Banco Central de Chile
Documentos de Trabajo

Central Bank of Chile
Working Papers

N° 141

Febrero 2002

OPEN QUESTIONS ABOUT THE LINK BETWEEN NATURAL RESOURCES AND ECONOMIC GROWTH: SACHS AND WARNER REVISITED

Daniel Lederman William Maloney

BANCO CENTRAL DE CHILE

CENTRAL BANK OF CHILE

Documentos de Trabajo del Banco Central de Chile
Working Papers of the Central Bank of Chile
Huérfanos 1175, primer piso.
Teléfono: (56-2) 6702475   Fax: (56-2) 6702231

Documento de Trabajo
N° 141

Working Paper
N° 141

OPEN QUESTIONS ABOUT THE LINK BETWEEN NATURAL RESOURCES AND ECONOMIC GROWTH: SACHS AND WARNER REVISITED

Daniel Lederman
The World Bank

William Maloney
The World Bank

Resumen

A diferencia de los argumentos pesimistas sobre el crecimiento potencial con recursos naturales presentados con anterioridad, Sachs y Warner (1995a, 1997a, 1997b, 1999) fundan su estudio en un análisis econométrico. Tomando como dada la especificación del modelo usado estos autores, abordamos tres preguntas:

1. ¿Es sensible al período muestral utilizado el efecto negativo de los recursos naturales (como porcentaje del PGB)?
2.¿Es sensible el resultado a la omisión de variables desconocidas?
3. ¿Es sensible el resultado a los problemas que típicamente sufren las regresiones de corte transversal?

Nuestros principales resultados señalan que el resultado de SW sobre un efecto negativo de las exportaciones de recursos naturales sobre el crecimiento no es robusto a la prueba del tiempo, que se debe posiblemente a efectos específicos de país no considerados, y que al abordar problemas de endogeneidad éste no se recupera. Sí encontramos, sin embargo, un efecto negativo y robusto de la concentración del ingreso por exportaciones sobre el crecimiento. Cerca de 50% de este efecto se debe a la correlación negativa de la concentración de exportaciones con el comercio intraindustrial, y a su correlación positiva con la volatilidad del tipo de cambio real.

Abstract

What makes the work of Sachs and Warner (1995a, 1997a, 1997b, 1999) distinct from previous pessimistic arguments about the growth potential of natural resources is their reliance on econometric analysis. Our aim is to take the authors' model specification as given, but we ask the following three questions:

1. Is the negative effect of natural resource exports (as a share of GDP) sensitive to the time period used in the analysis?
2. Is this result sensitive to unknown omitted variables?
3. Is this result sensitive to endogeneity problems that afflict the traditional cross-sectional growth regressions?

The main findings are that the SW result concerning the alleged negative effect of natural resource exports on growth does not pass the test of time, the NRX effect is probably due to unaccounted country-specific effects, and dealing with endogeneity issues does not recover the SW result. However, we find that export revenue concentration does have quite a robust negative effect on economic growth. And about 50% of this effect is due to the negative correlation between export concentration and intra-industry trade and a positive correlation between export concentration and volatility of the real effective exchange rate.

We thank Norman Loayza, Guillermo Perry, Luis Servén, and L. Colin Xu for helpful discussions and advice. Gabriel Montes provided impeccable research assistance. The opinions expressed in this paper belong to the authors and should not be interpreted as the views of The World Bank or the countries it represents.
E-mails: dlederman@worldbank.org ; wmaloney@worldbank.org.

Introduction

Concerns about natural resources are not new and were not invented by Jeffrey Sachs and Andrew Warner of Harvard University. Over two hundred years ago, Adam Smith wrote:

> "Projects of mining, instead of replacing capital employed in them, together with ordinary profits of stock, commonly absorb both capital and stock. They are the projects, therefore, to which of all others a prudent law-giver, who desired to increase the capital of his nation, would least chuse to give any extraordinary encouragement …"[1]

Nor are these concerns new for Latin American countries. Half a century ago, and best known among Latin American audiences, Prebisch (1959) expressed concerns regarding the supposedly poor potential for productivity growth of natural resource industries, as well as the well known concern about the allegedly deteriorating relative prices of commodities. More recently, Auty (1998) wrote that "since the 1960s the resource-rich developing countries have underperformed compared with the resource-deficient economies" (1998, viii).

What makes the work of Sachs and Warner (1995a, 1997a, 1997b, 1999) distinct, however, is their reliance on econometric analysis, which might provide an air of respectability to these old concerns about dependence on natural resources. Hence we should take their findings seriously. Nevertheless, the main contention of this paper is that the econometric analysis performed by Sachs and Warner raises more questions than it provides answers to an important issue for Latin American and other developing countries.

In evaluating econometric results, researchers can always find ways of debunking existing analyses. Yet from time to time influential empirical work props up without respect for the advances made by others. And the work by Sachs and Warner needs to be assessed fairly by replicating their analysis as close as possible but also by placing it in the context of the state of knowledge at the time when the authors were doing their research. This paper places the analysis provided by Sachs and Warner (1997a) in the context of what was known about the empirics of economic growth at that time. The focus on this particular paper is due to the fact that this contribution was an extensive revision of Sachs and Warner (1995), and it presents extensive robustness analysis of the results.[2] Indeed, Sachs and Warner (1997a) shows that their key finding does not disappear after including additional explanatory variables and using data supported by research previously published by Barro (1991); Mankiew, Romer and Weil (1992); and DeLong and Summers (1991). Our aim is to take the authors' model specification as given, but we ask the following three questions:

- Is the negative effect of natural resource exports (as a share of GDP) sensitive to the time period used in the analysis?
- Is this result sensitive to unknown omitted variables?
- Is this results sensitive to endogeneity problems that afflict the traditional cross-sectional growth regressions?

