



COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

DIVISION OF ECONOMICS AND BUSINESS
WORKING PAPER SERIES

Replicating Sachs and Warner: The 1997 Working Paper

Graham A. Davis

Working Paper 2012-08

<http://econbus.mines.edu/working-papers/wp201208.pdf>

Colorado School of Mines
Division of Economics and Business
1500 Illinois Street
Golden, CO 80401

August 2012

Colorado School of Mines
Division of Economics and Business
Working Paper No. **2012-08**
August 2012

Title: Replicating Sachs and Warner:
The 1997 Working Paper*

Author(s):
Graham A. Davis
Division of Economics and Business
Colorado School of Mines
Golden, CO 80401-1887
gdavis@mines.edu
Phone: +1 303 499 0144

ABSTRACT

This paper reports on my replication of the 1997 Sachs and Warner resource curse working paper. Exact pure replication is achieved. A test for statistical replication shows that some of the Sachs and Warner results attempting to determine the cause of the resource curse are not robust to the country sample. A test for scientific replication shows that findings of the resource curse are not sensitive to different measures of resource intensiveness, though they are subject to country sample and omitted variable bias. Reporting errors in the published paper show the value of researchers making both their data *and* code publicly available.

***JEL codes:* O13, Q32, Q33, B40, C80**

***Keywords:* Replication, Sachs and Warner, Resource curse**

* I would like to thank Bruce McCullough for the encouragement to write up my efforts on this replication, which I initially completed in 2004, and for his comments on an earlier draft of the paper. I also thank Laura Camfield and Richard Palmer Jones for taking interest in replication studies and for inviting me to present this paper in their panel on replication in development studies at the EADI/DSA General Conference 2011 in York.

Replicating Sachs and Warner: The 1997 Working Paper

Introduction

This paper is the first of my attempt to replicate six empirical papers published by Jeffrey Sachs and Andrew Warner finding that there is a “resource curse” (Sachs and Warner 1997a, 1997b, 1997c, 1999a, 1999b, 2001).¹ Here I replicate the 1997a paper, portions of which have been published in Meier and Rauch (2000, 161-167). It has not, however, been published in a refereed journal. Overall, after some initial difficulties, the replication was successful.

The resource curse suggests that economies with a high proportion of primary production suffer from slower than expected economic growth. The resource exporting economies are mainly developing economies, and so the result has critical importance for contemporary development theory given the ongoing primacy of resource production in these economies. Sachs and Warner (SW hereafter) argue that this slower growth is due to lost external economies of scale in manufacturing as that sector shrinks when the resource sector booms. Even though the presence of a resource curse has been disputed (e.g., Alexeev and Conrad 2009, Davis 1995, Lederman and Maloney 2007a), worries about the curse continue to invoke policy incentives that dissuade the production of primary products in favour of manufacturing and that at a minimum cause nascent resource exporters like Brazil, Mongolia and Afghanistan to worry about their development prospects.

Five of SW’s seven resource curse papers are amongst the highest cited papers in resource and development economics. Table 1 lists the number of citations and annual citation rate for each paper. Auffhammer (2009) proposes that SW’s 2001 *European Economic Review* paper is the most cited environmental and resource economics paper of the last decade. According to Harzing’s Publish or Perish software, the SW paper in the *Journal of African Economies* is the most cited paper ever to be published in that journal.

Table 1: Citations and Citation Rate for the Seven Sachs and Warner Resource Curse Papers

Paper	Place of Publication	Citations to date	Average annual citation rate
Sachs and Warner 1995, 1997a	NBER, HIID*	1,959	115
Sachs and Warner 1997b	<i>AER</i>	535	36
Sachs and Warner 1997c	<i>JAE</i>	776	52
Sachs and Warner 1999a	<i>JDE</i>	671	52
Sachs and Warner 1999b	EE Book Chapter	88	7
Sachs and Warner 2001	<i>EER</i>	1,074	98

Based on Harzig’s Publish or Perish software, v 3.2.4150, search conducted on 6/24/2011.

*Google Scholar combines cites for the 1995 paper with the 1997a paper, and lists these as the 1995 paper.

¹ The 1997a paper was previously published as a 1995 NBER paper, which in turn was previously published as HIID Development Discussion Paper No. 517a, October 1995. The main empirical difference in these papers is that in the 1997a paper the growth period is extended one year to 1990. Data for the 1995 working paper have not been publicly provided and that paper is therefore not replicable. There are other works in which one or both of the authors address economic growth, but I have deemed them to be too far astray from the original resource curse work to be included in this list.

In the physical sciences, such path-breaking and cited work would have been replicated dozens of times by now. In the social sciences, and in economics in particular, replication of results is rare; there is a lack of demand for replication in economics, such that undertakings on the supply side carry risks that are not compensated with the reward of publication (Hammermesh 2007; McCullough, McGreary, and Harrison 2008). As McCullough, McGreary, and Harrison (2006, 1093) muse, “If Pons and Fleischman had published their cold fusion results in an economics journal, the world would still be awaiting lower utility bills.” Of course, we now know that replication attempts revealed claims of cold fusion to be false.

