an important component of the terms

of trade, with consequent income and substitution effects on demand, and it also plays an important role in public finances. Therefore, it remains one of the driving forces of the Chilean business cycle. In the late 1980s, the Chilean economy entered into a regime characterized by moderate fluctuations, and it is important to examine whether this new regime has also changed the way copper affects the economy.

In this section we present empirical evidence on the relationship between copper prices and the business cycle. In particular, we show evidence on the volatility (standard deviation) of inflation, GDP, and the real exchange rate (RER). This evidence suggests that since the adoption of the inflation-targeting full flexible-exchange-rate regime in 1999, the response of the Chilean economy to copper price fluctuations has diminished.

The volatility of output and inflation in the Chilean economy from a long-term perspective is presented in table 1. Figure 9 shows volatility of GDP growth since the 1960s. The figure shows that volatility has sharply declined since 1990. That year marks the beginning of the central bank's autonomy and the first implementation of an inflation targeting regime, but where the inflation target was set on an annual basis in a path consistent with reducing Chile's historical two-digit inflation rates to normal international levels. In addition, during the 1990s the exchange rate regime was based on a band with infrequent adjustment of the central rate. For the case of inflation, its evolution may be contaminated with the very high inflation of the early 1970s, but the decline in volatility is confirmed by looking at the coefficient of variation. In addition, the decline in output volatility is also remarkable and consistent with what would be expected in a credible inflation targeting regime. It is worth highlighting the decline in volatility in the 1990s, but what we show in what follows is that the response of the economy to copper prices diminished further in the last decade.

Volatility measures based on quarterly figures are presented in Figure 10. All volatilities are computed using five-year rolling windows. Due to data availability, the sample starts in 1985. This figure shows the sharp decline in inflation and GDP volatility from 1990 onwards. In addition, it shows the volatility of the RER, which does not display a clear pattern during the last twenty years. This is not surprising, since a flexible exchange rate regime should increase the volatility of the RER in order to act as a shock absorber. Regarding copper prices, the two measures presented in Figure 10 show a sharp increase in volatility since the mid 2000s, which coincides with the rapid rise in copper prices.

Regarding GDP and inflation, the data show that the volatility of both variables declined during the 2000s, but at the end of the sample there is a significant increase. This recent period coincides with the shock of commodity prices that started in 2007 and the subsequent slump caused by the subprime crisis.

Indeed, Chile is one of the countries that experienced the sharpest increases in inflation among emerging economies in the run-up of commodity prices but also the largest decline since the crisis erupted (De Gregorio, 2010). The most remarkable component of the inflationary process of 2007-08 was how strongly the increase in international

food prices was transmitted domestically. Inflation rose from a year-over-year rate of 2.6 percent in December 2006 to 9.9 percent in October 2008, and then declined to -2.3 percent in November 2009. This was largely due to Chile’s high degree of commercial openness. There are practically no barriers to imports, no widespread protection of agriculture, or any large-scale distortions in the market pricing mechanism, so changes in external prices are quickly reflected in the domestic market. In fact, at least during the greater part of 2007, growing inflation was mostly caused by increasing food prices, rather than by a widespread inflationary process. Then the inflationary process spread to other prices, which subsequently fell sharply.

Of course, the issue is whether the rise in the volatility of output and inflation toward the end of the last decade was due to the greater volatility of copper prices or to general international conditions. To explain the inflation, it is easy to discard the impact of copper prices, but for output volatility more evidence is needed.

It is immediately clear from Figure 4 that GDP growth and real annual copper price changes display some co-movements. Since the late 1980s, the amplitude of economic activity has substantially decreased compared to the previous experience. Moreover, for similar amplitude of copper price shocks over the whole sample, we observe a break in growth amplitude. In fact, as previous figures show, growth volatility started decreasing in the early 1990s.

In order to explore the relationship between the price of copper and real GDP volatility, we calculated the standard deviation of annual growth over a 10-year rolling window of real GDP ( $\sigma_{gy}$ ), real price of copper ( $\sigma_{Pcu}$ ), real price of oil ( $\sigma_{Poil}$ ) and US real GDP ( $\sigma_{gy}^{US}$ ). Controlling for the degree of trade openness, we estimated the following equation:<sup>8</sup>

$$\sigma_{gy,t} = \beta_0 + \beta_1\sigma_{gy,t-1} + \beta_2\sigma_{gy,t}^{US} + \beta_3\sigma_{Poil,t} + \beta_4\sigma_{Pcu,t} + \beta_5\chi_t + \varepsilon_t \quad (1)$$

Variable  $\chi_t$  is an indicator of openness, measured as the share of exports plus imports in GDP.<sup>9</sup> The regression was estimated using an expanding window that starts in 1960. This strategy allows measuring the marginal impact of years added to the sample rather than changes in the results due not only to new data, but also to data that are being eliminated, which belong to a period with higher volatility.<sup>10</sup>

The results for the parameter  $\beta_4$  are presented in Figure 11. It corresponds to the short-term impact of the volatility of copper prices on output volatility. The results for the long-run coefficient  $\beta_4/(1-\beta_4)$  are similar. The figure shows that indeed the fluctuations

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<sup>8</sup>Using 5-year rolling volatilities does not change the results.

<sup>9</sup>Other controls were included, such as mining GDP as a share of real GDP and real exports; results hold including these variables. We also included the volatility of government expenditure and it was not significant.

<sup>10</sup>Results using a rolling regression are very similar and do not change the conclusions.

of copper prices in the 2000s have reduced their effects on output volatility.<sup>11</sup> The point estimate indicates that a 10 percent increase in copper price volatility increases output volatility by 1 percent. The increase in volatility observed more recently has the result of increasing the volatility of foreign output and oil prices, rather than increasing the response of the business cycle to copper fluctuations. Figure 12 shows actual and fitted volatility of output under two alternatives. The first one uses the values estimated with the fitted regression until 1999, and the second one with the full sample. The figure shows that the implied volatility of GDP in Chile would have been much larger with the estimations before the implementation of the inflation-targeting full flexible exchange rate regime.<sup>12</sup>

The evidence presented in this section suggests that after the implementation of the inflation-targeting full flexible exchange rate regime, the economy has become less volatile and more resilient to copper price fluctuations.

## 5 Terms-of-Trade Shocks, Real Exchange Rate, and Long-Run Dynamics

In this section we study the impact of terms of trade on the RER. This price is measured as the ratio between the prices of foreign goods (in domestic currency) and the prices of domestic goods. Hence, it represents the cost of foreign goods in terms of domestic goods; a rise in this relative price is a real depreciation. Figure 13 shows the evolution of the price of copper, terms of trade and the RER. It is clear that the terms-of-trade shocks have been particularly sizable in the last decade, mainly driven by copper price movements; while the real exchange rate has fluctuated but moderately with respect to export price shocks.<sup>13</sup>

There are many approaches for studying RER dynamics, and a model that considers the entire macroeconomic environment would be most desirable. However, here we follow an eclectic approach; we use a vector-error correction model introduced by Johansen (1988). This modeling strategy allows estimating a reduced-form representation of the dynamics and interactions between the RER and its fundamentals.

This type of model has been used by, among others, Clark and MacDonald (1998) for analyzing RER movements and misalignments from the RER's long-run fundamentals, Céspedes and De Gregorio (1999) used a similar approach for the period before 2000. The approach supposes both a short-run and a long-run relationship between RER and

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<sup>11</sup>Results are basically the same when the volatility of terms of trade is used instead of the volatility of the copper price.

<sup>12</sup>Larraín and Parro (2008) show that exchange rate flexibility reduces output volatility. They use an index of exchange market intervention using the change in reserves, and show that the lower this index is, the lower is output volatility.

<sup>13</sup>Over the sample period, the price of copper and terms of trade have a correlation in levels slightly above 0.9, and were equal to 0.67 in quarterly percent changes during the period post-2000.

a set of fundamental variables. The long-run cointegrating relationship implicit in this approach is interpreted as the fact that these variables move together in the long run. The adjustment of the RER to changes in fundamentals is gradual. The relationship implied by economic theory does not necessarily hold at short frequencies, but in the long term RER moves according to its fundamentals.

Hence, in this framework the RER is consistent with a long-run equilibrium condition on the balance of payments, which is determined by a set of fundamental variables. These fundamentals could be listed by domestic and foreign key variables. Following Faruqee (1995), these variables can be summarized according to the two different channels through which they affect the RER. One set of fundamentals includes those related to the current account (according to trade conditions) and the other is related to the capital account (according to the net foreign assets position). Regarding trade, the variables are relative productivity between tradables and non-tradables (according to the well known Balassa-Samuelson effect), government expenditure, and terms of trade. Regarding the capital account, the variable we use is the net foreign assets position, which summarizes the country's propensity to be a net lender or a net debtor.

The variable TNT is the productivity ratio between the tradable and the non-tradable sectors. This ratio summarizes the Balassa-Samuelson effect, and has a negative impact on the RER. With labor mobility, equal wages across sectors, and purchasing power parity (PPP) for tradable goods, an increase in the productivity of the tradable sector induces an increase in wages in the non-tradable sector (De Gregorio, Giovannini, and Wolf, 1994). This increase in wages in the non-tradable sector leads to an increase in costs (and relative prices) in the non-tradable goods. Hence, with such a mechanism the RER tends to appreciate.

The variable ToT has a negative impact on the RER, that is, it generates a real appreciation. An increase in ToT produces an income effect and raises demand for both tradable and non-tradable goods. Since prices of tradable goods are externally determined, an increase in the terms of trade raises the relative price of non-tradable goods. The variable (G/Y) is the ratio of government expenditure to GDP, which has also a negative impact on the RER under the assumption that most of government expenditure goes to non-tradable goods. Finally, as a stock variable, we include the net foreign asset position as a percentage of GDP (F/Y). This variable has a negative impact on the RER. In fact, an increase in foreign assets is consistent, from an intertemporal point of view, with a lower sustainable level of net exports, which induces a RER appreciation. Hence, we may posit the following relationship:

$$\log(RER_t) = \beta_0 + \beta_1 TNT_t + \beta_2 ToT_t + \beta_3 (G/Y)_t + \beta_4 (F/Y)_t + \varepsilon_t \quad (2)$$

We follow the traditional vector-error correction model procedure and estimate a vector error correction representation with one long-run relationship and two lags, as described

by this equation (3):<sup>14</sup>

$$\Delta y_t = c + \alpha\beta y_{t-1} + \sum_{i=1}^{p-1} \delta_i \Delta y_{t-i} + u_t \quad (3)$$

Where  $y$  is a vector such as  $y = (\text{ToT TNT } (F/Y) (G/Y) \text{ RER})'$ , all variables are in log except government expenditure and net foreign assets. We estimate the system represented in (3) using data from 1977 Q1 to 2010 Q3. This type of reduced-form model allows us to analyze the path of the RER after a permanent terms-of-trade shock.

We then estimate equation (3) splitting up the sample period in 1999 (see Table 3). September this year corresponds to the beginning of the inflation-targeting full flexible exchange-rate regime. By that time, the inflation targeting framework in Chile had been operating for almost a decade, though with a yearly target, there were capital controls, and there was a currency regime based on exchange rate bands. Since 2000 the peso has floated according to a flexible regime where interventions have occurred sporadically, according to a rule-based scheme, to preserve monetary policy independence.

Results presented in figure 14 show the response in levels of the RER to an orthogonalized permanent terms-of-trade shock. As the RER is in log and multiplied by 100, the level attained after the shock can be directly interpreted as a percent change from the initial equilibrium. The contemporaneous effect is larger in the period post-1999; it varies from -20 to -30 percent, respectively. This result is consistent with the expected response of a flexible exchange rate regime where external shocks are directly absorbed by the nominal exchange rate. In the model with pre-1999 estimates, the RER starts appreciating sharply three quarters after the shock. After two years, the real appreciation is greater than the one that resulted from the post-1999 estimates. When the effect of the shock stabilizes, the equilibrium RER reached with pre-1999 estimates is more overvalued than this one reached with post-1999 estimates.