---

[1] Adam Smith (1776, 562); cited in Wright (2001).
[2] The other papers by Sachs and Warner (1995, 1997b, 1999) contain the basic results of 1997a, at times using a slightly longer time span (1965-1990 instead of 1970-1989), and often including additional time-invariant

To be fair, Sachs and Warner (1995) themselves recognize that the first question is worth investigating further, given the strong historical evidence concerning the developmental success of countries such as the United States, Canada, Australia, Finland and Sweden, which are still today relying on their abundant natural resources. However, Sachs and Warner have not yet reconciled their econometric evidence with the historical evidence. We believe that perhaps the strongest evidence against the "resource curse" hypothesis restated by Sachs and Warner in fact comes from lessons from history. Some recent reviews of the historical literature in that regard are Wright (2001), Maloney (2002), and De Ferranti et al. (2002).

Yet we also need to evaluate the econometric evidence provided by Sachs and Warner along other dimensions. Questions 2 and 3 above are related to issues concerning econometric methodology. The fact that Sachs and Warner, writing in 1995 and later in 1997, insisted on testing their hypothesis by relying exclusively on cross sections of countries as pioneered by Barro (1991) is intriguing. Indeed, at least since Levine and Renelt (1992) we have known that cross-country growth regressions are quite sensitive to the inclusion of various regressors. Moreover, by the mid 1990s, Knight, Loayza and Villanueva. (1993), Caselli, Esquivel and Lefort (1996), among others, had already analyzed important shortcomings of pure cross-sectional regressions of the determinants of economic growth and had provided alternative estimation strategies. This paper conducts additional, but definitively not new, econometric analyses of the basic Sachs and Warner (1997a) model using panel data techniques that attempt to correct two deficiencies – the problem of unknown omitted variables and the problems created by the likely endogeneity of some of the explanatory variables. It remains a subject for future

explanatory variables such as dummies identifying tropical and landlocked countries, plus some additional social variables.

research to conduct further analyses with even more recent techniques such as those used by Levine, Loayza and Beck (2000).[3]

In sum, this paper provides an investigation of technical, empirical questions raised by the Sachs and Warner results. The following section briefly presents the Sachs-Warner (SW henceforth) basic model specification and discusses results with a sample of countries in earlier periods of time, ranging from 1820 to 1989, based on growth rates data from Maddison (1994). Section II presents results of the SW regressions estimated in differences, which control for unknown time-invariant explanatory variables. Section III addresses the issues raised by tow types of endogeneity problems presented by the SW specification – namely, the endogeneity-by-construction of the initial level of income per capita and the "reverse-causation" problem affecting several explanatory variables such as the investment rate. The final section IV summarizes the main findings of these analyses and suggests directions for future research.

I. The Sachs and Warner empirical model: Does it survive the test of time?

As mentioned in the introduction, SW (1995) recognized the need to further investigate whether their results concerning the supposedly negative effect of natural resource exports (NRX from now on) passes the test of time. In other words, do their results hold for different periods of time?

[3] More recently, distinguished economists have raised serious concerns about the general practice of testing a plethora of hypothesis about economic growth by relying exclusively on cross-country growth regressions. See for example, Solow (2001). Edward Leamer (2001) delivered a scathing lecture on this subject at the IMF Institute.

As a necessary precursor to the historical test, SW (1995, 1997a) estimate the following stylized model:

$$\text{(1)} \qquad \dot{y} = \ln y_t - \ln y_{t-z} = \gamma \ln y_{t-z} + \beta' X_{i,t} + \alpha NRX_{i,t-z} + \varepsilon_{i,t},$$

where the left-hand side or dependent variable is the growth rate of GDP per capita (actually, the GDP per economically active population). This growth rate is basically the differences of the natural logarithms of income per capita between the final year 't' and the initial year 't-z'. In turn, SW followed the standard Barro (1991) specification, which includes the initial (log of the) level of income per capita as an explanatory variable. In their basic multivariate specification (i.e., prior to conducting their robustness analysis by adding the explanatory variables suggested by the authors mentioned in the introduction), SW also include three additional explanatory variables, represented by the vector of X variables in (1). These are: the index of trade policy openness, which is the number of average number of years that a country was identified as having an open trade regime by Sachs and Warner (1995b); the average annual rate of change of the terms of trade; and the ratio of gross domestic investment over GDP, or the investment rate. Appendix I at the end of this paper contains a detailed description of the variables and their sources. For the purpose of this paper, the key parameter in equation (1) is α, which provides the magnitude of the impact of natural resource exports over GDP on subsequent economic growth.

Equation (1) is a stylized version of the basic SW model. In their exercises presented in SW (1995 and 1997a), the authors start with a simple regression that only includes the log of the initial level of income and the NRX variable. Due to data limitations for estimating a full version of the SW model, the test of time was conducted only with the simplest SW model. The data for the NRX variable is the same one used by SW, which corresponds to the NRX of 1970. This was done because, as far as we know, there are no reliable data on the composition of exports across countries since the nineteenth century. This approach presumes that the ranking of the countries by their NRX values in 1970 roughly corresponds to the ranking in earlier periods of time. This presumption could definitely be wrong. We suspect that, if the true data were available for the earlier historical periods, the results would be biased against the SW results because the dependence on natural resources by fast-growing economies in the nineteenth and early twentieth centuries, such as the U.S., Canada, etc., was higher in the earlier periods. Indeed, the process of development is likely to lead to a reduced dependence on natural resources as economies accumulate physical and human capital – see Martin (2002). We use the growth rates for previous periods of time from Maddison (1994). This author covers the growth performance of several developed and developing countries during five periods: 1820-1869; 1870-1913; 1913-1949; 1950-1972; and 1973-1989. These growth rates were also used to estimate the initial levels of income for each historical period analyzed in Table 1.