Given the practical limitations to replicating all published work, one strategy is to select those works that have had greatest influence on the field and on public policy. The SW portfolio on the resource curse fits that criterion. To my knowledge the portfolio has not been tested for reproducibility of results. In fact, Stijns (2005) notes his *inability* to replicate regressions 1.3, 1.4, and 1.5 in SW’s 1997a paper. Mehlum et al. (2006) do, on the other hand, manage to replicate regression 1.4, but do not comment on the reproducibility of other results. Schonger (2002) replicates the coefficient estimates in SW regressions 1.1 through 1.5, though he reports SW’s t-statistics, which I will show to be erroneous.

Hammermesh (2007) defines three types of replication: pure replication, “to make or do something again in exactly the same way;” statistical replication, “different sample, but the identical model and underlying population;” and scientific replication, “different sample, different population, and perhaps similar but not identical model.” Pure replication must necessarily precede statistical and scientific replication to ensure that any differences between the former and the latter are due to different sample, population, or model, and not due to an error in the original work. I primarily conduct pure and statistical replication in this paper, though I make brief mention of scientific replication in the final section of the paper. My main task was the replication of each of the 32 least-squares regressions in the paper.

This paper is best read with a copy of Sachs and Warner (1997a) at hand, easily locatable on Google. Appendix 2 provides a glossary of the SW variable abbreviations that I referred to in this paper.

The Nature of the Sachs and Warner Resource Curse Studies

In 1995, SW produced a paper examining primary resources’ role in economic growth. Their purpose was to investigate what they variously call “a conceptual puzzle,” “a surprising feature of economic life,” and an “oddity:” namely, the negative association identified by previous researchers between the intensity of a country’s natural resource (agriculture, mining, and fuels) production and subsequent economic growth. The 1995 paper examines the impact of resource intensity in 1970 against productivity growth from 1970 to 1989. A second paper, written in 1997 (Sachs and Warner 1997a), updates the growth period to 1990 with little impact on the results. Both find empirical support for a resource curse.

In the 1997 paper SW calculate for a population of 211 developed and developing countries the intensity of natural resource production in 1970. Resource intensiveness is measured as the 1970 share of agricultural, mining, and fuel exports in GNP (variable SXP). They measure economic growth as the average annual change in real GDP per economically active population from 1970 to 1990 (variable GEA7090), which is growth in labor productivity. In Table I they regress

GEA7090 on SXP using ordinary least squares linear regressions, controlling for the log of the 1970 real GDP per economically active population (variable LGDPEA70). The regression results show that conditional on initial income levels, those economies with higher levels of initial resource exports grew more slowly from 1970 to 1990. This “resource curse” is maintained as additional conditioning variables are added in a series of eight regressions in Tables I, III, IV, V, VI, and VII. SW produce three additional tables of regressions (Tables VIII, X, and XI) exploring indirect routes through which primary exports may be causing the slower growth.

The results in these regressions support their hypotheses, presented in detail in the 1995 paper, that a shrinking manufacturing sector is to blame, a negative form of Dutch disease a la Matsuyama (1992). These regressions also test for the impact of institutions on growth. Regression 5 in Table I identifies that growth is impacted by good institutions, and Table XI shows that institutional quality is a function of resource intensity. SW do not make much of this result, however, as they conclude that the indirect effects of resources on institutions and of institutions on growth are small compared to the remaining direct effect of resources on growth.

Pure Replication

SW provide a readme file describing four data files: a STATA (version 5) do file that they apparently use to do the econometric analysis; a STATA data set; and Excel and HTML files with the data. The five files are available at <http://www.cid.harvard.edu/ciddata/ciddata.html>. There is no description of the codes used for the variables in the data file, though many of these can be found in the 1997a paper. I used EViews 5.1 with an Intel Pentium M 1.86 GHz processor to conduct the replication given the data presented in the downloadable Excel file.

As they note in footnote 13 of their paper, SW first check their sample for outliers. They regress GEA7090 on LGDPEA70, SXP, and SOPEN (a measure of trade openness), which is regression 1.2 in their paper, and determine outliers based on the DFITS statistic computed in STATA. The DFITS results are included as a column in the data files. While the paper states that an observation is excluded if $DFITS > 2\sqrt{k/n}$ where k is the number of regressors (inclusive of the constant) and n is the sample size, the STATA code actually tests for $|DFITS| > 2\sqrt{k/n}$ since DFITS can be negative. There is complete data for GEA7090, LGDPEA70, SXP, and SOPEN for 91 of the 211 countries, and so $k = 4$ and $n = 91$. On the basis of this test they exclude Chad, Gabon, Guyana, and Malaysia as outliers. I am able to replicate their list of outliers by computing the DFITS statistic using STATA version 11.2.²

There are 95 countries in the data set with complete growth and resource export data. The relationship between growth and resource exports is depicted in SW’s Figure 1. SW claim that the figure shows the relationship between growth and resource exports for 95 developing countries. The figure in fact includes both developing and developed countries.