This result points out that during the period of inflation-targeting full flexible exchange rate regime, terms-of-trade permanent shocks have more immediate effects on the RER but are smaller in the long run. During the period of exchange rate bands the effects of copper price shocks are more gradual, but deeper. In fact, as we can see in Table 3, the adjustment parameter of long-run RER disequilibrium has increased (in absolute terms) from -0.06 to -0.37 during the period post-1999. That means that a higher share of lagged RER disequilibrium is corrected every period in the vector-error correction model system. RER fluctuations converge more quickly to the RER's long run equilibrium after a permanent shock.

These results show that in a flexible exchange rate regime, the exchange rate acts as a shock absorber. Of course, it is not free of costs when the exchange rate adjustment is faster, but the final level is less affected. This evidence points toward a more efficient

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<sup>14</sup>For further details see Appendix A.

mechanism for transmission of external shocks. External shocks are primarily absorbed by the nominal exchange rate and then directly transmitted to the RER. A fully flexible nominal exchange- rate regime is sometimes associated with higher short-run volatility, although that volatility does not necessarily imply greater long-run uncertainty. Hence, nominal exchange rate flexibility need not always be associated with long-run real costs related to more volatility.<sup>15</sup> In the next section we analyze more deeply the issue of volatility of the RER at different horizons.

Short-term volatility can be hedged with developed forward markets, while price signals are transmitted more quickly to the economy. Moreover, as discussed in De Gregorio and Tokman (2005), the implementation of the floating exchange rate regime has motivated the proliferation of a deeper exchange rate derivative market. At the onset of the flexible currency regime in 1999, the total amount of -both local and foreign- derivative contracts represented 1.7 times GDP, and 10 years later this ratio increased to nearly 3.7. Thus, there has been a reduction in balance sheet vulnerabilities and the corporate sector has been able to eliminate part of its exposure to nominal exchange rate fluctuations.

## 6 Macroeconomic Fluctuations and Real Exchange-Rate Volatility

Since the peso has been allowed to float its volatility has increased.<sup>16</sup> External shocks are in part directly transmitted to the Chilean economy through nominal exchange rate fluctuations which affect, among other variables, the RER and economic decisions. Since the RER is a relative price that in the long run leads allocation of resources, it is important to examine how RER volatility has been affected.

A fully flexible nominal exchange rate policy implies a rise in the speed and number of channels through which the economy is hit by external shocks. Moreover, in a sticky-prices world we can argue that a considerable part of RER fluctuations are caused by nominal exchange rate movements, at least in the short run.

Nominal exchange rate flexibility contributes to smooth external fluctuations. In fact, when external shocks hit the economy this price moves freely instead of staying fixed and generating imbalances, misalignments, or further costly real adjustments. Thus, corrections occur through the price mechanism and not through quantities. Real effects should be reduced, as a traditional Mundell-Fleming analysis would imply.

However, the RER absorbs real shocks and as a relative price it moves in order to convey

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<sup>15</sup>In the context of an appreciation due to a boom in the price of natural resources, welfare costs are different across sectors. The stabilization of the exchange rate generates welfare gains in the tradable goods sectors, but with costs of inefficiency that in general may outweigh the gains. For a formal analysis and calibration of this problem see Lama and Medina (2010).

<sup>16</sup> During the 2000s, the standard deviation of four quarter percent changes has more than doubled compared to its average during the 1990s; it has increase from 2% to 4.6%.



information that, in part, leads to changes in the allocation of resources between the tradable and the nontradable sectors. In the economy, for the sake of minimizing real costs, it is a crucial condition that relative prices must not be distorted. It is not entirely clear whether the increased nominal exchange rate volatility that we have been experiencing since the early 2000s is not distorting and inefficiently transmitted to the RER, a key relative price. To answer this question, it is fundamental to understand how nominal and real shocks are transmitted to the RER. Since short- and long-run RER movements have different implications, a central question is how short- and long-run RER volatility have behaved in the face of higher nominal exchange rate volatility.

For the 1990s, Soto (2003), using a Blanchard-Quah approach, estimated that 30 percent of the short-run variance of RER forecast errors is explained by nominal shocks. However, it remains unanswered how short- and long-run RER volatility have been affected during the last 25 years.

Short-run RER fluctuations do not have the same implications that long-run fluctuations do. In fact, short-run RER volatility induced by temporary external fluctuations would be consistent with RER playing a shock absorber role in the short run. As long as fluctuations are temporary, long-run reallocations and major adjustments are not needed. Hence, it would be inefficient if in the presence of temporary external real fluctuations, we observed contemporaneous increases in the long-run RER rate volatility. Consequently, this situation could be interpreted as a source of instability and welfare costs.

In order to analyze this question, we need to decompose real exchange rate dynamics into long- and short-run fluctuations. There are not many straightforward frameworks for doing this, because long- and short-run real exchange rate components are not observed variables.

Stock and Watson (2007) developed the unobserved components and stochastic volatility framework for analyzing time-varying stochastic volatilities of the permanent and transitory components of inflation in the United States. This framework is well suited to studying persistent processes with stochastic breaks. Thus, it allows modeling a variable such as the RER and decomposing it into two unobserved variables: permanent and transitory components. Hence, it could help in disentangling different aspects of our question.<sup>17</sup>

The results presented in Figure 16 show short- and long-run stochastic volatilities for the Chilean RER at quarterly frequency. Compared to the level experienced during the 1990s, evidence points toward an increase of average short run volatility during the 2000s. However, long-run volatility has remained stable since the late 1980s. Hence, the increased exposition of the RER, through the channel of the flexible exchange rate, has been mostly reflected by rising short-run RER fluctuations. This is consistent with the argument that in the short run the floating nominal exchange rate framework has

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<sup>17</sup> Further details of the model are explained in Appendix B.

worked as a shock absorber mechanism without necessarily increasing long-run RER volatility.

Moreover, it is worth noting that during late 1970s and early 1980s both kinds of RER volatility, and especially long-run RER volatility, fluctuated more than during the recent period. In fact, the early 1980s corresponds to a period of external and internal imbalances and a strong real adjustment. At this time, the nominal exchange rate was fixed and RER was strongly appreciated. This generated a severe balance-of-payments and financial crisis that led to a strong devaluation with very large real losses in output and employment.

Besides, during the late 1990s, early 2000s, and late 2000s, the Chilean economy was affected by worldwide turbulent episodes. During late 1990s the Asian and Russian crisis hit emerging economies generating strong devaluations and high volatility. For the Chilean economy, these episodes represented sizeable external shocks that generated high volatility in the nominal exchange rate. As we can see, these shocks did not severely affect long-run RER volatility. However, short-run RER volatility stayed high for a long period during the early 2000s. To some extent, exchange rate flexibility helped absorb external shocks, minimizing the real effects by increasing short-run RER volatility.

However, in some cases excessive nominal exchange rate volatility could be incoherent with fundamentals and thus could be a source of macroeconomic instability. Therefore, even in a fully flexible exchange rate regime the central bank may intervene in the foreign exchange market. Interventions in a fully flexible exchange rate regime did occur in Chile in 2001, 2002, 2008, and 2011 (De Gregorio, 2011).

Overall, the main implications we can draw from the evidence make clear that since the implementation of fiscal prudence and especially during the fully flexible exchange rate regime, long-run RER volatility has remained stable. Moreover, since the early 2000s, short-run RER volatility has fluctuated more. However, it has not reached extremely high levels in spite of systematic increases in nominal exchange rate volatility (see Figure 17).

Along the same line, sharp external fluctuations that directly hit the Chilean economy, such as copper price shocks, have had a particular impact on the short-run RER volatility (see Figure 18). However, these recent sharp spikes do not produce excessive volatility in the RER, either in the short or the long-run.

The evidence reported in Figures 17 and 18 shows that the macroeconomic policy framework applied in Chile has been able to mitigate both the excess of volatility implied by external shocks, in particular by copper price shocks, and the effects of fluctuations in the nominal exchange rate on the volatility of the real exchange rate, and hence on competitiveness.

We may conclude that the Chilean policy framework as a whole, and in particular the country's currency regime, have operated as shock absorber devices. In fact, in the

face of sharp external shocks, evidence shows that stabilizing mechanisms are at work making the Chilean economy much more resilient than in earlier periods.

## 7 Simulation of a Copper Price Shock Using a DSGE Model

To further analyze the effects of the current policy framework on economic performance after a commodity (copper) price shock, we simulate a dynamic stochastic general equilibrium model on a small, open emerging-market economy. The model has been estimated for the Chilean economy with data from 1986 through 2007.<sup>18</sup>

The size of the temporary shock is 40 percent, which corresponds roughly to the actual size of commodity-price shocks observed before the financial crisis.

Three alternatives for the monetary policy are considered: (i) a Taylor policy rule under which the central bank responds to changes in output and *core* inflation;<sup>19</sup> (ii) a Taylor-type policy rule where the monetary authority not only responds to output and inflation but also to RER fluctuations;<sup>20</sup> and (iii) a Taylor rule like the one in (i) but coupled with a successful exchange rate intervention that keeps the RER unchanged for two quarters.<sup>21</sup> The results of these simulations are presented in Figure 19.

The copper price shock leads to a mild real appreciation of the currency. The extent of the appreciation is smaller than the one reported in the estimations for the long-run RER, since in this case the shock is smaller—it is only to the price of copper, which is only a part of the terms of trade. The estimations also take into account policy reaction, and the change in the copper price is assumed to be transitory, contrary to cointegrating regressions that estimate the effects of permanent shocks. In addition, the small effect on the RER is explained in part by the fact that the model assumes that the government follows a structural balance targeting rule, under which most of the proceeds from a higher copper price are saved. The shock also generates a fall in exports, due to the real appreciation, and a boost to other domestic sectors that leads to an increase in total output.

The effect on inflation of the copper price shock depends crucially on the monetary

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<sup>18</sup>For details, see Medina and Soto (2007b).

<sup>19</sup>The simulations use core rather than CPI inflation in the policy rule in order to capture the forward-looking behavior of the central bank in Chile. In small open economy models, like the one utilized in our exercise, it is often the case that a forward-looking policy rule leads to indeterminacy. To avoid this problem, we assume that the central bank considers core inflation a good predictor of future inflation and responds to fluctuations in this variable.

<sup>20</sup>This type of rule mimics the behavior of the Central Bank of Chile during the 1990s when, alongside a target for inflation, there was an explicit exchange rate band.

<sup>21</sup>The exchange rate intervention is modeled as a shock to the uncovered interest rate (UIP) condition in order to keep the real exchange rate fixed for two periods (quarters). The shock converges back to zero with a persistence of 0.85.

policy. Under the Taylor policy rule (policy rule (i)), although there is an expansion in total output, the appreciation of the currency is such that inflation decreases marginally after the shock. On the other hand, when the central bank systematically responds to fluctuations in the RER (under policy rule (ii)), the real interest rate falls in response to the shock, which leads to a more muted appreciation of the currency and generates a larger expansion in output. As a result, inflation increases and the nominal policy rate rises. Notice that policy rule (ii) reduces the volatility of exports, but it increases the volatility of overall output and of inflation, and therefore it reduces welfare.

If the central bank is able to successfully avoid RER fluctuations in the short run (two quarters in the simulations that fade away slowly) by using an alternative instrument other than the policy rate (e.g., by intervening in the foreign currency exchange market), the result is a more muted initial response of exports to the shock and a slight increase in inflation. Contrary to the other policy rules, this policy results in a reduction of output in the short run due to the impact on the nontradable sector. Notice, however, that in order to contain inflation pressures, in this case the policy rate -both nominal and real- needs to increase after some quarters. This in turn results in a delayed appreciation of the currency and precludes exports from returning quickly to their steady-state level.