Table 1 shows that the negative effect of NRX holds only for periods containing the years between 1950 and 1989. In fact, this variable has a positive effect (although not statistically significant) during 1820-1870 and 1913-1950. Moreover, this change of sign for the earlier periods is probably not the result of a different sample of countries. This conclusion can be derived from the last two columns of Table 1, which show that the negative and significant effect of the NRX after 1950 remains when we use the same sample of countries for which we had growth data for 1913-1950.

The evidence discussed thus far indicates that the SW results concerning NRX probably would not survive the test of time. Due to the data limitations (and other econometric problems discussed in the following sections) we believe that the best evidence showing that the SW results do not survive the test of time are in-depth historical studies of the economic performance of several successful economies that developed by exploiting their natural riches. In any case, the simple analysis presented here should at least convince some readers that the SW result should be approached with some caution.

II. Are the SW Results sensitive to time-invariant omitted variables?

Manzano and Rigobón (2001) have already pointed out that the SW result concerning the negative sign of α in equation (1) might be due to the correlation between the ratio of natural resource exports (as a share of GDP) and other time-invariant country characteristics. Manzano and Rigobón further argue that the SW result disappears after they control for the ratio of foreign debt to GDP in 1980 for a cross-section of country growth rates during 1980-1990. However, the point is more general than that: in the presence of unobserved country-specific effects, any explanatory variable that might be correlated with such effects might yield inconsistent estimates.

More formally, equation (1) needed to be amended, in order to include time-invariant country effects as follows:

(2) $$\dot{y}_t = \ln y_{i,t} - \ln y_{i,t-z} = \gamma \ln y_{i,t-z} + \beta' X_{i,t} + \alpha NRX_{i,t-z} + \eta_i + \varepsilon_{i,t}$$

The η_i is the country-specific effect. The coefficients estimated with a model such as (2) are inconsistent when the explanatory variables are correlated with the country-specific effect. Regarding growth regressions, Casselli, Esquivel and Lefort (1996) pointed out that the difference with respect to the highest level of income in the sample of countries (i.e., the level to which the other countries are converging) acts as a proxy of the country-specific effect in cross sectional regressions, and thus the resulting estimates are inconsistent. In particular, the γ tends to be biased upwards. This bias could then contaminate any of the other coefficients of explanatory variables that are correlated with the initial level of income. Knight, Loayza and Villanueva (1993) had also dealt with the problem of the omitted country-specific effects in traditional cross-country growth regressions.

This type of econometric problem was widely recognized in the early 1990s, when researchers in various areas of inquiry had stopped working with pure cross sections and moved on to the use of so-called "fixed-effects" estimators. One way of getting rid of the unobserved country-effects is to first difference equation (2), so that it becomes:

(3) $$\dot{y}_t - \dot{y}_{t-1} = \gamma(\ln y_{i,t-1} - \ln y_{t-2}) + \beta'(X_{i,t} - X_{i,t-1}) + \alpha(NRX_{i,t-1} - NRX_{i,t-2}) + (\varepsilon_{i,t} - \varepsilon_{i,t-1}),$$

where the subscripts 't' represent a period of time and 't-1' represents the previous periods, etc. (Please note that we have omitted the 'z' subscript, which in equations (1) and (2) represented the number of years between the final year and the initial year.) In this specification, the fixed effects have disappeared and the estimates of the relevant coefficients are consistent (unbiased) if there are no other problems (see below).

In any case, Table 2 shows the estimates of the relevant SW coefficients derived from the OLS differences estimator as in equation (3). The data range from 1975 to 1999, and the estimates are based on observations of five-year periods. The results in column one show that only three variables remain statistically significant at the 10% level with this methodology: the SW index of trade policy openness, the investment rate, and initial level of income per capita. The SW ratio of natural resource exports over GDP is not significant at standard levels of confidence. When we added two possibly important, omitted variables (the level of educational attainment of the adult population and the ratio of government consumption over GDP), the coefficients presented in column 2 show that the NRX variable is still not significant and has a positive sign. In contrast, the years of schooling, as well as investment, the initial level of income and the openness index are significant and have the expected signs.

Columns 3-5 in Table 2 contain results of the differences estimator with a new variable that is related to the structure of exports, but it does not necessarily have to do with natural resources – the bi-variate correlation of 0.44 between the two variables is positive but not overwhelmingly high. That is, the concentration of exports revenues. Based on export data disaggregated at the 4-digit level of the SITC, we constructed the Herfindahl index of export revenue concentration, which varies between zero and one, inclusively.[4] Under column 3, the specification includes both the SW NRX and our measure of export concentration. The former recovers some of its strength, although it is still not significant at the 10% level of significance. The export concentration index has the expected negative sign and it is highly significant. When the SW variable is excluded (column 4), the results remain virtually unchanged: increases in export concentration reduce the rate of economic growth; increases in policy openness increase growth; increases in the initial level of income reduce growth (the convergence or catch-up effect); and increases in investment raise the rate of growth. When the two additional variables (education and government consumption) are added to the model (column 5), export concentration loses its significance but remains negative. However, the schooling variable is not significant either, while government consumption has a positive and significant effect. It is worth highlighting that these results also appear in other papers, such as Caselli et al. (1996).

Some of the coefficients in Table 2 are rather puzzling. In particular, the changes in the annual variation of the terms of trade appear with a negative and often significant sign. Before we spend much time trying to interpret this particular result, which is not the key focus of this paper, we should acknowledge that the results presented in Table 2 are not free of problems. In particular, the differences OLS estimator does not control for the likely endogeneity of some of the explanatory variables. This issue is addressed in the following section.