² I thank Arturo Vazquez Cordano and Michael Heeley for assisting me with this portion of the replication attempt.

Table 2: Regressions in Table I of Sachs and Warner (1997a) Testing for the Resource Curse

Regression	Specification	<i>n</i>
1.1	$GEA7090 = \alpha_0 + \alpha_1LGDPEA70 + \alpha_2SXP + \varepsilon$	87
1.2	$GEA7090 = \alpha_0 + \alpha_1LGDPEA70 + \alpha_2SXP + \alpha_3SOPEN + \varepsilon$	87
1.3	$GEA7090 = \alpha_0 + \alpha_1LGDPEA70 + \alpha_2SXP + \alpha_3SOPEN + \alpha_4INV7089 + \varepsilon$	87
1.4	$GEA7090 = \alpha_0 + \alpha_1LGDPEA70 + \alpha_2SXP + \alpha_3SOPEN + \alpha_4INV7089 + \alpha_5RL + \varepsilon$	71
1.5	$GEA7090 = \alpha_0 + \alpha_1LGDPEA70 + \alpha_2SXP + \alpha_3SOPEN + \alpha_4INV7089 + \alpha_5RL + \alpha_6DTT7090 + \varepsilon$	71

Table I in SW presents five different specifications testing for the resource curse. The specifications are reproduced in Table 2 above. In each of these regressions they draw from the 87 countries for which complete data exists for regressions 1.2 and 1.3. I list the 87 countries in Appendix 1. SW do not include in their paper this list of countries, though I discovered that the data files code the excluded countries as $excl1 = 0.00$ and the excluded countries as $excl1 = 1.00$. One would not be able to come up with the correct country sample for regression 1.1, for which there is complete data for 94 countries, if one did not read the STATA file to know which additional four countries to exclude from that regression.³

Given that we now know country sample I am able to replicate regression 1.1 save for two differences in the reported t-statistic values in regression 1.1. Table 3 reports the results including the regression constant, which is not reported by SW. Regression 1.2 was also successfully replicated.

An initial problem with replicating regression 1.3 had to do with the reported regressor INV7089 (the investment to GDP ratio averaged over the period 1970-1989). The raw data file contained both INV7089 and LINV7089, the latter being the natural log of the former. The regression table in the SW paper reports that INV7089 was used in regression 1.3. This is what tripped up Stijns in his replication attempt – he used INV7089.⁴ The SW STATA do file shows that the correct regressor is LINV7089.⁵ With LINV7089 as the independent variable, regression 1.3 is also exactly replicated. The country size drops to 71 in regressions 1.4 and 1.5 because there are 16 countries for which no rule of law (RL) data is available (see Appendix 1). I am also able to replicate regressions 1.4 and 1.5. Note that there is an error in the Title of Table I in SW: it should be “Partial Associations Between Growth (1970-90) and Natural Resource Intensity (1970),” not “Partial Associations Between Growth (1970-90) and Natural Resource Intensity (1971).”⁶

³ Cape Verde Islands, Iceland, Fiji, and Panama are excluded from Regression 1.1 so as to make a consistent country sample across the first three regressions.

⁴ I can replicate regressions SW3 through SW5 in Stijns (2005, p. 117) by using INV7089 in SW regressions 1.3 through 1.5.

⁵ Mehlum et al. (2006) correctly note that the regressor is log investment, which is why their replication was successful.

⁶ The notes to the data state that SXP is for 1970, taken from a 1995 World Bank data diskette. I have verified that the diskette only contains 1970 data for fuel and non-fuel exports. It does not contain 1971 data.

Table 3: Sachs and Warner Regression 1.1 with Corrections in Bold. Dependent variable: Average annual growth in real GDP per economically active population, 1970 – 1990 (GEA7090)

	(SW 1.1)	(GD 1.1)
Constant		3.29 (1.84)
Initial productivity (LGDPEA70)	-0.11 (0.55)	-0.11 (-0.54)
Primary exports in GNP in 1970 (SXP)	-9.43 (-4.75)	-9.43 (-4.74)
Openness (SOPEN)		
Ln of Investment Ratio (LINV7089)		
Rule of Law Index (RL)		
Growth in Terms of Trade (DTT7090)		
Adjusted R ²	0.20	0.20
Sample Size	87	87
Standard error	1.62	1.62

SW then go on to note in a footnote to their Table I that if the four outliers are not excluded the estimated coefficients on SXP “range from -6.0 to -8.5, with t-ratios always exceeding 4 in absolute value.” I have verified that this is the case, though since Chad does not have rule of law (RL) data it is technically not added back to regressions 1.4 and 1.5 in this exercise.