Overall, this model shows that letting the exchange rate fluctuate may result in smaller welfare losses, in particular considering that inflation falls and output rises. Of course, in this model the exchange rate intervention is assumed to be successful and the intervention is used only as a short-run stabilization tool. In addition, this model does not allow for bubbles or extreme deviations of exchange rates that may justify certain forms of intervention (De Gregorio, 2010).

## 8 Concluding Remarks

The impact of natural resources on the business cycle and economic development has been an important topic in economic research and policy. Chile is an economy that has been able to grow quickly and build a stable macroeconomic environment while at the same time it is rich in natural resources, in particular copper. Therefore, Chile has suffered from neither the curse of natural resources nor the excessive volatility in terms-of-trade fluctuations. Compared to other countries abundant in natural resources but unable to take advantage of them, Chile has relatively strong institutions, high levels of human capital, and a stable macroeconomic environment, all of which help in avoiding the natural resource curse. On the other hand, the reduced impact of copper price fluctuations on the business cycle is due to macroeconomic policies.

This paper has focused on how increasingly resilient the Chilean economy has been to copper price fluctuations. Trying to disentangle all of the underlying factors is a difficult task and may involve subjective judgment. Indeed, even recent evidence is inconclusive about what proportion of the external conditions drives output instability

in developing countries.<sup>22</sup> For this reason, in this paper we use evidence from different areas to examine the impact of copper prices on economic fluctuations. The evidence shows that having a flexible exchange rate, a rule-based fiscal policy, and a flexible inflation targeting regime have all contributed to this resilience. Chile has followed prudent fiscal policies since the mid 1980s, which is an important factor in explaining the reduction in the volatility of output observed since the 1990s. In addition, the further decline in volatility and more limited impact of copper are due to the implementation of monetary policy with an inflation targeting framework and a floating exchange rate.

The operation of the fiscal rule since the early 2000s has provided predictability to pursue the inflation target based on a two-year horizon. Thus, fiscal and monetary policies have complemented to reduce the amplitude of the business cycle and provide sound basis for long-term growth, while reducing the dependence of Chile's economic performance to copper price fluctuations.

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<sup>22</sup>See for example Raddatz (2007) and Castillo and Salas (2010). While the former reports that external conditions explain a small fraction of output fluctuations on low-income economies, the latter argues for the case of Chile and Peru that the commodity price boom of the mid-2000s is a main driver of the economic expansion of recent years.

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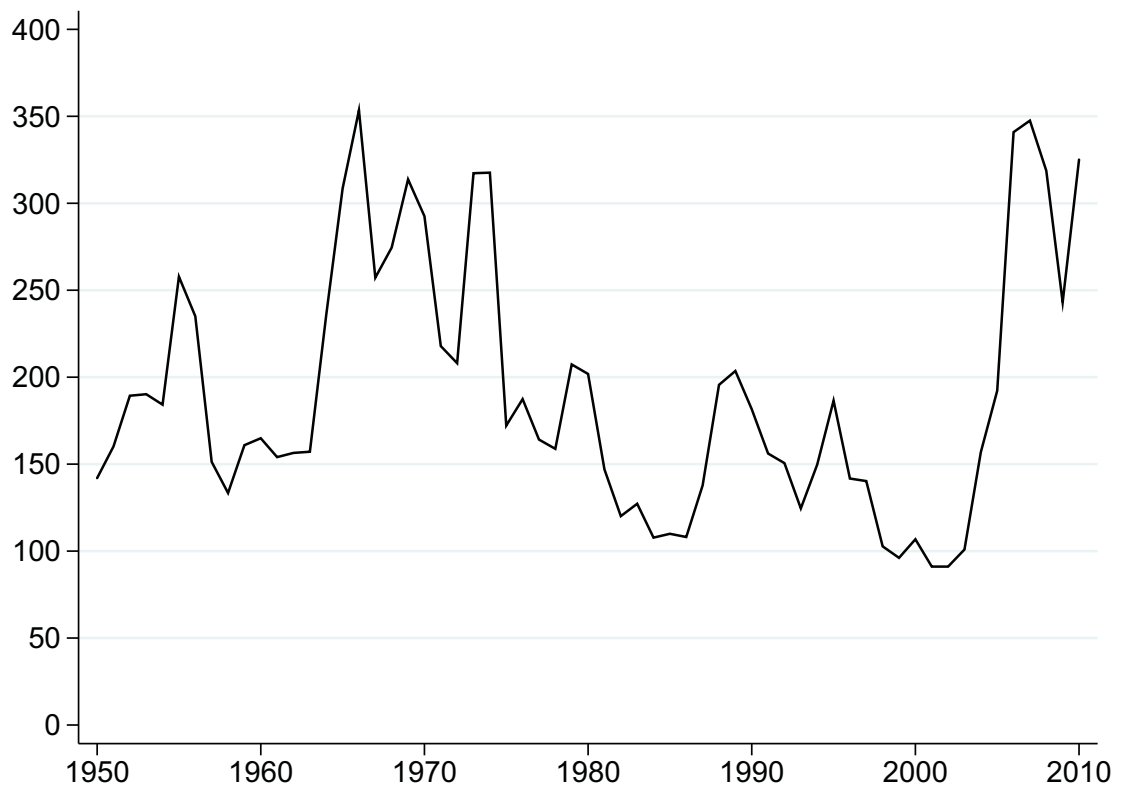


Figure 1: Chilean copper production as share of world production  
(production is measured in metric tons)



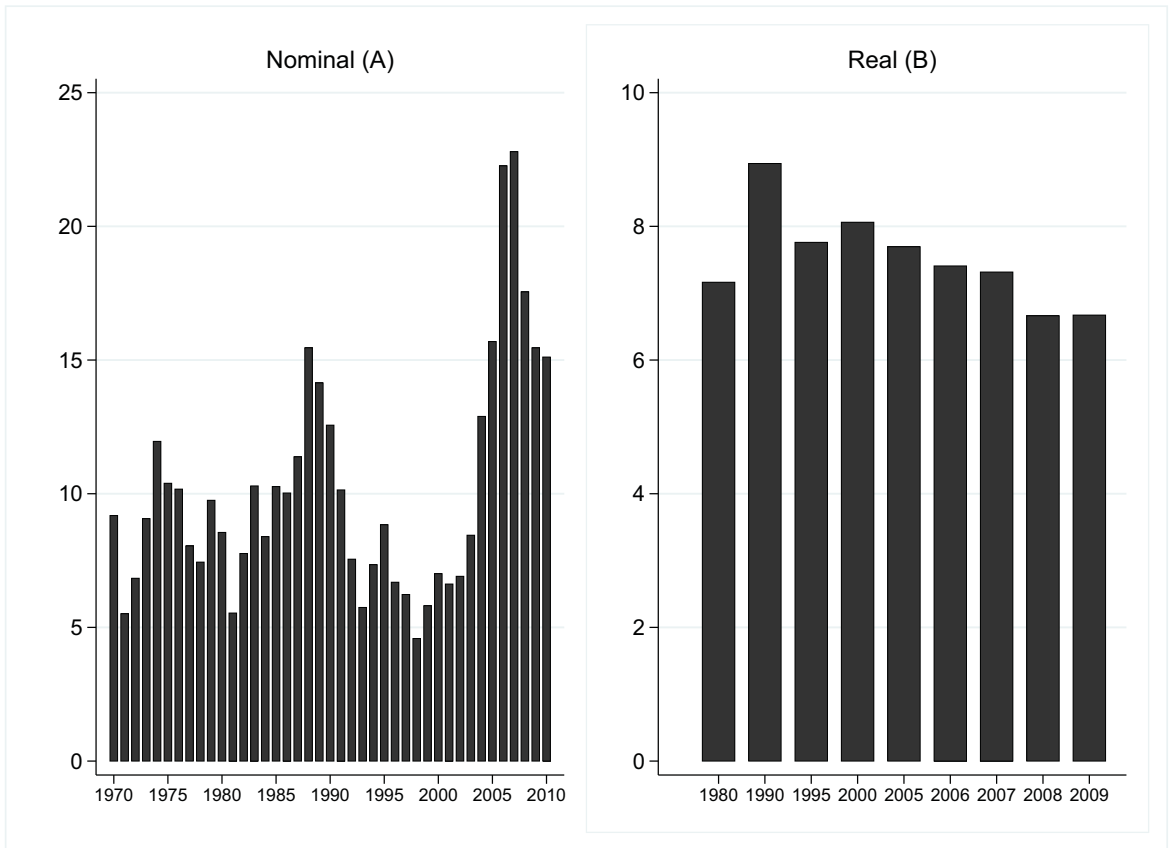
Sources: Díaz, Lüders, and Wagner (2010) and the Chilean Copper Commission (CoChilco).  
Note: Shares are obtained dividing Chilean production by world production, values are all expressed in metric tons.

Figure 2: Real price of copper (US cents per pound, measured at 2010 prices)



Source: The Chilean Copper Commission (CoChilco).  
Note: The price of copper is by the U.S. PPI.

Figure 3: Mining as a share of total GDP (percent)

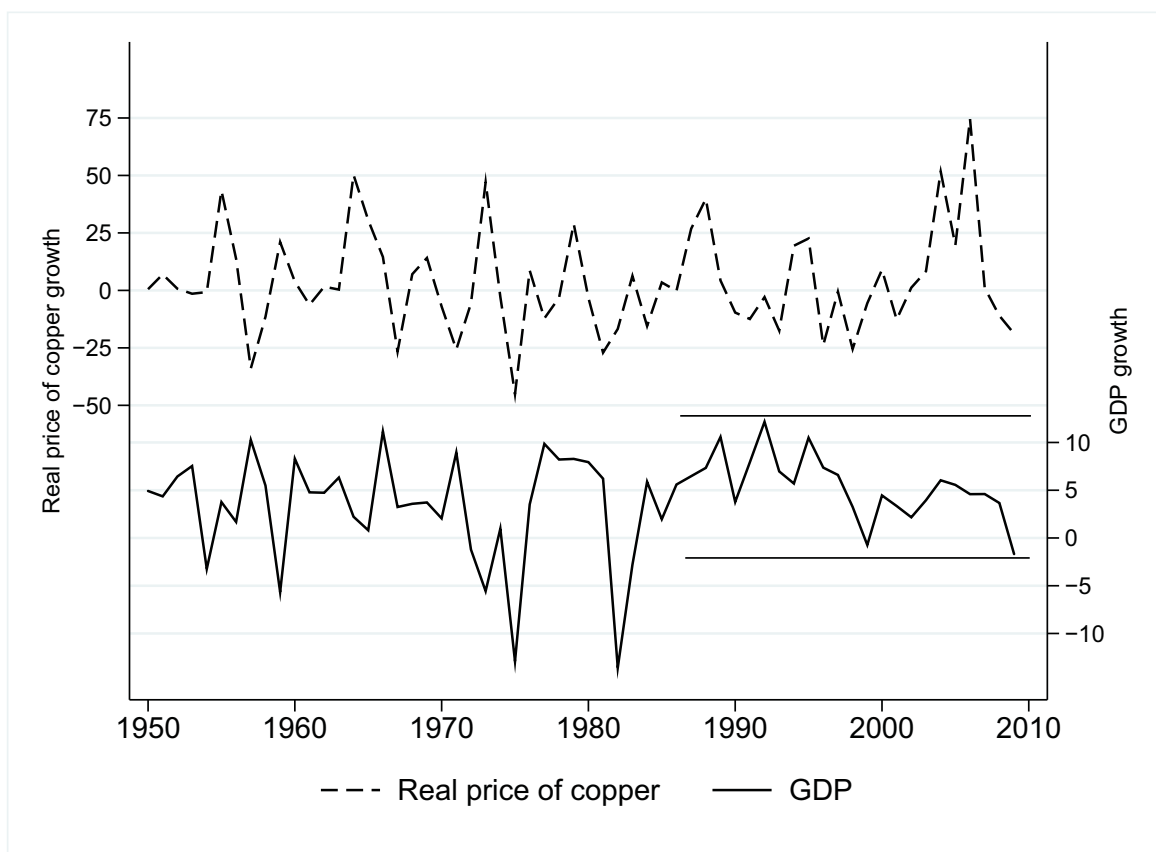


(A) At current prices.