---

[4] The index is defines as: $H = \sum_i^n \left(\frac{x_i}{\sum_i^n x_i} \right)^2$, where subscript ‘i’ stands for a particular product and ‘n’ is the total number of products. When a single export product produces all the revenues, H=1; when export revenues are evenly

III. Are the SW Results sensitive to well-known endogeneity problems?

The previous section showed that the Sachs and Warner results regarding the allegedly negative effect of natural resource exports on economic growth might be spurious, because it might simply reflect the fact that this variable is correlated with unknown country-specific characteristics that do not vary over time. However, this results itself, as well as the original SW, might be due to inconsistent estimators caused by endogeneity. For example, at least since the publication of the paper by Knight, Loayza and Villanueva (1993) we have known that the traditional cross-section growth regression suffers from a problem of endogeneity due to the presence of the initial level of income as an explanatory variable. This problem can be seen clearly in equation (1) above, but it remains in the differences estimator of equation (3). In equation (1) the problem is that the initial level of income per capita appears in the dependent variable, and hence, by construction, the initial level of income is endogenous.

Since the publication of Caselli, Esquivel and Lefort (1996) we have known that there might be other sources of biases in traditional cross-country regressions due to the possibility that some of the explanatory variables, such as investment, that are usually included in these models tend to be caused by the growth rate itself. To deal with the problem of the omitted country-specific effects, as well as the problems of endogeneity by construction and of reverse causality, Caselli et al. (1996) suggested the application of the General Method of Moments with instrumental variables as developed by Arellano and Bond (1991). These findings and methods were available to SW in the mid 1990s.

---

distributed over a large number of products, H approaches 0.

The Arellano-Bond differences estimator relies on two moment conditions or assumptions about the correlation between the changes in the error terms and the key explanatory variables. The two moment conditions are:

(4) $E[y_{i,t-z} \cdot (\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0$ for z ≥ 2; t=3, … , T

(5) $E[X_{i,t-z} \cdot (\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0$ for z ≥ 2; t=3, … , T

These conditions simply state that the expected correlation between the differenced error term in equation (3) and the initial level of income lagged at least two periods is zero. Likewise, the expected correlation between the differenced error term and other lagged (potentially endogenous) explanatory variables in levels is zero. That is, the GMM-IV method proposed by Arellano-Bond uses lagged levels of potentially endogenous variables as instruments for the differences of these variables. Hence this approach extends the differences estimator to a instrumental-variable framework where lagged values of the endogenous variables are used as instruments. However, the GMM estimation also allows for the inclusion of instrumental variables that are not part of the model (i.e, "external" instruments). These moment conditions are a departure from the strict exogeneity assumptions that are implicit in the SW and other pure cross-sectional analyses of the determinants of economic growth across countries.

When using the GMM-IV technique it is important to check the validity of the instruments. We rely on Hansen's (1982) J-statistic, which tests the null hypothesis of zero correlation between the error terms and the instruments. Since we have more instruments than parameters being estimated, because we use the levels of endogenous variables lagged two and three period plus regional dummies, this test is performed by examining the correlation between each instrument and the error term one at a time.

Table 3 shows our GMM-IV regression results. Hansen's J-statistic appears at the bottom of the table. All the specifications presented herein pass the test, since the p-values indicate that we cannot reject the null of zero correlation between the instruments and the errors.

Column one shows the results for a model where the initial level of income and the investment rate are assumed to be endogenous. In this specification, the NRX variable is not significant. The only statistically significant variables is the initial level of income. In fact, this variable is highly significant in all the specifications presented in Table 3. The magnitude of this catch-up effect tends to be twice as high as the ones reported in Table 2, which were derived from the OLS differences estimator. These results are consistent with the increase in the magnitude of this variable after controlling for fixed effects and endogeneity, as reported by Caselli et al. (1996).

Column two lists the results for the same model, but with our index of export concentration. This latter variable is quite significant and has the expected negative coefficient. The magnitude of those coefficients are driven by the units of the export concentration index. The coefficient in column two implies that a one standard deviation, or a 0.22 increase in export concentration (say, from an index of 0.50 to 0.72 – see Appendix 2 for the summary statistics) would "cause" a 2% decrease in the growth rate of income per capita across five-year periods.

Column three shows the results for the same model but with the assumption that the index of export concentration is also endogenous. Column four further assumes that trade policy is endogenous, as suggested by the rather large literature on the political economy of trade policy – see, for example, Lederman (2001). Under both specifications, the export concentration index maintains its negative and significant sign, although the magnitude of the estimated negative effect is now much larger. The new coefficients imply that a one standard deviation increase in the concentration index is associated with a decline of about 5% in the growth rate of GDP per capita.

As a preliminary exploration of the channels through which export concentration might affect economic growth, the last column of Table 3 contains the GMM-IV regression results that include the Grubel-Lloyd (1975) index of intra-industry trade (IIT)[5] and the standard deviation of the annual rate of change of the real effective exchange rate (REER) as a proxy of macroeconomic volatility. These two additional variables are also assumed to be endogenous. The inclusion of IIT in the model is justified by a large literature that links IIT to trade driven by monopolistic competition and economies of scale (i.e., productivity gains) as in Krugman (1979). Likewise, Servén (1998) shows that macroeconomic volatility reduces investment and thus growth. And these two variables might be related or at least correlated (see below) to the degree of export concentration. The results show that the coefficient of the export concentration index declines by about 50% once these two additional variables are included in the model. However,

---

[5] The index is defined as: $IIT = 1 - \frac{\sum_{i}^{n} | X_i - M_i |}{\sum_{i}^{n} (X_i + M_i)}$, where "i" indicates a product category and "n" is the total number of products. This index varies between 0 and 1, and it shows the share of total trade that is conducted among identical products (i.e., imports and exports of the same product category).

export concentration still has a rather large direct negative and significant impact on economic growth. This coefficient implies that an increase of one standard deviation in the index of export concentration is associated with a fall of 2.4% in the growth rate.