The remaining 27 regressions in the SW paper revert to the full population of 211 countries, including the four outliers. This is not made clear in the paper, but is clear in the STATA file. The sample size for each regression is now simply the number of countries for which the data for the set of regressors was complete.

The next table of regression results is Table III, which tests whether the resource curse finding in Table I is dependent on the measure of resource intensity. Table III introduces three alternative resource intensity measures, SNR, PXI70, and LAND, and sequentially replaces SXP with these

in regression 1.5. The resource curse remains regardless of the measure of resource intensity. I was able to replicate the regressions in Table III exactly save for the t-statistic on LAND in regression 3.4. It should be -4.08, not -3.78. From the STATA file the dependent variable in these regressions is actually GEA7090, not GEA7089 as reported by SW in the table. The SNR variable is reported in the table notes as being mineral production divided by GNP in 1970. The paper's text and variable descriptions state that the data is from 1971. I was unable to determine which of these is correct.

Given that Table III finds that the measure of resource intensiveness is immaterial, SW stay with their preferred measure, SXP, in the remaining regressions. Table IV adds more conditioning variables. The dependent variable is actually GEA7090, not GEA7089 as reported by SW in the table. The table notes refer to variable INV7090, and yet the regressor is reported as INV7089 in both the table and the STATA file. The data files only contain data for INV7089, and so this is the correct regressor. Note that the investment variable is not logged in this table.

Tables V, VI, and VII add still different control variables to check for the robustness of the resource curse. I managed to exactly replicate Tables V, VI, and VII. In Table V the independent variables are actually KLLSEC and KLLLY70, not LSEC and LLY70 as listed by SW in the table. In Tables VI and VII the dependent variable is actually GEA7090, not GEA7089 as reported by SW in the tables.

Table VIII regresses sectoral data against SXP and additional conditioning variables looking for a causal mechanism for the resource curse. I had some trouble replicating regression 8.2 in Table VIII until I realized that the independent variable is LGDPNR70 (natural log of GNP produced in sectors other than the natural resource sector) per the table notes on p. 32 and the STATA file, not LGDPEA70 as reported by SW in Table VIII.

Table IX tests to see whether the resource curse differed between the 1970s and 1980s. In regression 9.2 variable SXP80 is used in the regression, not SXP as reported by SW in the regression and in the table note. With this change I replicated regressions 9.1 and 9.2. Note that the column headings should be Growth 1970 – 1980 and Growth 1980 – 1990, not Growth 1970 – 1979 and Growth 1980 – 1989 as reported by SW in the table.

In footnote 17 SW mention that policy in earlier periods may be driving the resource curse results seen in the 1970s and 1980s. The state that they test for this by controlling for growth in the 1960s, but that “growth in the 1960's does not enter the regression significantly, and does not alter the significance of the SXP coefficient” (p. 20). It is not clear from the footnote text which regression they test this way. The note comes in the same paragraph as discussions of regressions 9.1 and 9.2, which test for a changing resource curse effect between the 1970s and the 1980s. The STATA file makes it clear that they in fact returned to regression 1.5, additionally controlling for GR6070 (average annual real growth per capita from 1960 to 1970).⁷ I confirm that that GR6070 is statistically insignificant in that regression and that the significance of the SXP coefficient only goes down from -6.89 to -6.51 when GR6070 is included as an independent variable. However, if I add GR6070 to regression 9.1, which tests for the resource curse in only the 1970s, SXP becomes statistically insignificant, suggesting that there may be something to their theory, at least for the resource curse of the 1970s (Adding

⁷ The STATA file incorrectly refers to footnote 18 instead of footnote 17. Footnote 18 is a discussion about Botswana.

Table 4: Sachs and Warner Regressions 9.1 and 9.2. Dependent variable: Average annual growth in real GDP per economically active population, 1970 – 1980 (GEA7080) in 9.1 and 1980 – 1990 (GEA8090) in 9.2.