(B) At 2003 prices.

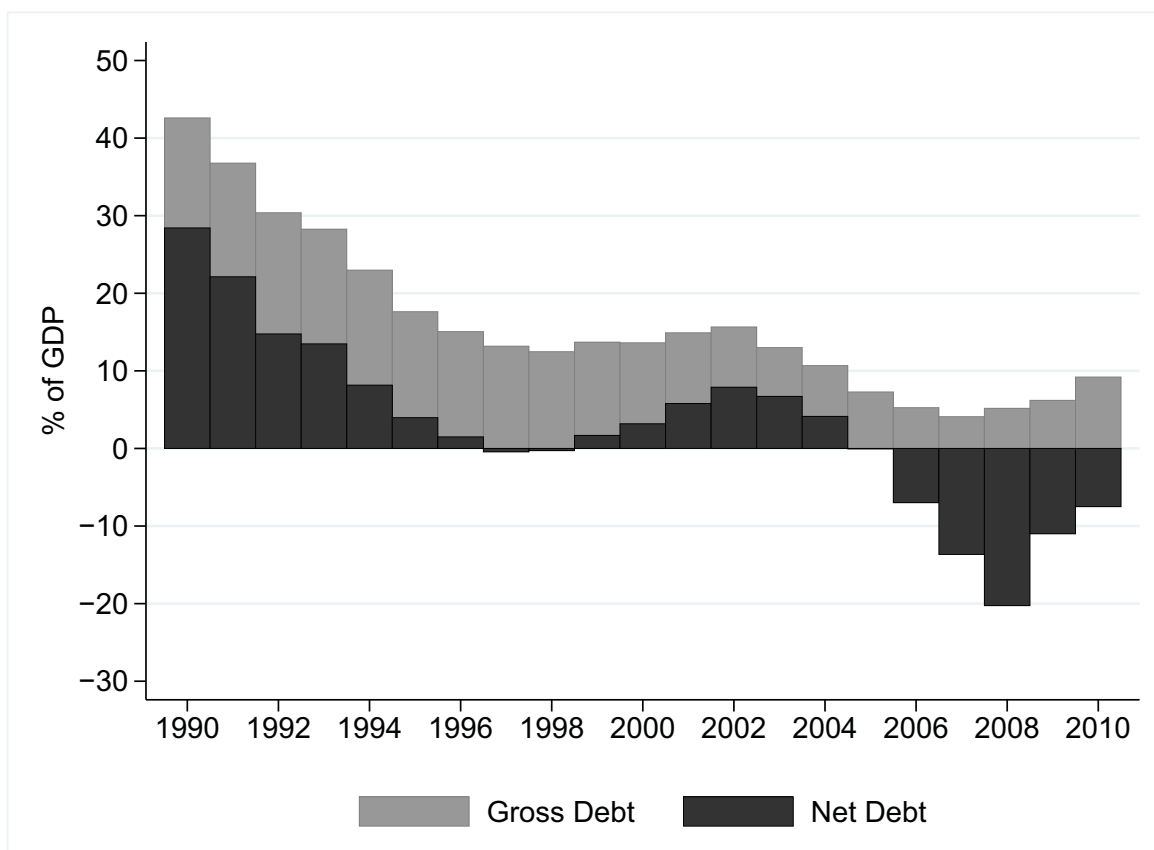
Source: Central Bank of Chile.

Figure 4: GDP and price of copper growth  
(percent)



Sources: Díaz, Lüders, and Wagner (2010) and Central Bank of Chile.

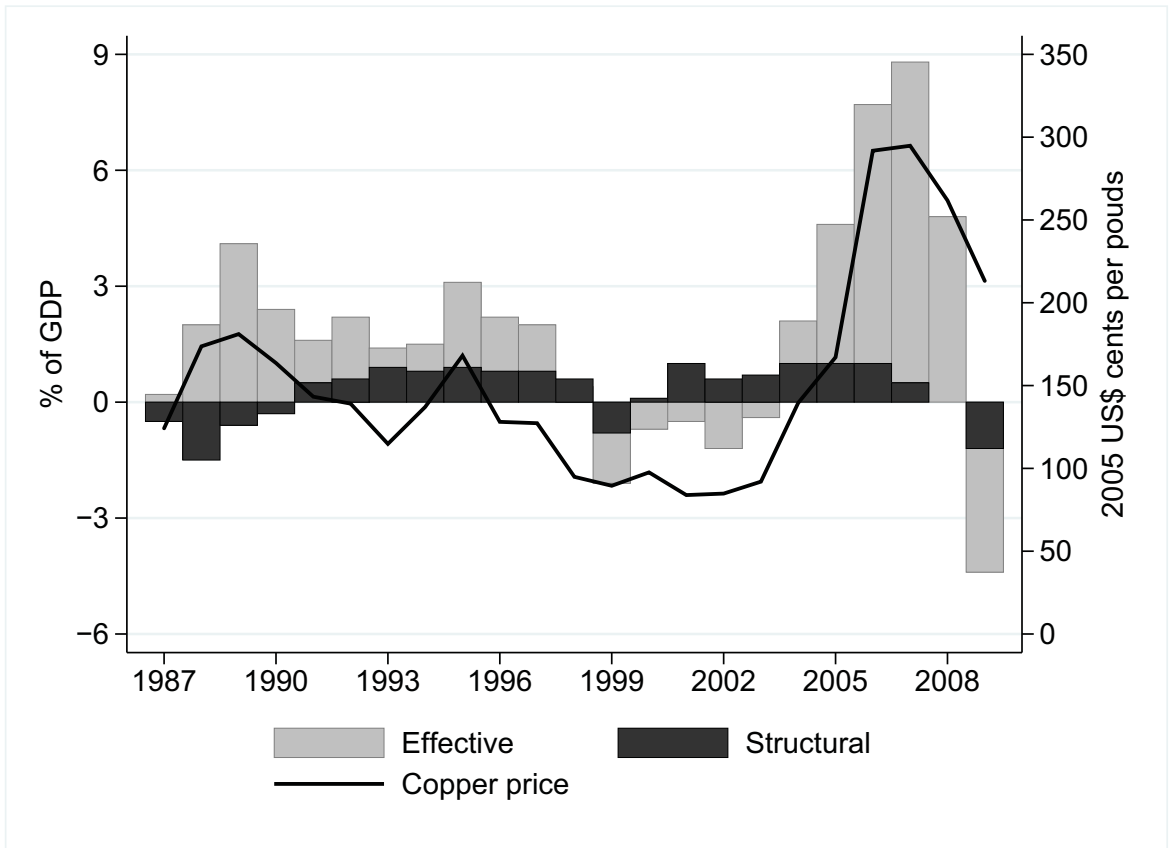
Figure 5: Public debt  
(central government)



Source: Budget agency, Ministry of Finance, Chile (DIPRES)

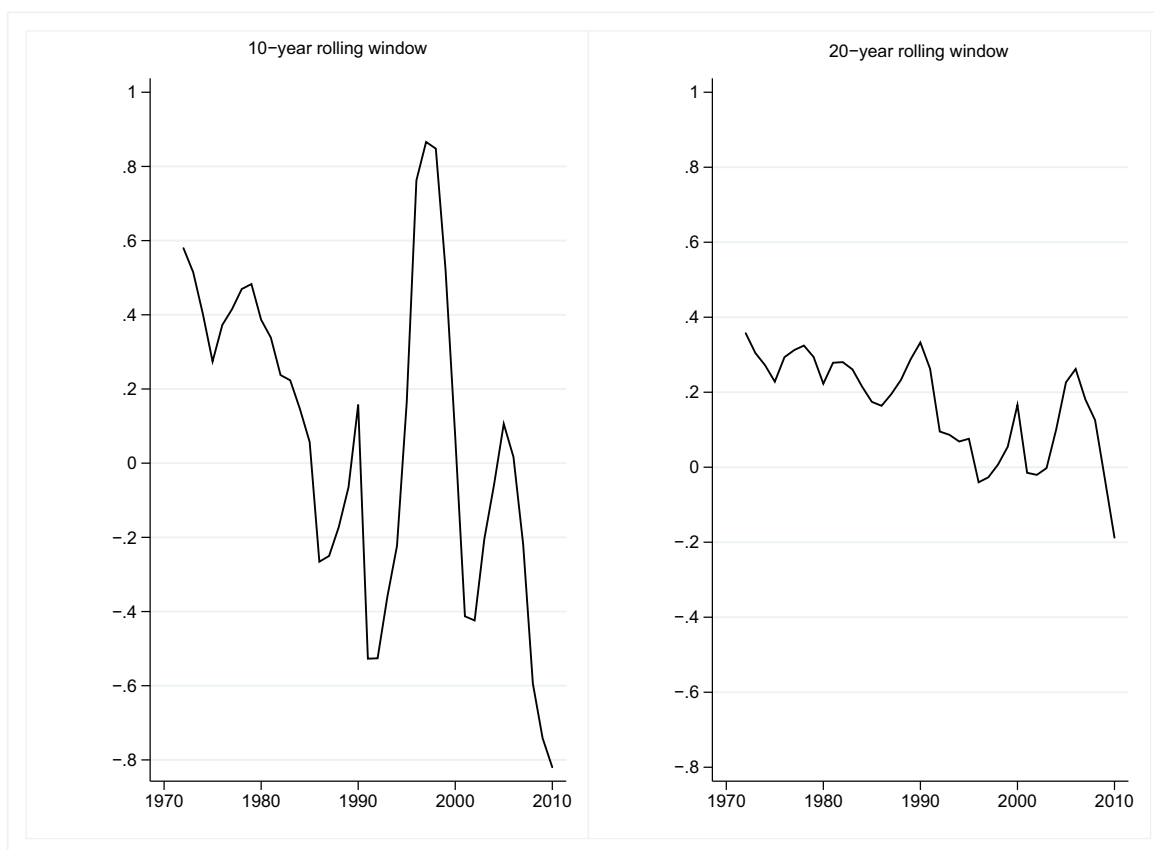
Note: Gross debt corresponds to total financial liabilities (external and internal) of the central government. Net debt corresponds to the gross debt minus total financial assets (external and internal) of the central government.

Figure 6: Fiscal balance and real price of copper



Sources: The Chilean Copper Commission (CoChilco); Ministry of Finance, Chile.