In addition, both the index of IIT and the volatility of the REER are both significant at the 10% level. The magnitude of the coefficient for the IIT variable implies that a one standard deviation increase in this index is associated with a rise of 4.4% in the growth rate. In contrast, the impact of macroeconomic volatility is smaller: a one standard deviation increase in volatility is associated with a decline of 0.4% in the growth rate.

Late last year Vial and Sachs (2001), as part of their background research for the *Latin American Competitiveness Report*, published a new set of results from OLS differences estimations. In this case, the authors changed the original model of SW, apparently replacing the NRX variable with the ratio of NR exports over total exports, and they also replaced their index of policy openness with the ratio of the sum of imports and exports over GDP. The new Vial-Sachs results indicate that the share of NR exports over total exports remains significant with the negative sign in the differences estimators. We reproduced those results with the OLS differences estimator and the new Vial-Sachs results hold. However, they do not hold in the GMM-IV estimations, while the export concentration index does remain statistically significant, although the coefficient declined to –7.6 and is significant at the 5% level. In any case, it seems that the pessimists about the potential of natural resources remain active, running new sets of regressions, but have yet to catch up with the existing methodological know-how.

IV. Conclusions

In sum, the main findings of this paper are that the SW result concerning the alleged negative effect of natural resource exports on growth does not pass the test of time, the NRX effect is probably due to unaccounted country-specific effects, and dealing with endogeneity issues does not recover the SW result.

However, we find that export revenue concentration does have quite a robust negative effect on economic growth. And about 50% of this effect is due to the negative correlation between export concentration and intra-industry trade (which is –0.47 and significant) and a positive correlation between export concentration and volatility of the real effective exchange rate (which is actually relatively low at 0.07).

Nevertheless, we consider this results to be preliminary. Much work remains to be done in order to better understand how natural resources and/or trade structure might affect economic growth. Future research could be fruitful in these areas. In particular, researchers should evaluate the impact of these variables on growth by applying the GMM system estimator suggested by Arellano and Bover (1995) as done by Levine, Loayza, and Beck (2000) in the context of cross-country growth regressions with panel data. This methodology rescues some of the cross-sectional variance that is lost in the differences GMM estimator, by estimating a system of equations that also includes equation (3) in levels, but with the lagged differences of the endogenous variables as instruments. This method has proven to add more precision (efficiency) to the estimated coefficients.

In addition, future research could attempt to further clarify the channels through which export concentration affects growth. Furthermore, further analysis of the potential effect of natural resources on growth could attempt to examine whether such riches affect economic growth via terms of trade changes, which was the channel suggested by SW (1995) and by Suescún (2000), among others, including Prebisch (1959). This type of analysis might entail looking at the statistical significance of terms of trade variations when interacted with natural resource dependence variables, such as the SW index. However, it is noteworthy that these authors emphasize that NRX can reduce growth when commodity prices rise through a Dutch Desease type of effect. This might occur if non-NR tradable sectors have unexploited economies of scale or produce productivity externalities. If so, then the reverse should occur when terms of trade deteriorate for NR exporters. Hence future research could also aim to test for the existence of asymmetries in the effects of terms of trade variations for NR exporters.

Another channel through which NR exports and export concentration might affect growth is through its effects on public institutions. This is the effect that Lane and Tornell (1999) have labeled the "voracity effect". Other analysts refer to this impact on social institutions as the "rentier experience" (Isham et al. 2001). The main gist of these arguments is that NR and/or concentration of export revenues in a few commodities might lead to a sort of tragedy of the commons, where economic and social agents attempt to appropriate the revenues from the scarce resources, thus leading the corruption and other directly unproductive activities. However, these analyses, if done with the use of cross-country growth regressions, should be done with a careful appreciation of the existing know-how about the do's and don't's of growth empirics.

References

Arellano, Manuel, and Stephen Bond. 1991. "Some Tests of Specification for Panel Data: Montecarlo Evidence and an Application to Employment Equations." Review of Economic Studies 58(2): 277-297.

Arellano, Manuel, and Olympia Bover. 1995. "Another Look at the Instrumental-Variable Estimation of Error Component Models." Journal of Econometrics 68(1): 29-52.

Auty, Richard M. 1998. Resource Abundance and Economic Development. Helsinki: UNU World Institute for Development Economics Research.

Barro, Robert J. 1991. "Economic Growth in a Cross Section of Countries." Quarterly Journal of Economics 106: 407-444.

Caselli, Francesco, Gerardo Esquivel, and Fernando Lefort. 1996. "Reopening the Convergence Debate: A New Look at Cross-Country Growth Empirics." Journal of Economic Growth 1(3): 363-389.

De Ferranti, David, Guillermo Perry, Daniel Lederman, and William Maloney. 2002. From Natural Resources to the Knowledge Economy: Trade and Job Quality. The World Bank: Washington, DC.

De Long, Bradford, and Lawrence Summers. 1992. "Equipment Investment and Economic Growth." Quarterly Journal of Economics 106(2): 455-502.

Easterly, William, Norman Loayza, and Peter Montiel. 1997. "Has Latin America's Post Reform Growth Been Disappointing?" Journal of International Economics 43: 287-311.

Grubel, Herbert G., and P.J. Lloyd. 1975. Intra-Industry Trade: The Theory and Measurement of International Trade in Differentiated Products. New York: John Wiley & Sons.

Hansen, Lars Peter. 1982. "Large Sample Properties of Generalized Method of Moments Estimators." Econometrica 50(4): 1029-1054.

Isham, J., Lant Pritchett, and Michael Woolcock. 2001. "The Varieties of the Rentier Experience: How Natural Resource Endowments and Social Institutions Affect Economic Growth." Mimeo. The World Bank, Washington, DC.

Knight, Malcolm, Norman Loayza, and Delano Villanueva. 1993. "Testing the Neoclassical Theory of Economic Growth: A Panel Data Approach." IMF Staff Papers 40: 512-541.