	(9.1)	(9.1a)	(9.2)	(9.2a)
Constant	8.21 (3.65)	7.91 (3.34)	13.05 (4.70)	14.05 (5.16)
Initial productivity (LGDPEA70)	-1.25 (-4.07)	-1.23 (-3.81)	-1.88 (-5.00)	-1.99 (-5.47)
Primary exports in GNP (SXP, SXP80)*	-3.89 (-2.43)	-2.64 (-1.36)	-6.15 (-3.42)	-5.59 (-3.21)
Openness (SOPEN7, SOPEN8)*	1.82 (3.10)	1.89 (3.05)	2.51 (4.14)	2.11 (3.50)
Growth in Terms of Trade (DTT7080, DTT8090)*	0.11 (3.23)	0.11 (3.20)	0.02 (0.17)	0.04 (0.43)
Ln of Investment Ratio (LINV7079, LINV8089)*	1.51 (4.15)	1.52 (3.60)	0.63 (1.25)	0.39 (0.78)
Rule of Law Index (RL)			0.55 (3.34)	0.58 (3.60)
Growth in 1960s (GR6070)		-0.02 (-0.18)		0.23 (2.02)
Adjusted R ²	0.31	0.28	0.60	0.61
Sample Size	101	96	73	71
Standard error	2.04	2.08	1.52	1.46

*SXP, SOPEN, DTT, and LINV are all synchronized with the dependent variable, and so regression 9.1 uses the data for the 1970's and regression 9.2 uses the data for the 1980's. RL is for the 1980's, and so is not used in the 1970's regression.

GD6070 to regression 9.2, which tests for the resource curse in the 1980s, does not cause SXP80 to become statistically insignificant. GR6070 is, however, statistically significant in that case). Table 4 above provides the comparison of regressions 9.1 and 9.2 with and without GR6070 as a conditioning variable.

Table X investigates the relationship between natural resource intensity and other economic variables. Table XI investigates the relationship between natural resource intensity and the quality of institutions. I replicated all of the regressions in these tables.

The conclusion of this section is that SW's results can be exactly purely replicated once the countries included in the regressions are determined and the errors in the paper's reported regressors are corrected. Both adjustments required information from the STATA file. The replication revealed three inconsequential differences in the reported t-statistics (two in regression 1.1 and one in regression 3.4). I have reported the correct values. There is no doubt that the SW data allows them to measure a resource curse in the 1970s and 1980s that is robust to various sets of conditioning variables. The only question mark given their model and econometric method is the robustness of the resource curse in the 1970s, since conditioning on growth in the previous decade (a proxy for policy in the previous decade) causes the coefficient on SXP in that regression to become insignificant. This is an important finding, as it indicates that the resource curse may instead be lower growth that is a result of legacy policies rather than a result of primary production.

The replication attempt took longer than it should have because of the many inconsistencies between the reported regressors in the paper and the actual regressors in the STATA file. Without the STATA file the replication may have been impossible. Eleven years ago I and graduate students Jean-Philippe Stijns at Berkeley and Martin Schonger at Bonn shared our frustrations at not being able to replicate Table I. It was Martin who eventually realized that the independent variable in Table I should be LINV7089, not INV7089. His replication of SW Table I is included in his thesis (Schonger 2002).

Statistical Replication

As I noted above, SW do not maintain a consistent country sample across the various regressions. For example, SW regressions 3.1 through 3.4 test for whether the resource curse is sensitive to the specification of primary production by replacing SXP in regression 1.5 with other measures of resource intensiveness. However, three outliers (Gabon, Guyana, and Malaysia) omitted from the sample in regression 1.5 are added back in the Table III regressions, increasing the sample size to 74.⁸ The inconsistency of country selection across regressions is a troubling aspect of SW's empirical work given strong evidence that growth regressions of this type are highly sensitive to the subset of the population used in the sample (Knabb 2005, Norman 2009). For the record, regressions 1.1 through 1.5 sample from the set of 87 countries listed in Appendix 1, while the regressions in Table III onwards sample from the full 211 countries in the data base and use the set of countries for which complete data for that regression is available. There are only 22 countries that are common across all 32 regressions, with other countries being used in some regressions but not others.

In an examination of sample effects, I can confirm that the resource curse associated with the alternative indicators of resource intensiveness listed in Table III is not changed by excluding the three outliers. I can also confirm that it is not Singapore and Trinidad & Tobago that are driving the resource curse result, as suggested by Lederman and Maloney (2007b); the results in Tables I and III are robust to the removal of those two countries.

The country subsamples used in the resource curse tests in Tables I and III only include three of the top ten resource-intensive economies (as measured by SXP) in the data set. Resource intensive countries such as Iraq, Oman, Saudi Arabia, Botswana, Niger, and Zaire have no

⁸ There is no PXI70 data for Zimbabwe in regression 3.3, resulting in a sample size of 73 in that regression.

growth data and so are not included. These countries' omission is not inconsequential. SW suggest that Botswana is an example of a natural resource-abundant economy that grew rapidly, and that its exclusion may be biasing the results towards a resource curse. Indeed, when Sala-i-martin et al. (2004) find that the fraction of mining (and oil and gas) in GDP in 1988 has a *positive* effect on overall economic growth from 1960-1996, contrary to the received wisdom of the resource curse, they posit that this may be because of the inclusion of the "outlier" Botswana. But Botswana is, rather, an example of a non-resource abundant economy that grew rapidly in the 1970s and 1980s, supporting the resource curse. With its low resource intensity in 1970 ($SXP = 0.05$) it is more like Hong Kong ($SXP = 0.03$) and Singapore ($SXP = 0.03$) than a resource-abundant economy. Adding Botswana to the country sample should not overturn the resource curse, but strengthen it. Somalia, Tanzania, Barbados, Haiti, and Myanmar, some of the poorer performing developing economies in the non-resource intensive category, also lack growth data, and so are excluded. Adding these countries to the sample may weaken the resource curse.