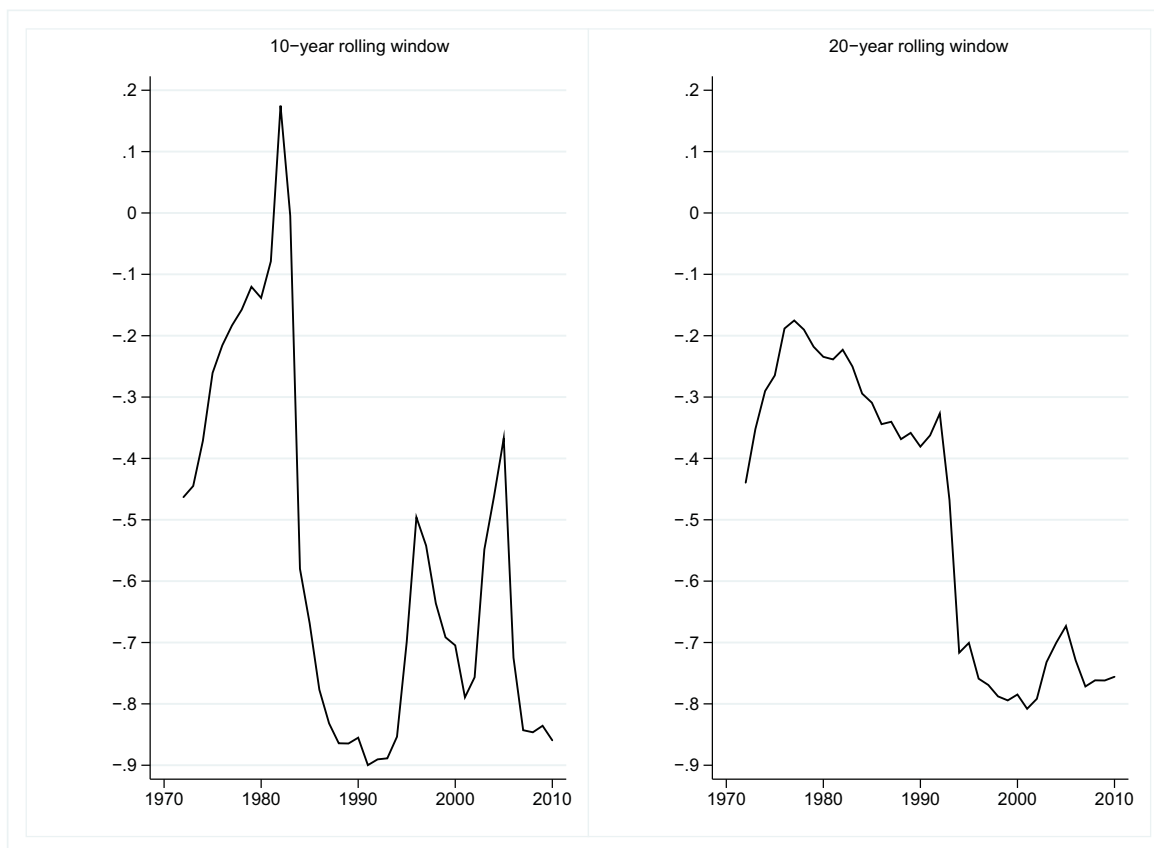
Figure 7: Correlation between the cyclical components of real GDP and real government expenditure



Sources: Díaz, Lüders, and Wagner (2010) and World Economic Outlook (WEO April 2011).

Note: For each year, the graphs show the resulting correlation with the data contained in a window bounded by the current year and the  $k - 1$ -previous years, bounds included. Cyclical components are calculated by first transforming the variables in log and then subtracting the trending component which is defined by an HP filter. Real government expenditure corresponds to the nominal total central government expenditure deflated by the GDP deflator. For trend estimate purposes, by using WEO projections, the data is projected until 2016. During the second half of 1990s, output and total government expenditure have a short period of positive co-movement which attains its maximal value for the years 1997 – 98.

Figure 8: Correlation between the cyclical components of real price of copper and real government expenditure

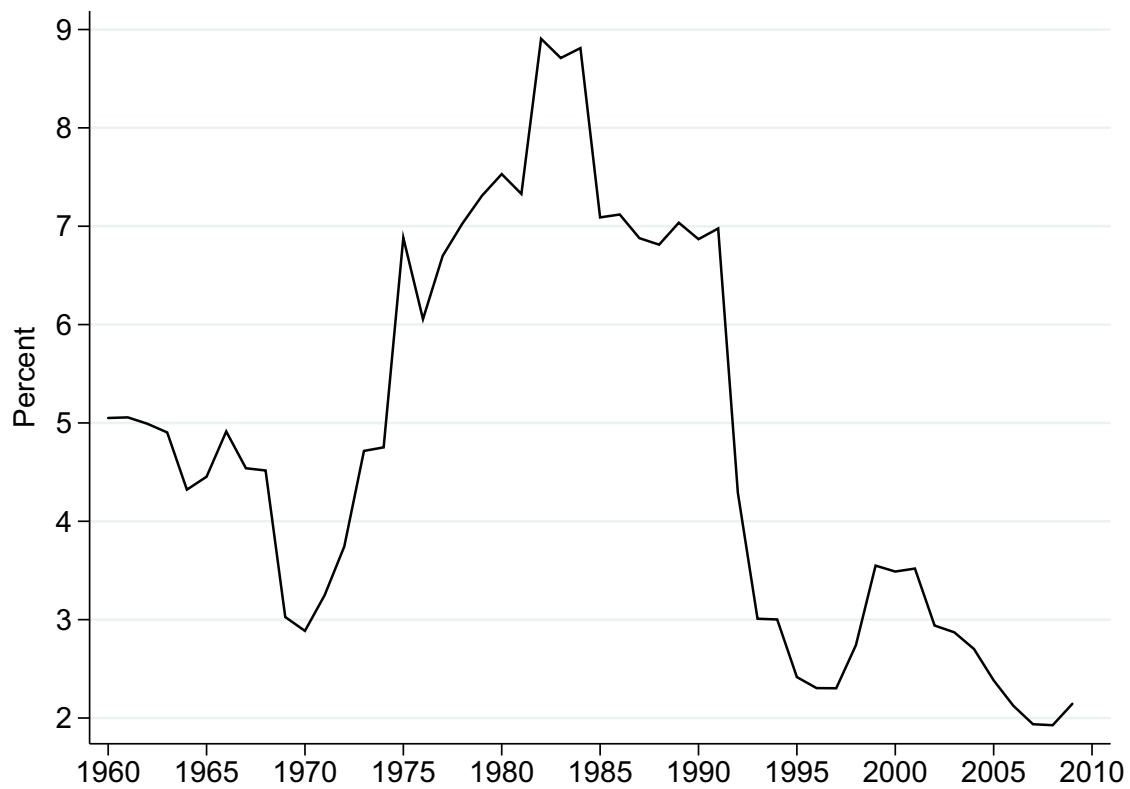


Sources: Díaz, Lüders, and Wagner (2010) and World Economic Outlook (WEO April 2011).

Note: For each year, the graphs show the resulting correlation with the data contained in a window bounded by the current year and the  $k - 1$ -previous years, bounds included. Cyclical components are calculated by first transforming the variables in log and then subtracting the trending component which is defined by an HP filter. Real government expenditure corresponds to the nominal total central government expenditure deflated by the GDP deflator. For trend estimate purposes, by using WEO projections, the data is projected until 2016.

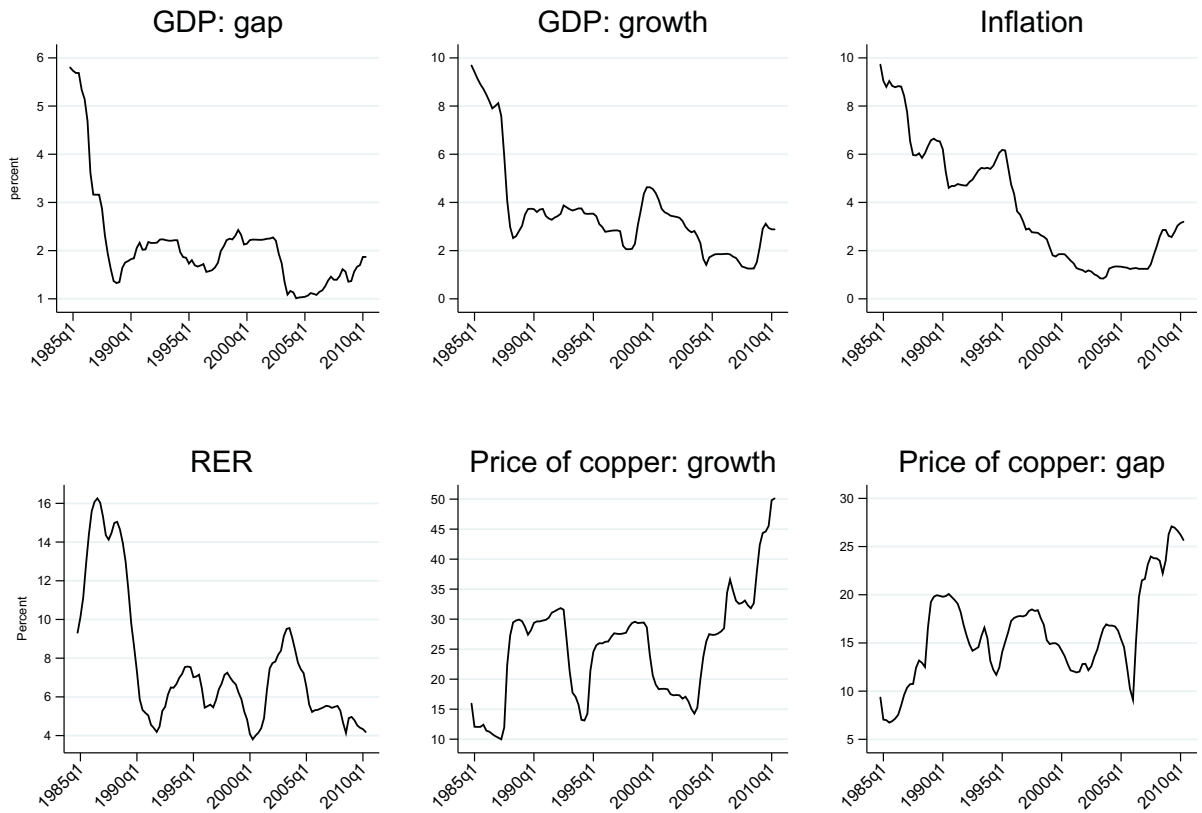


Figure 9: GDP growth volatility  
(10-year rolling window)



Sources: Díaz, Lüders, and Wagner (2010) and Central Bank of Chile.

Figure 10: Volatilities (percent)  
(5-year rolling window)



Sources: Central Bank of Chile and International Finance Statistics.

Note: Gap corresponds to a % deviation from an HP trend.

Note: Growth corresponds to 12-month % changes.

Note: Inflation corresponds to 12-month CPI % changes.