Krugman, Paul. 1979. "Increasing Returns, Monopolistic Competition and International Trade." Journal of International Economics 9: 469-479.

Lane, Philip, and Aaron Tornell. 1999. "The Voracity Effect." American Economic Review 89: 22-46.

Leamer, Edward. 2001. "How Much Data, How Much Economics, and How Much Economist in the Stew of Results on the Determinants of Growth." Lecture delivered at the IMF Institute Economics Training Program Seminar, June 4, Washington, DC.

Lederman, Daniel. 2001. The Political Economy of Protection: Theory and the Chilean Experience. Ph.D. Dissertation, Johns Hopkins University, Baltimore, Maryland.

Levine, Ross, and David Renelt. 1992. "A Sensitivity Analysis of Cross-Country Growth Regressions." American Economic Review 82(4): 942-963.

Levine, Ross, Norman Loayza, and Thorsten Beck. 2000. "Financial Intermediation and Growth: Causality and Causes." Journal of Monetary Economics 46: 31-77.

Maddison, Angus. 1994. "Explaining the Economic Performance of Nations, 1820-1989." In W. Baumol, R. Nelson, and E. Wolff, editors, Convergence of Productivity: Cross-National and Historical Evidence, pp. 20-60. New York: Oxford University Press.

Maloney, William. 2002. "Innovation and Growth in Resource Rich Economies." Mimeographed. Office of the Chief Economist for Latin America and the Caribbean, The World Bank, Washington, DC.

Mankiew, Gregory, David Romer, and David Weil. 1992. "A Contribution to the Empirics of Economic Growth." Quarterly Journal of Economics 106(2): 407-437.

Marin, William. 2002. "Outgrowing Resource Dependence: Theory and Evidence." Mimeographed. Development Research Group, The World Bank, Washington, DC.

Prebisch, Raúl. 1959. "Commercial Policy in the Underdeveloped Countries." American Economic Review, Papers and Proceedings 49(2): 251-273.

Rodríguez, Francisco, and Jeffrey Sachs. 1999. "Why Do Resource-Abundant Economies Grow More Slowly?" Journal of Economic Growth 4: 277-303.

Sachs, Jeffrey, and Joaquín Vial. 2001. "Can Latin America Compete?" In The Latin American Competitiveness Report, 2001-2002, edited by J. Vial and P. Cornelius, pp. 10-29. Cambridge, Massachusetts: Center for International Development and World Economic Forum.

Sachs, Jeffrey, and Andrew Warner. 1995a. "Natural Resource Abundance and Economic Growth." National Bureau for Economic Research Working Paper 5398, Cambridge, Massachusetts.

Sachs, Jeffrey, and Andrew Warner. 1995b. "Economic Reform and the Process of Global Integration." Brookings Papers on Economic Activity 1: 1-95.

Sachs, Jeffrey, and Andrew Warner. 1997a. “Natural Resource Abundance and Economic Growth – Revised.” Working Paper of the Center for International Development, Harvard University, Cambridge, Massachusetts.

Sachs, Jeffrey, and Andrew Warner. 1997b. “Fundamental Sources of Long-Run Growth.” American Economic Review, Papers and Proceedings 87(2): 184-188.

Sachs, Jeffrey, and Andrew Warner. 1999. “The Big Push, Natural Resource Booms and Growth.” Journal of Development Economics 59: 43-76.

Sachs, Jeffrey, and Andrew Warner. 2001. “Fundamental Sources of Long-Run Growth.” American Economic Review, Papers and Proceedings 87(2): 184-188.

Sala-I-Martin, Xavier. 1997. “I Just Ran Two Million Regressions.” American Economic Review, Papers and Proceedings 87: 178-183.

Servén, Luis. 1998. “Macroeconomic Uncertainty and Private Investment in Developing Countries: An Empirical Investigation.” Policy Research Working Paper 2035, The World Bank, Washington, DC.

Smith, Adam. 1776 [1976]. An Inquiry into the Nature and Causes of the Wealth of Nations. Oxford: Clarendon Press.

Solow, Robert. 2001. “Applying Growth Theory across Countries.” The World Bank Economic Review 15(2): 283-289.

Suescún, Rodrigo. 2000. “Optimal Commodity Price Stabilization over the Business Cycle.” Borradores Semanales de Economía (Colombia) 154, Central Bank of Colombia, Bogotá, Colombia.

Wright, Gavin. 2001. “Resource-Based Growth Then and Now.” Mimeographed. Department of Economics, Stanford University, Palo Alto, California.

Table 1. Historical Sensitivity

Dep.var.: Average Annual Growth Rate	Period						
	1820-1870	1870-1913	1913-1950	1950-1973	1973-1989	1950-1973(1)	1973-1989(1)
Log GDP per capita, initial	0.70**	0.49**	0.4304**	0.219	-0.139	0.392	-0.41*
	(4.39)	(2.99)	(2.75)	(0.83)	-(0.65)	(1.23)	-(1.79)
Primary exports / GDP (1970)	2.92	-2.09	3.53	-7.87*	-14.29**	-12.78**	-10.4**
	(1.58)	-(0.77)	(1.64)	-(1.97)	-(3.91)	-(2.40)	-(2.38)
Constant	-4.31**	-2.25*	-2.62**	2.03	4.08**	1.012	6.27**
	-(3.97)	-(1.97)	-(2.22)	(0.96)	(2.14)	(0.41)	(3.11)
Obs.	**19**	**23**	**32**	**37**	**37**	**32**	**32**
Adj R-squared	**0.57**	**0.24**	**0.23**	**0.08**	**0.27**	**0.12**	**0.19**

(t-student values)

Notes: * Significant at 10% level; ** Significant at 5% level; (1) Common sample with period 1913-1950

Source: Authors' calculations using growth data from Maddison (1994).