To see whether the findings of a resource curse in Table I are dependent on country sample, I expanded the data sample for Table I's regressions by adding back the four outliers and filling in the missing growth data for Oman, Saudi Arabia, Botswana, Niger, Zaire, Somalia, Tanzania, Barbados, Haiti, and Myanmar using GEA7089 data rather than GEA7090 data, taken from the same data source as GEA7090. I also add back the four missing countries from regression 1.1. The five regressions, which now have a sample size of 105, 101, 101, 79, and 79, still show a strongly statistically significant resource curse, supporting Davis's (2011) proposition that Sala-i-martin et al. (2004) find a resource blessing not because of the inclusion of Botswana in their sample, but because they measure resource intensity near the end of the growth period and are picking up reversion in production levels.

I also use the SW 91-country subsample listed in Appendix 1 to test all of the regressions in Tables VIII, X, and XI, which explore indirect routes through which primary exports may be causing the slower growth found in Table 1 using this same subsample. This seems more appropriate than the approach SW take, since one is interested in the indirect routes operating in the country subsample in which the resource curse has been identified in Table I. It turns out that delimiting the investigation to the 91-country subsample matters in seven of the regressions. First, the SXP coefficient in regression 8.1 turns from statistically significant to statistically insignificant due to the removal of nine countries from the sample, weakening SW's conjectures about the resource curse observed in Table I operating through a decline in manufacturing and lost external economies of scale. Second, the SXP^2 coefficient in regression 10.4 turns from statistically significant to statistically insignificant due to the removal of 13 countries from the sample. This creates a lack of support for SW's claim that there is a U-shaped relationship between resource intensity and trade openness and that the heavily resource-intensive economies are less protectionist than the less resource-intensive economies.

Finally, the SXP coefficient turns from significant to insignificant in each of regressions 11.1 through 11.5 due to the elimination of 10 or more countries from the sample, depending on the regression (Regressions 11.1 and 11.2 now only have 55 countries in the sample, down from 65, and regressions 11.3 through 11.5 now have 74 countries, down from 85). These results weaken SW's proposition that higher resource intensity is related to poorer institutional quality, and that this is part of the reason for slower growth. That the measured impact of resource extraction on institutional quality is dependent on country subsample is consistent with Norman's (2009) observations for a similar data set.

The results of this section indicate that SW's finding of the resource curse is robust to different country samples. Their evidence that the resource curse is a result of resource production's impact on institutional quality and manufacturing output is not.

Scientific Replication

The subsequent research that explores the resource curse can be considered scientific replication of the original SW work. This research has been recently reviewed in Frankel (2010) and van der Ploeg (2011). Of all of this work, only Stijns (2005), Mehlum et al. (2006), and Davis (2011) begin with a pure replication of certain of the SW results. In this section I review the statistical replications by Mehlum et al. and Davis, and perform some additional scientific replication.

One of the most fertile areas for resource curse research has been the link between institutions and growth. SW find that institutional quality affects economic growth. After purely replicating SW regression 1.4 in their Table 3, Mehlum et al. perform a scientific replication of the link between institutional quality and growth by adding a missing resource curse/institutions interaction effect to the SW regression. They find that institutional quality only matters for the growth of resource rich countries, and that resource rich countries can have good or bad institutions that create or hinder growth. In other words, SW's lone institutional quality variable becomes insignificant once the interaction term is added to the regression. These results hold across both the SW 1997a and 1997c data sets that use different country samples, periods of analysis, and measures of institutional quality.

The general idea that the resource curse outcome is subject to good or bad institutions, and Mehlum et al's result in particular, gets considerable play in van der Ploeg's (2011) review of the resource curse literature (see Section 3.3). But despite Mehlum et al's assurances of statistical replicability of their results through the use of two SW data sets, I find that their institutions/resources interaction effect becomes insignificant at the 5% level in 65% of cases where a single country is randomly omitted from their 71-country SW sample. In one of these cases (Nicaragua) the interaction effect becomes insignificant at the 10% level. In other words, in more cases than not their reported result is contingent on the luck of there being complete data for the 71st country in the sample.