Figure 11: Impact of copper price volatility on GDP growth volatility

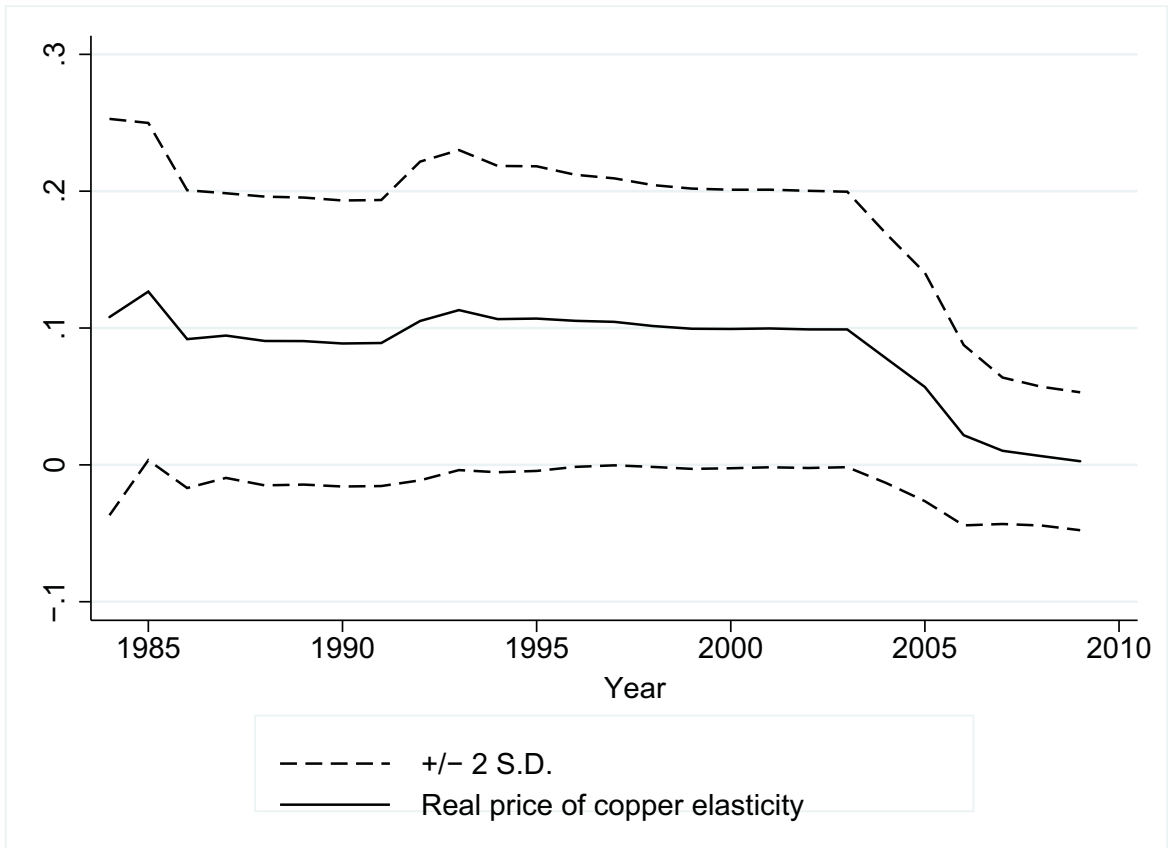


Figure 12: Actual and fitted output volatility

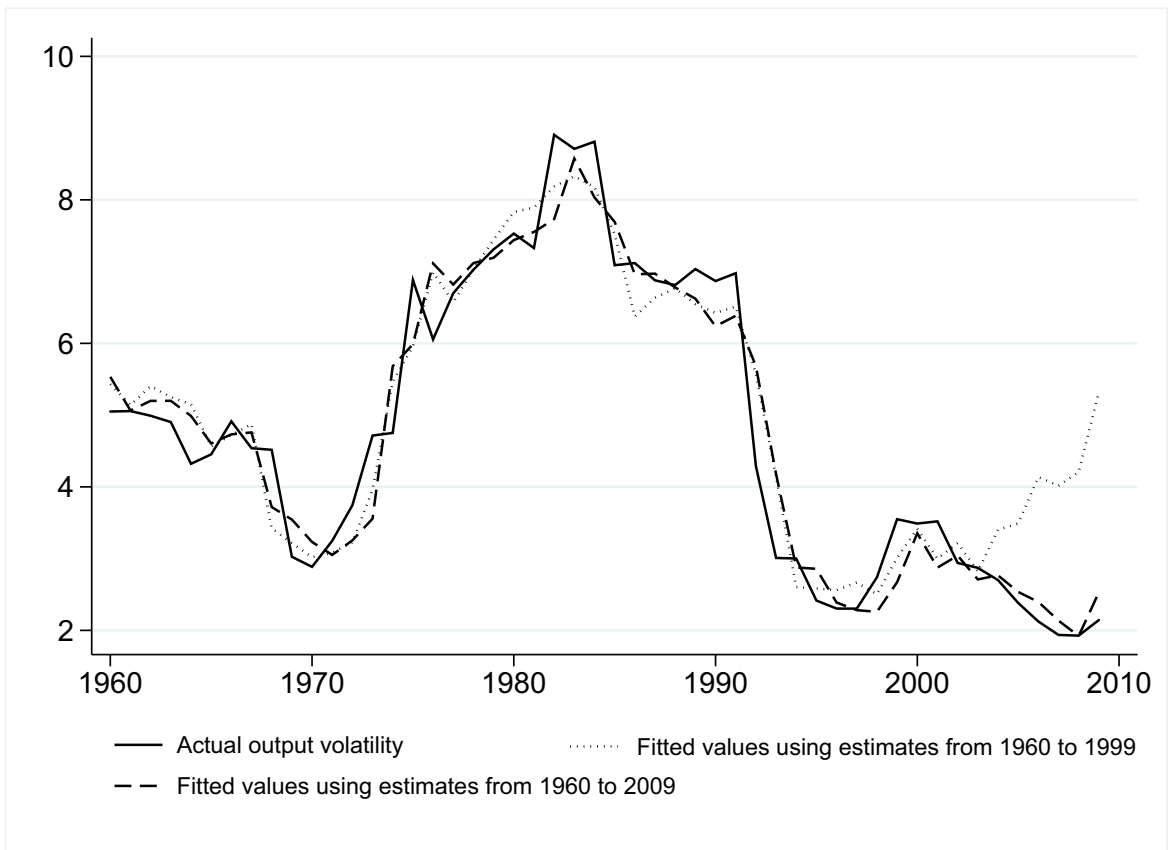
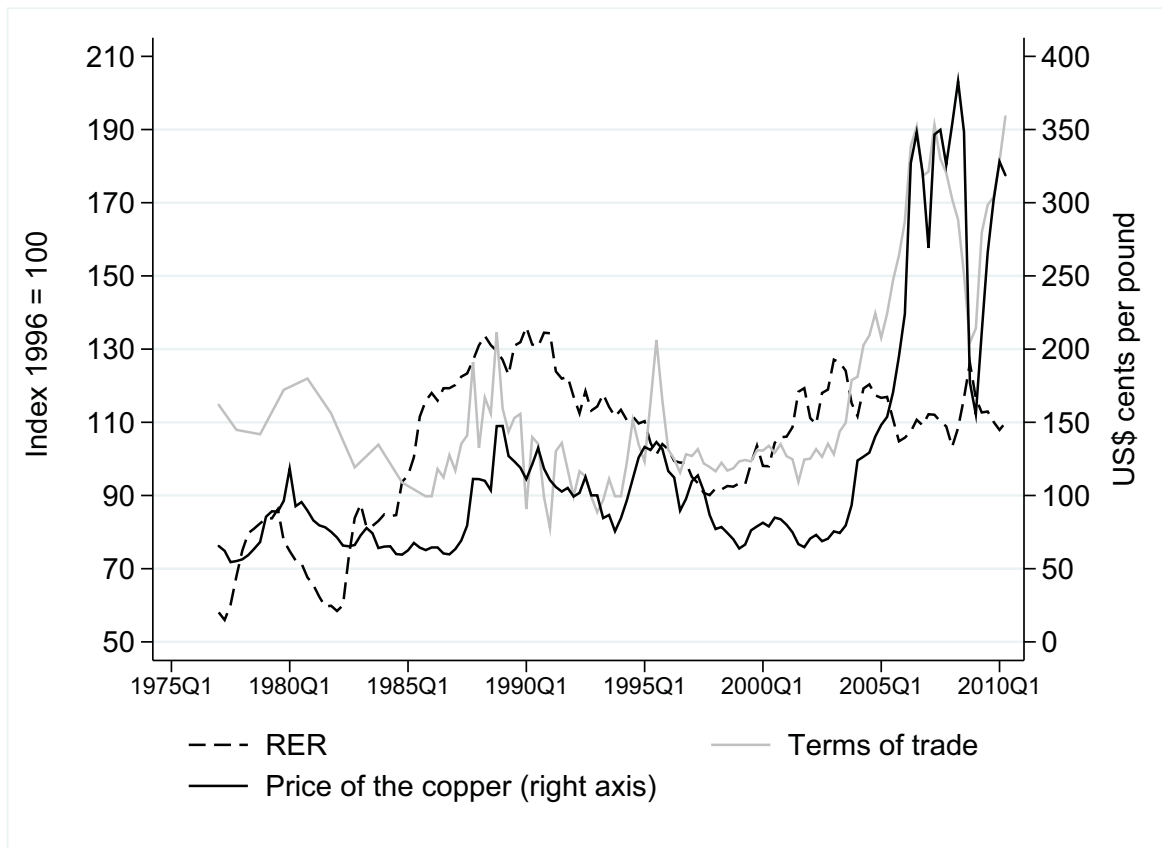


Figure 13: Real exchange rate, terms of trade, and price of copper



Source: Caputo, R., M. Núñez, and R. Valdés (2010).