Table 2. Controlling for Country-Specific Effects: Regressions in Differences

Dependent Variable	Growth of GDP per economically active population (a)				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Initial value of primary exports / GDP (b)	-0.0067	0.0012	-0.0440		
	(-0.29)	(0.05)	(-1.64)		
Openness SW (b)	3.00***	2.65***	2.97***	2.98***	2.96***
	(4.63)	(4.11)	(4.90)	(4.90)	(4.99)
Export concentration			-4.9260**	-4.8163**	-2.6377
			(-2.46)	(-2.40)	(-1.36)
Annual change in terms of trade	-0.023	-0.027*	-0.028**	-0.027*	-0.035***
	(-1.54)	(-1.85)	(-2.07)	(-1.95)	(-2.65)
Log of Initial real GDP per capita	-2.1939***	-2.7561***	-2.2411***	-2.2949***	-2.5796***
	(-5.90)	(-5.99)	(-4.49)	(-4.59)	(-4.98)
Average Investment/GDP	2.9030***	3.9428***	2.3711***	2.1673***	3.6402***
	(4.19)	(5.62)	(3.32)	(3.08)	(5.09)
Average years of schooling (b)		0.5437**			0.3701
		(2.28)			(1.51)
Initial government consumption		0.0369			0.1268***
		(0.92)			(3.10)
Adjusted R squared	0.14	0.19	0.17	0.16	0.22
Observations	380	373	320	320	313
Number of countries	122	111	100	101	101

t-statistics in parentheses. (a) Period dummies included as explanatory variables. (b) Missing values for these variables were imputed. See Appendix 1 for further information.

* 10%, ** 5% and *** 1% level of significance

Table 3. Controlling for Endogenous Variables: GMM-IV Regressions in Differences

Dependent Variable	Growth of GDP per economically active population (a)				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Initial value of primary exports / GDP (b)	-0.0017 (-0.04)				
Openness SW (b)	0.5343 (0.69)	0.7347 (1.15)	0.0655 (0.07)	-0.4298 (-0.26) §	0.2713 (0.21) §
Export concentration		-9.2257*** (-2.65)	-23.3364** (-2.01) §	-24.0299** (-2.07) §	-11.7312* (-1.75) §
Change in terms of trade	-0.015 (-0.93)	-0.0238** (-2.07)	-0.0195 (-1.24)	-0.0183 (-1.12)	-0.0265 (-1.35)
log of Initial real GDP per ec.act.pop.	-5.4352** (-2.00) §	-5.2209** (-2.33) §	-7.048*** (-2.77) §	-7.6819*** (-3.08) §	-5.0506** (-2.31) §
Investment	2.8673 (1.41) §	1.2030 (0.68) §	3.4818 (1.45) §	3.9278 (1.51) §	-0.0806 (-0.06) §
Average years of schooling (b)	0.2454 (0.66)	0.2507 (0.73)	-0.0456 (-0.10)	-0.1169 (-0.27)	-0.5289 (-0.89)
Initial government consumption	-0.0776 (-1.00)	-0.0262 (-0.35)	0.0172 (0.20)	0.0277 (0.31)	0.0518 (0.51)
Intra-industry trade					20.9207* (1.67) §
Real exchange rate volatility					-1.7284* (-1.67) §
Hansen J Test (P-value)	0.68	0.33	0.37	0.31	0.46
Observations	127	109	109	109	107
Number of countries	112	99	99	99	99

Z-values in parenthesis. (a) Instruments are the endogenous variables in levels lagged 2 and 3 periods, plus regional dummies. Period dummies included as explanatory variables. (b) Missing values for these variables were imputed. See Appendix 1 for further information
§ designates the instrumented variables.
* 10%, ** 5% and *** 1%

Appendix I: Variables and Sources

Variables	Definition	Sources
Growth real GDP per ec. act. pop	Average annual rate of growth of real GDP divided by the economically active population. GDP is in 1995 Constant U$S	Author's construction using WDI
Log real GDP per ec.act.pop.	Natural log of GDP divided by the economically active population,initial value per period. GDP is in 1995 Constant U$S	Author's construction using WDI
Growth real GDP per capita	Average annual rate of growth of GDP per capita at 1985 US prices. Historical data.	Maddison (1994)
Log of GDP per capita	Natural log of GDP per capita at 1985 US prices, initial value per period. Historical data.	Based on data from Maddison (1994)
Primary exports / GDP*	Share of exports of primary products in GNP, initial value per period.	WDI
Primary exports intensity	Share of exports of primary products in total merchandise exports.	WDI
Openness	Average openness, defiinied as exports + imports / GDP.	WDI
Openness Sachs and Warner*	Percentage of years with open economic regime.	Sachs and Warner (1995)
Investment	Average of the natural log of the ratio :Gross Capital Formation / GDP, in %	WDI
Terms of trade	Average annual growth of the external terms of trade. The external terms of trade is the ratio of an exports price index to an import price index.	WDI
Exports concentration	Average Herfindahl Index of export value.	Based on data from UNCOMTRADE
Imports concentration	Average Herfindahl Index of import value.	Based on data from UNCOMTRADE
Intra industry trade	Grubel and Lloyd Intra Industry Trade Index	Based on data from UNCOMTRADE
Average years of schooling*	Average number of years of schooling in the population of 25-65 years. Initial value per period.	Barro and Lee (2000)
Initial level of government consumption/GDP	Government consumption, central government.	IMF, WDI
Volatility of exchange rate*	Standard deviation of monthly interannual changes in real effective exchange rate.	Author's construction using IMF and JP Morgan databases

*Missing values for these variables were imputed. For average years of schooling the variables used in the imputation were: regional dummies, period dummies, forest land (hectares per worker), crop land (hectares per worker), and trade/GDP. For average primary exports/GDP the variables used were: regional dummies, period dummies, and the log of the initial GDP per capita. For volatility of the exchange rate the variables used were: regional dummies, period dummies, log of the initial GDP per capita, and the change in the terms of trade.