Another missing independent variable in the SW work is the direct effect of resource booms and busts on measured economic growth. SW (p. 7) make note of the problem of controlling for resource booms (and busts), and suggest that they do this by taking terms of trade effects into account in certain of their regressions. This would control for price-led booms, but not for quantity-led booms. Davis (2011) uses data that would have been available to SW at the time of their paper to control for mineral and energy booms over the sample period. He finds that the change in mineral and energy production is statistically significant in each of SW's Table I regressions, and that once this is modeled the resource curse diminishes or even goes to zero.⁹ At the time of their research SW had access to the same data that Davis uses in his work, and so this lack of scientific replication is not a result of scientific progress or improved econometric methods.

⁹ Davis uses his own computation of SNR in place of SXP in these regressions. These results also hold when SXP is used as the resource intensity measure.

Also of interest in the resource curse literature is whether or not empirical findings of a resource curse are robust to the way that primary production intensity is modeled (Davis 2011). Variable SXP has been suggested to pick up trade patterns not necessarily related to endowments (Lederman and Maloney 2007b), with high values the result of rather than a cause of underdevelopment (Alexeev and Conrad 2009, Mehlum et al. 2006). Mineral and energy production (SNR) is thus a preferred indicator of resource abundance. Minerals and energy have been particularly targeted as being responsible for the resource curse (Butkiewicz and Yanikkaya 2010), and are more likely to be the target of resource-grabbing institutions (Mehlum et al. 2006). I replaced SXP with SNR in each of the 9 SW resource curse regressions that contained GEA7090 as the dependent variable and SXP as an independent variable. The difference between the statistical significance of the two variables in each regression is minimal under both the original sample of 91 countries and also under the full country sample with growth data for 10 countries added. This is also the case when the resource intensity variables LAND (land area per capita in 1971) and PXI70 (ratio of primary exports to total exports in 1970) replace SXP, with the exception that PXI70 is statistically insignificant in regression 5.2 when using the 91 country sample. The fact that the initial value of LAND, which is a proxy for the initial stock endowment, still results in a resource curse lends support to Davis's (2011) suggestion that those who find no resource curse when using stock measures of resource intensity are in fact finding differences due to *when* a country's resource intensity is measured—near the beginning of the growth period (as here) or near the end (as in other work looking at stock measures)—rather than due to how it is measured.

Finally, given Alexeev and Conrad's (2009) argument that per capita measures of resource production are more appropriate than GDP shares and that controlling for initial income levels may be biasing the results, I test the five resource curse regressions in SW Table I using mineral and energy production per worker (M71/EAPOP71) with and without controls for initial level of per capita income. The data is taken from Davis (2011). In each regression the coefficient on per worker mineral production is negative and statistically significant at the 5% level.¹⁰

Conclusions

Overall, my pure replication effort confirms SW's conclusion that countries with intensive primary resource production as of 1970 grew more slowly from 1970 to 1990 than equivalent economies that did not have large primary resource sectors as of 1970. This should be of some comfort to the thousands who have cited SW's results in support of a resource curse and to the many more who have been influenced by them in terms of development policy. It also warrants the myriad of research that the original findings spawned, as the SW work did indeed set up a conundrum that needed to be solved. Now that the SW results have been shown to be purely replicable, that work can continue in earnest.

Given the low replicability equilibrium of economics research (Anderson et al. 2008), it is surprising that pure replication of SW was a success. Success would have been impossible had SW not posted their data and an appropriately commented STATA file. This reinforces the calls in the replication literature for authors to make available their data *and* code.

¹⁰ The sample size is now 113, 107, 107, 78, and 78 across regressions 1.1 through 1.5.

While my pure replication was successful, my statistical replication was not, revealing a lack of robustness of certain of SW's regressions investigating sectoral and institutional mechanisms by which the resource curse operates. This causes me to suspect that the paper's attempt to explain the resource curse via an endogenous growth effect involving shrinking manufactures is more tentative than even SW suggest.

Pure and statistical replication does not test the validity of the econometric specification that SW use, only that their reported results are consistent with the data that they provide. For example, their regressions may have endogeneity problems (Alexeev and Conrad 2009), or bias as a result of dropping countries for which there are missing values.¹¹ Many of the papers in Lederman and Maloney (2007a) examine these issues and generally find fault with the Sachs and Warner analysis, though none begin with a replication of Sachs and Warner. The scientific replications by Mehlum et al. (2006) and Davis (2011) that do begin with a replication of Sachs and Warner find omitted variable bias, though I in turn find that Mehlum et al.'s results are very sensitive to their country sample.

In the latest review of the resource curse literature van der Ploeg (2011, p. 381) casually observes that both cross-country and panel-data results are "sensitive to changing the sample period, the sample of countries, or the definition of various explanatory variables." He bleakly suggests that the data may simply not allow one to distinguish the causes of the different growth outcomes across resource-based economies. These statements are difficult to verify in the absence of studies that begin with replication, since differences across studies may indicate errors in analysis or reporting rather than weaknesses in the data. This paper, along with Mehlum et al. (2006) and Davis (2011), does find that the SW results are sensitive to country sample and omitted variable bias. Further studies that test for data period, data sample, and variable definition effects should also begin with replication so that any observed differences can assuredly be attributed to data differences rather than error in analysis or method.