Figure 14: Log RER response to 100 percent orthogonal terms-of-trade shock

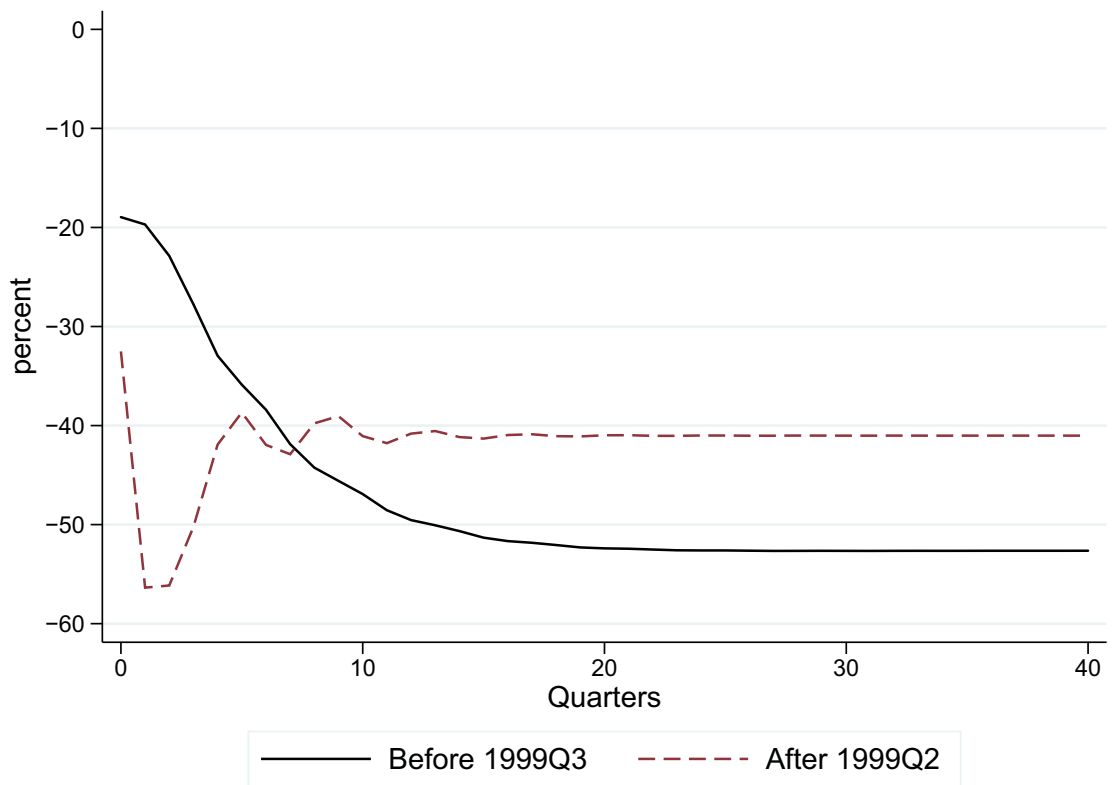
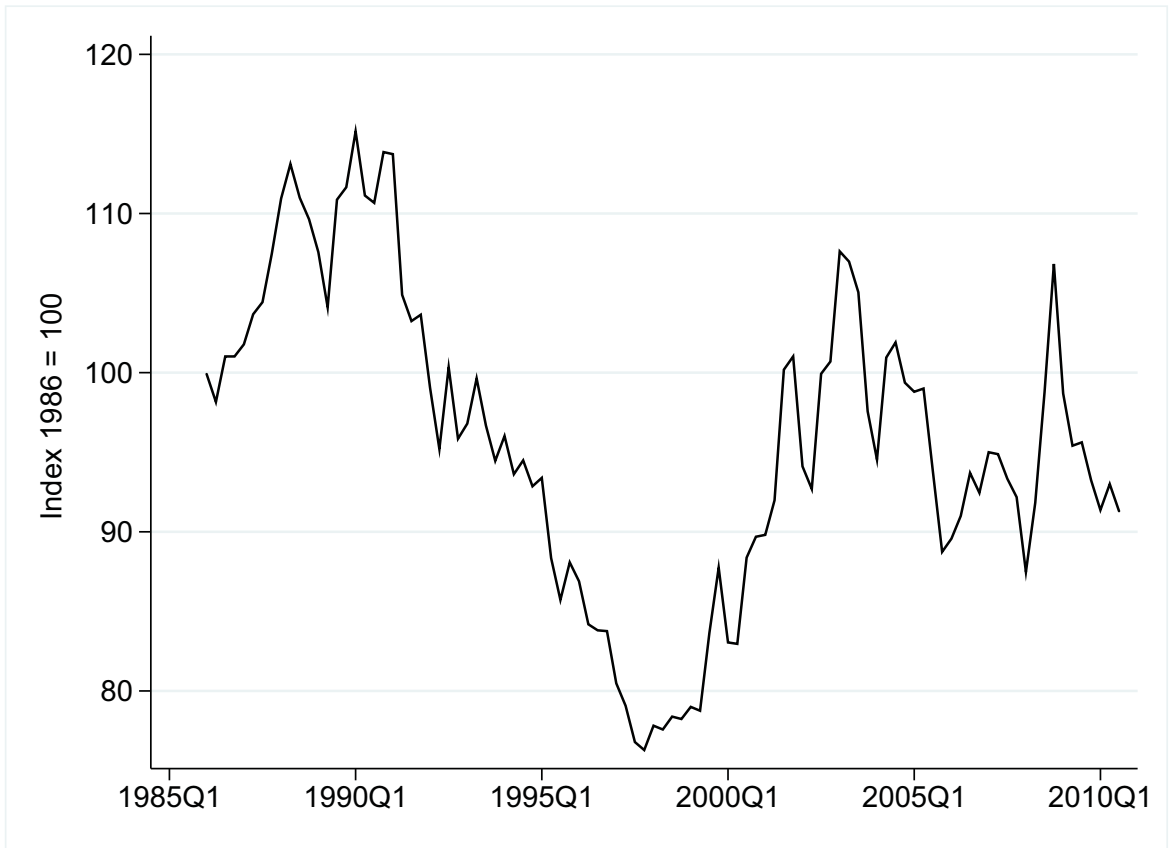
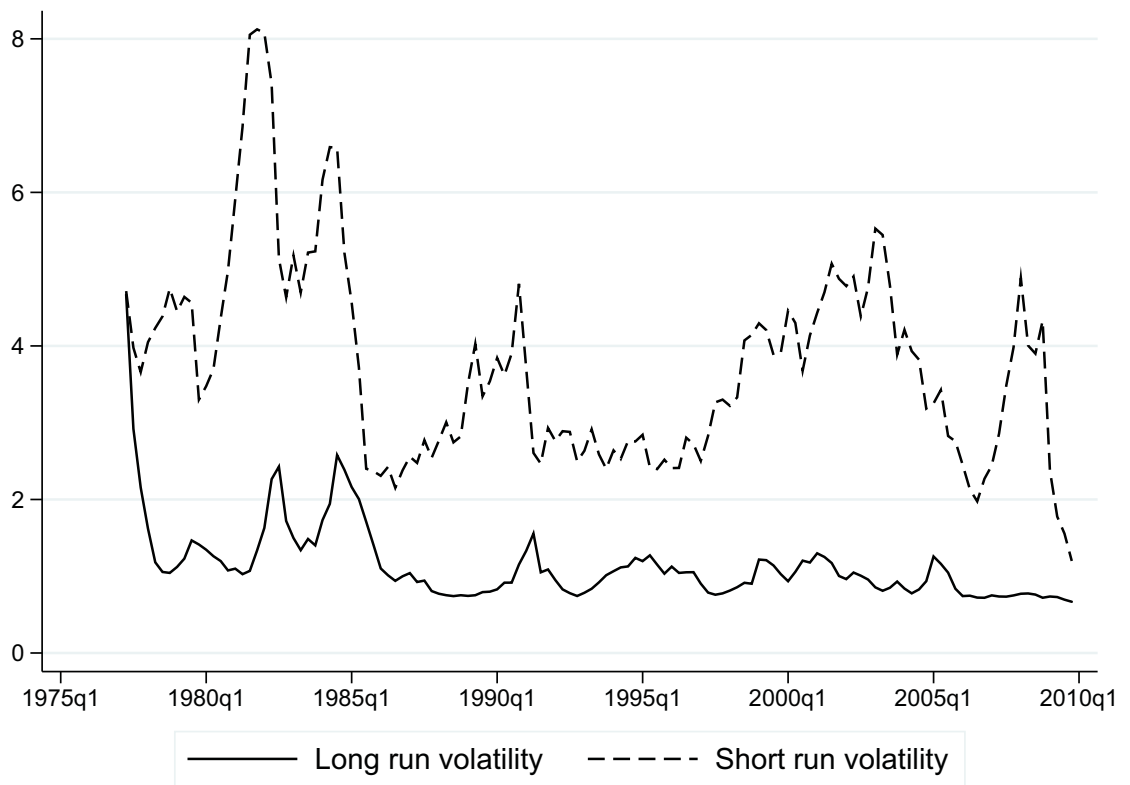


Figure 15: Real exchange rate



Source: Central Bank of Chile.

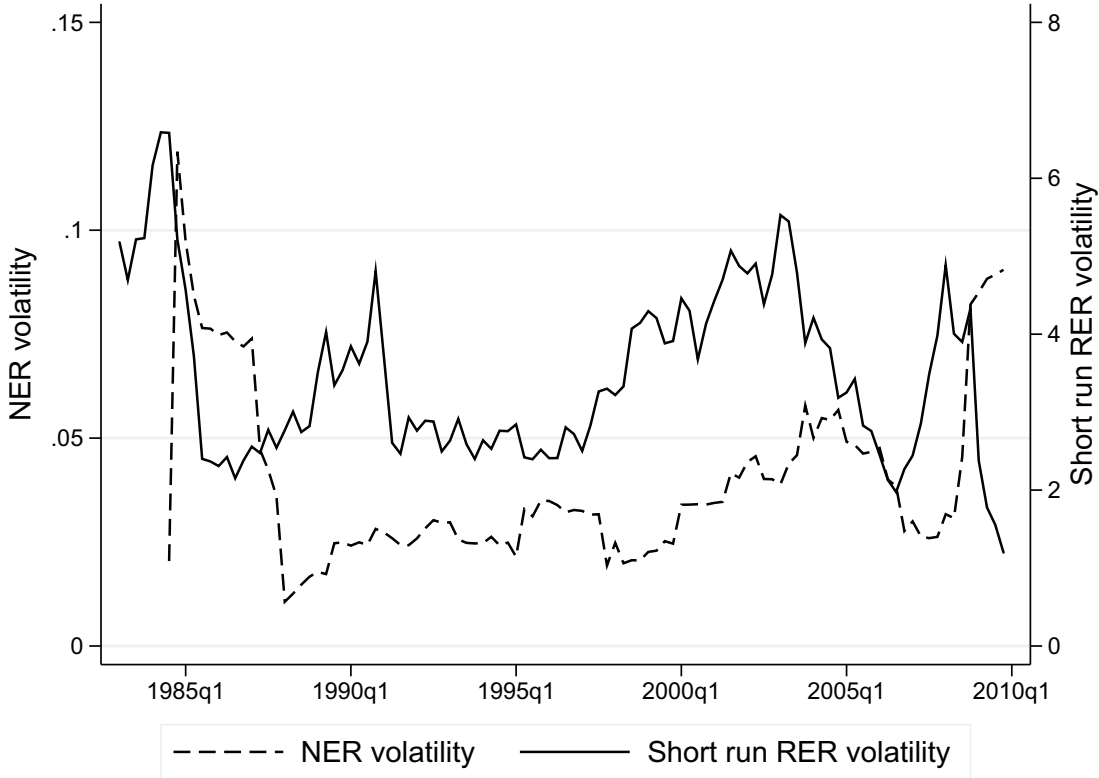
Figure 16: Chilean RER stochastic volatilities



Note: Results were obtained with a Stock and Watson (2007) UC-SV model; for details see Appendix B.