Appendix II: Summary statistics

Five year period database					
	Obs.	**Mean**	**Std. Dev.**	**Min**	**Max**
gea	709	0.73	3.56	-17.58	24.00
lgdpea0	722	8.12	1.48	5.16	11.10
sxp0	523	17.62	35.38	0.15	501.75
linv	786	3.07	0.39	1.10	4.28
op	770	0.79	0.48	0.11	3.80
sopen	550	0.49	0.49	0.00	1.00
sch250	527	4.77	2.93	0.30	12.13
cgv0	725	16.92	8.07	1.22	76.22
exp_herfin	818	0.23	0.22	0.00	1.00
iit	804	0.23	0.21	0.00	1.00
sd_reer	699	0.11	0.23	0.01	5.02
dtt	514	-0.97	7.88	-111.27	36.53
Historical Database					
	Obs.	**Mean**	**Std. Dev.**	**Min**	**Max**
g	172	1.73	1.61	-1.50	8.00
log y	152	7.67	1.01	5.44	9.75
sxp	159	7.37	5.86	0.64	29.32

Key:

gea = growth of GDP per economically active population
lgdpea0 = log of GDP per economically active population, first year
sxp0 = natural resource exports over GDP, first year
linv = log of investment over GDP
op = imports plus exports over GDP
sopen = Sachs-Warner index of opennes (average years with open trade regime)
sch250 = educational attainment of population over 25 years of age, first year
cgv0 = government consumption as share of GDP, first year
exp_herf = Herfindahl index of export revenues concentration
iit = Grubel-Lloyd index of intra-industry trade
sd_reer = Standard deviation of the annual rate of change of the Real Effective Exchange Rate
dtt = annual rate of change of the terms of trade

g = growth of per capita GDP for historical series from Maddison (1994)
log y = initial level of income for historical time periods, based on growth data from Maddison (1994)
sxp = natural resource exports over GDP of 1970

Documentos de Trabajo **Banco Central de Chile**	**Working Papers** **Central Bank of Chile**
NÚMEROS ANTERIORES	PAST ISSUES

La serie de Documentos de Trabajo en versión PDF puede obtenerse gratis en la dirección electrónica: http://www.bcentral.cl/Estudios/DTBC/doctrab.htm. Existe la posibilidad de solicitar una copia impresa con un costo de $500 si es dentro de Chile y US$12 si es para fuera de Chile. Las solicitudes se pueden hacer por fax: (56-2) 6702231 o a través de correo electrónico: bcch@condor.bcentral.cl

Working Papers in PDF format can be downloaded free of charge from: http://www.bcentral.cl/Estudios/DTBC/doctrab.htm. Printed versions can be ordered individually for US$12 per copy (for orders inside Chile the charge is Ch$500.) Orders can be placed by fax: (56-2) 6702231 or e-mail: bcch@condor.bcentral.cl

DTBC-140 Febrero 2002
Prebisch-Singer Redux
John T. Cuddington, Rodney Ludema y Shamila A Jayasuriya

DTBC-139 Febrero 2002
The Relative Richness of the Poor? Natural Resources, Human Capital and Economic Growth
Claudio Bravo-Ortega y José De Gregorio

DTBC-138 Febrero 2002
Depreciación del Capital Natural, Ingreso y Crecimiento Sostenible: Lecciones de la Experiencia Chilena
Eugenio Figueroa B. y Enrique Calfucura T.

DTBC-137 Febrero 2002
The Distribution of Stochastic Shrinkage Parameters in Ridge Regression
Hernán Rubio y Luis Firinguetti

DTBC-136 Enero 2002
Value at Risk: Teoría y Aplicaciones
Christian A. Johnson

DTBC-135 Enero 2002
Agency Problems in the Solutions of Banking Crises
Gonzalo I. Sanhueza

DTBC-134 Enero 2002
On the Determinants of the Chilean Economic Growth
Rómulo A. Chumacero y J. Rodrigo Fuentes

DTBC-133 Diciembre 2001
Cálculo del Stock de Capital para Chile, 1985-2000
Ximena Aguilar M. y María Paz Collinao

DTBC-132 Diciembre 2001
Políticas de Estabilización en Chile durante los Noventa
Carlos José García T.

DTBC-131 Noviembre 2001
Ten Years of Inflation Targeting: Design, Performance, Challenges
Norman Loayza y Raimundo Soto

DTBC-130 Noviembre 2001
Trends and Cycles in Real-Time
Rómulo A. Chumacero y Francisco A. Gallego

DTBC-129 Noviembre 2001
Alternative Monetary Rules in the Open-Economy: A Welfare-Based Approach
Eric Parrado y Andrés Velasco

DTBC-128 Noviembre 2001
Price Inflation and Exchange Rate Pass-Through in Chile
Carlos José García y Jorge Enrique Restrepo

DTBC-127 Noviembre 2001
A Critical View of Inflation Targeting: Crises, Limited Sustainability, and Agregate Shocks
Michael Kumhof

DTBC-126 Noviembre 2001
Overshootings and Reversals: The Role of Monetary Policy
Ilan Goldfajn y Poonam Gupta

DTBC-125 Noviembre 2001
New Frontiers for Monetary Policy in Chile
Pablo S. García, Luis Oscar Herrera y Rodrigo O. Valdés

DTBC-124 Noviembre 2001
Monetary Policy under Flexible Exchange Rates: An Introduction to Inflation Targeting
Pierre-Richard Agénor

DTBC-123 Noviembre 2001
Targeting Inflation in an Economy with Staggered Price Setting
Jordi Galí