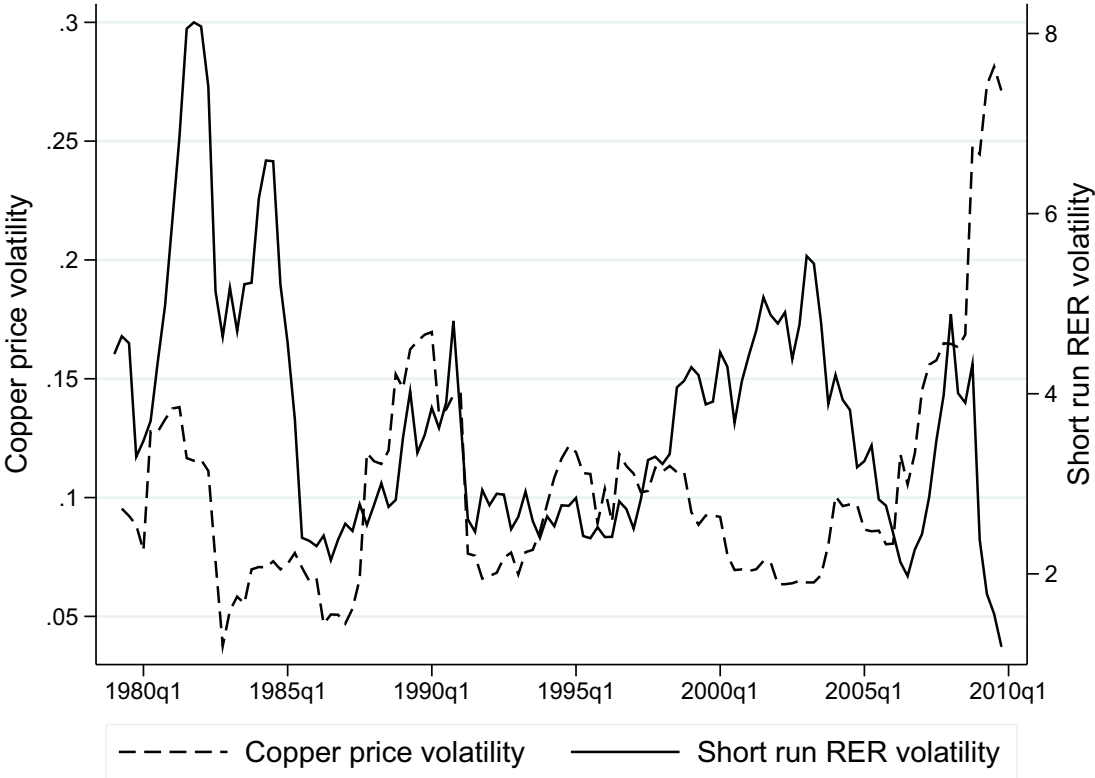


Figure 17: Short Run RER and Nominal Exchange Rate volatilities



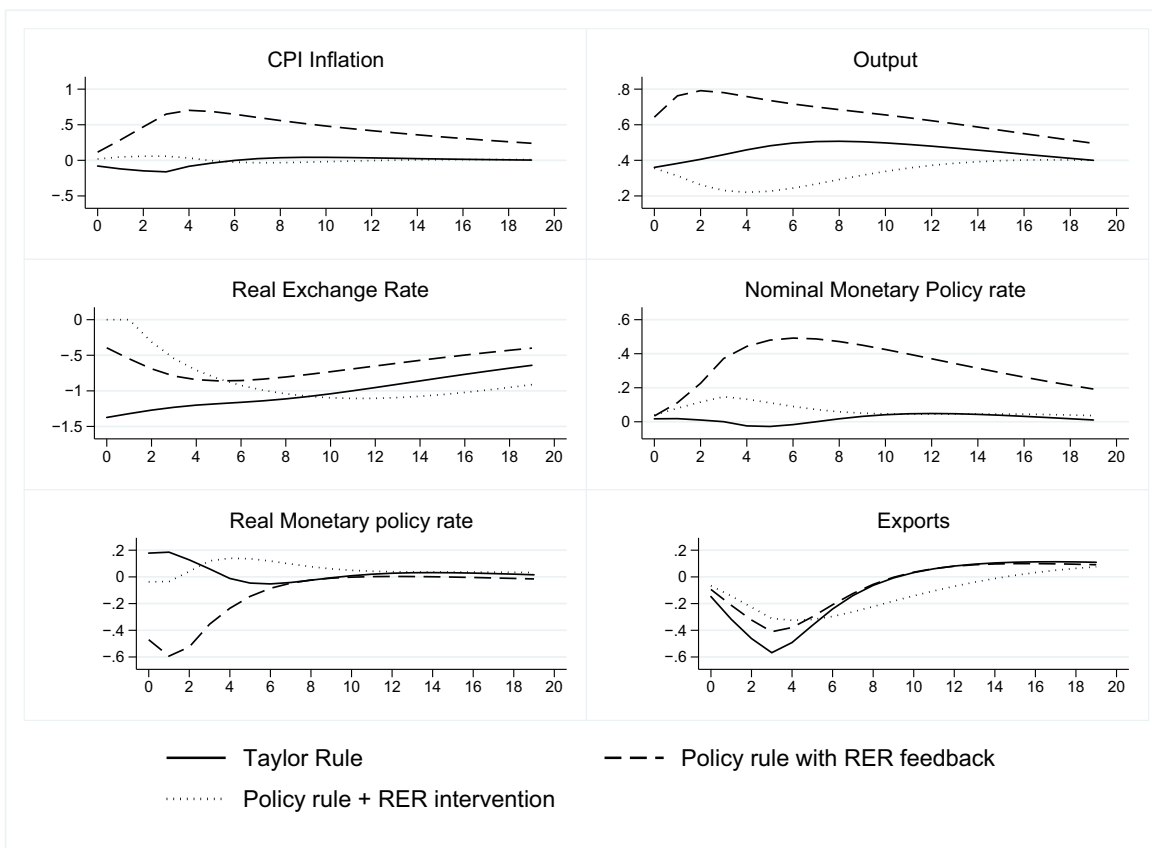
Note: NER volatility corresponds to the standard deviation of quarterly percent changes estimated on a 10-quarter rolling window.

Figure 18: Short Run RER and Nominal Exchange Rate volatilities



Note: Copper price volatility corresponds to the standard deviation of quarterly percent changes estimated on a 10 – quarter rolling window.

Figure 19: Impulse-response to a copper price shock



Note: Values on the right axis are in percent. All variables denote percent deviations from trend, for output and real exchange rate which values are cumulate deviations.

Table 1: Volatilities (percent)

Period	1950 - 2009	1950 - 1990	1990 - 2009
<b>Inflation</b>			
Average standard deviation	102.9	119.5	6.5
Average coefficient of variation	2.1	1.7	0.9
<b>GDP growth</b>			
Average standard deviation	5	5.6	3.2
Average coefficient of variation	1.2	1.6	0.6
<b>GDP gap</b>			
Average standard deviation	5.1	5.9	2.9
Average coefficient of variation	-85	-20.3	15.2

Sources: Díaz, Lüders, and Wagner (2010) and Central Bank of Chile.

Table 2: Cointegration rank test

Null hypothesis	Eigenvalue	Trace-Statistic	Critical Value	p-val
None *	0.33	97.97	69.82	0
At most 1	0.17	46.69	47.86	0.06
At most 2	0.09	21.72	29.8	0.31
At most 3	0.06	9.33	15.49	0.34
At most 4	0.01	1.42	3.84	0.23

Note: The VECM has no trend and an unrestricted constant, the underlying VAR has 3 lags. (\*) means rejection of the null hypothesis at 95% of confidence.

## A Appendix A

We follow the traditional *vector-error correction model* literature and estimate a  $VAR(p)$  in levels in order to select the optimal lag length of the underlying unrestricted VAR. Following standard criteria, we find that three lags adequately represent the dynamics contained in the data. Traditional cointegration tests, trace and eigenvalue statistics (see Table 2 in the text) and economic theory suggest one long-run relationship among the mentioned set of variables. Then, we use a Johansen (1988) technique and estimate the following vector error correction representation:

$$\Delta y_t = c + \alpha \beta y_{t-1} + \sum_{i=1}^{p-1} \delta_i \Delta y_{t-i} + u_t$$

Where  $y_t$  is a  $(5 \times 1)$  vector such as  $y = (\text{ToT TNT } (F/Y) (G/Y) \text{ RER})'$ , all the variables are in log except government expenditure and net foreign assets; the matrices  $\delta_i$  ( $5 \times 5$ ) contain short-run parameters and  $\beta$  is a  $(1 \times 5)$  vector of cointegration,  $\alpha$  is a  $(5 \times 1)$  vector with long-run disequilibrium coefficients, and  $c$  is a  $(5 \times 1)$  vector with intercepts. The innovations are represented by the vector  $u_t$  which has mean zero and a variance-covariance matrix  $\Omega = \Sigma \Sigma'$  which is assumed to have a structure described by a Cholesky decomposition, such as  $\Sigma$  is lower triangular and has the same ordering of exogeneity as the one shown by vector  $y_t$ . Hence, terms of trade innovations are the most exogenous elements in the system, and so on. We estimate the system represented in (3) using data from 1977Q1 to 2010Q3 (see Table 3 in the text).

## B Appendix B

We follow the framework developed by Stock and Watson (2007) for decomposing the RER into a permanent component  $\tau_t$  and a transitory one  $\eta_t$ . The permanent component  $\tau_t$ , and the variances of  $\varepsilon_t$  and  $\eta_t$  follow a random walk:

$$\begin{aligned} RER_t &= \tau_t + \eta_t, \text{ where } \eta_t = \sigma_{\eta,t} \xi_{\eta,t} \\ \tau_t &= \tau_{t-1} + \varepsilon_t, \text{ where } \varepsilon_t = \sigma_{\varepsilon,t} \xi_{\varepsilon,t} \end{aligned}$$

Where  $\xi_t = (\xi_{\eta,t}, \xi_{\varepsilon,t})$  iid  $N(0, I_2)$  are independently distributed. And stochastic volatilities are modeled as:

$$\begin{aligned} \ln \sigma_{\eta,t}^2 &= \ln \sigma_{\eta,t-1}^2 + v_{\eta,t} \\ \ln \sigma_{\varepsilon,t}^2 &= \ln \sigma_{\varepsilon,t-1}^2 + v_{\varepsilon,t} \end{aligned}$$

Where  $v_t = (v_{\eta,t}, v_{\eta,t})$  are independently distributed. The model is written in a state space form and is estimated using a Kalman filter and solved numerically through a Gibbs sampler. Results are shown in Figure 16.

Table 3: VECM estimates

	VECM estimates 19977Q1 – 1999Q2				VECM estimates 1999Q3 – 2010Q2				
	$\Delta(ToT)_t$	$\Delta(TNT)_t$	$\Delta(F/Y)_t$	$\Delta(G/Y)_t$	$\Delta(ToT)_t$	$\Delta(TNT)_t$	$\Delta(F/Y)_t$	$\Delta(G/Y)_t$	$\Delta(RER)_t$
$Z_{t-1}$	-0.06 (0.04)	-0.06*** (0.02)	0.30*** (0.06)	-0.03** (0.01)	0.95*** (0.26)	0.04 (0.10)	1.07*** (0.44)	-0.13*** (0.03)	-0.37* (0.22)
$\Delta(ToT)_{t-1}$	-0.22** (0.10)	0.05 (0.06)	-0.43*** (0.15)	-0.02 (0.04)	-0.44 (0.29)	-0.12 (0.11)	-1.18** (0.48)	0.09*** (0.03)	0.08 (0.23)
$\Delta(ToT)_{t-2}$	-0.22** (0.10)	0.05 (0.06)	0.60*** (0.16)	-0.02 (0.04)	-0.99*** (0.30)	0.04 (0.11)	-0.07 (0.50)	0.07** (0.03)	0.21 (0.24)
$\Delta(TNT)_{t-1}$	-0.05 (0.18)	-0.21** (0.10)	-0.43 (0.27)	-0.10 (0.07)	0.41 (0.43)	-0.32* (0.17)	0.02 (0.73)	-0.02 (0.04)	0.42 (0.35)
$\Delta(TNT)_{t-2}$	-0.03 (0.16)	0.15* (0.09)	-0.41* (0.24)	-0.08 (0.06)	-0.44 (0.43)	-0.20 (0.17)	0.10 (0.73)	-0.00 (0.04)	0.51 (0.35)
$\Delta(F/Y)_{t-1}$	-0.03 (0.08)	0.03 (0.04)	-0.30*** (0.12)	0.01 (0.03)	0.04 (0.12)	0.03 (0.05)	0.24 (0.21)	-0.03** (0.01)	-0.08 (0.10)
$\Delta(F/Y)_{t-2}$	0.35*** (0.07)	-0.04 (0.04)	-0.12 (0.10)	-0.00 (0.02)	0.31** (0.13)	-0.06 (0.05)	0.32 (0.22)	-0.01 (0.01)	-0.08 (0.11)
$\Delta(G/Y)_{t-1}$	0.07 (0.29)	0.78*** (0.17)	-0.01 (0.43)	-0.60*** (0.11)	-0.87 (1.24)	-0.99** (0.48)	-1.16 (2.08)	-0.04 (0.13)	-0.42 (1.01)
$\Delta(G/Y)_{t-2}$	0.52 (0.32)	0.10 (0.19)	0.30 (0.48)	-0.16 (0.12)	0.57 (1.22)	-0.53 (0.47)	2.83 (2.04)	0.17 (0.13)	-0.68 (0.99)
$\Delta(RER)_{t-1}$	-0.18 (0.18)	-0.02 (0.10)	0.27 (0.27)	0.03 (0.07)	-0.24 (0.22)	0.02 (0.08)	-0.13 (0.37)	0.04* (0.02)	-0.05 (0.18)
$\Delta(RER)_{t-2}$	0.38** (0.17)	-0.20** (0.10)	0.38 (0.26)	-0.20*** (0.06)	-0.12 (0.21)	-0.14* (0.08)	0.36 (0.35)	0.05*** (0.02)	-0.41** (0.17)
Constant	-0.00 (0.01)	0.00 (0.00)	-0.00 (0.01)	-0.00 (0.00)	0.00 (0.01)	0.01 (0.00)	0.00 (0.02)	0.00** (0.00)	0.01 (0.01)
Co-int vector	0.57	1.07	0.25	-0.50	3.83	-0.81	-1.57	21.17	1
SE of CV	0.22	0.22	0.04	0.51	0.54	1.22	0.22	3.01	—
Num. obs.	87	87	87	87	45	45	45	45	45
R <sup>2</sup>	0.36	0.44	0.48	0.56	0.46	0.40	0.42	0.65	0.35

Note:  $Z_{t-1}$  denotes the lagged cointegration residual. CV denotes the cointegration vector, and SE denotes standard errors. (\*), (\*\*), and (\*\*\*) indicate significance at 5%, 10%, and 1%, respectively.

Table 4: Unit root tests

Lags	Variable	Augmented Dickey-Fuller		Phillips-Perron	
		$z_t$	$p - val$	$z_t$	$p - val$
1	$F/Y$	-1.21	0.67	-1.09	0.72
2	$F/Y$	-1.34	0.61	-1.15	0.69
3	$F/Y$	-1.22	0.66	-1.17	0.69
1	$G/Y$	-2.41	0.14	-3.12	0.02
2	$G/Y$	-2.02	0.28	-3.07	0.03
3	$G/Y$	-1.87	0.34	-3	0.03
1	RER	-3.09	0.03	-2.66	0.08
2	RER	-2.59	0.09	-2.66	0.08
3	RER	-2.21	0.2	-2.66	0.08
1	ToT	-0.73	0.84	-0.92	0.78
2	ToT	-0.32	0.92	-0.74	0.84
3	ToT	0.06	0.96	-0.55	0.88
1	TNT	-1.51	0.53	-1.47	0.55
2	TNT	-1.56	0.5	-1.5	0.53
3	TNT	-1.77	0.4	-1.51	0.53

Note: Tests assume that under the null hypothesis the variables have a unit root,  $z_t$  represents the test statistic.



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