¹¹ Listwise deletion will yield biased coefficient estimates when the missingness of data is correlated with the level of the dependent variable, in this case real per capita economic growth. Such a correlation seems likely for this type of analysis: in the 91 country sample in SW, the 17 countries that are missing rule of law (RL) data have an average growth rate of 0.46, while the 74 that have RL data have an average growth rate of 1.34.

References

- Alexeev, Michael, and Robert Conrad (2009), The elusive curse of oil, *Review of Economics and Statistics* 91(3): 586-98.
- Auffhammer, Maximilian (2009), The state of environmental and resource economics: a Google Scholar perspective, *Review of Environmental Economics and Policy* 3(2): 251-69.
- Anderson, Richard G., William H. Greene, B. D. McCullough, and H. D. Vinod (2008), The role of data/code archives in the future of economic research, *Journal of Economic Methodology* 15(1): 99-119.
- Butkiewicz J. L., and H. Yanikkaya (2010), Minerals, institutions, openness, and growth: an empirical analysis, *Land Economics* 86(2): 313–328.
- Davis, Graham A. (1995), Learning to love the Dutch Disease: evidence from the mineral economies, *World Development* 23(10): 1765-79.
- Davis, Graham A. (2011), The resource drag, *International Economics and Economic Policy* 8: 155-176.
- Frankel, Jeffrey A. (2010), The natural resource curse: a survey. NBER working paper 15836, Cambridge, MA.
- Hammermesh, Daniel S. (2007), Viewpoint: replication in economics, *Canadian Journal of Economics* 40(3): 715-33.
- Knabb, Shawn D. (2005), The contribution of institutions, trade, and geography to the development process: how robust is the empirical evidence to variations in sample? *Empirical Economics* 30: 393-409.
- Lederman, Daniel, and William F. Maloney, eds. (2007a), *Natural Resources: Neither Curse nor Destiny*. Washington, DC: The World Bank.
- Lederman, Daniel, and William F. Maloney (2007b), Trade structure and growth, in *Natural Resources: Neither Curse nor Destiny*, Daniel Lederman and William F. Maloney, eds. Washington, DC: The World Bank. Pp. 15-39.
- Matsuyama, K. (1992), Agricultural productivity, comparative advantage, and economic growth, *Journal of Economic Theory* 58: 317-334.
- Mehlum, Halvor, Karl Moene, and Ragnar Torvik (2006), Institutions and the resource curse, *Economic Journal* 116 (January): 1-20.
- Meier, Gerald, and James E. Rauch (2000), *Leading Issues in Economic Development*. New York: Oxford University Press.
- McCullough, B. D., Kerry Anne McGreary, and Teresa D. Harrison (2006), Lessons from the JCMB archive, *Journal of Money, Credit, and Banking* 38(4): 1093-1107.

McCullough, B. D., Kerry Anne McGreary, and Teresa D. Harrison (2008), Do economics journal archives promote replicable research?, *Canadian Journal of Economics* 41(4): 1406-20.

Norman, Catherine S. (2009), Rule of law and the resource curse: abundance versus intensity, *Environmental and Resource Economics* 43: 183-207.

van der Ploeg, Frederick (2011), Natural resources: curse or blessing?, *Journal of Economic Perspectives* 49 (2): 366-420.

Sachs, Jeffrey D., and Andrew M. Warner (1995), Natural resource abundance and economic growth. NBER Working Paper No. 5398, December.

Sachs, Jeffrey D., and Andrew M. Warner (1997a), Natural resource abundance and economic growth. Center for International Development and Harvard Institute for International Development, November.

Sachs, Jeffrey D., and Andrew M. Warner (1997b), Fundamental sources of long-run growth, *American Economic Review* 87(2): 184-88.

Sachs, Jeffrey D., and Andrew M. Warner (1997c), Sources of slow growth in African economies, *Journal of African Economies* 6(3): 335-76.

Sachs, Jeffrey D., and Andrew M. Warner (1999a), The big push, natural resource booms and growth, *Journal of Development Economics* 59: 43-76.

Sachs, Jeffrey D. and Andrew M. Warner (1999b), Natural resource intensity and economic growth, in *Development Policies in Natural Resource Economies*, ed. by Jörg Mayer, Brian Chambers, and Ayisha Farooq. Cheltenham, UK: Edward Elgar. Pp. 13-38.

Sachs, Jeffrey D., and Andrew M. Warner (2001), The curse of natural resources, *European Economic Review* 45: 827-38.

Sala-i-martin, Xavier, Gernot Doppelhofer, and Ronald I. Miller (2004), Determinants of long-term growth: a Bayesian averaging of classical estimates (BACE) approach, *American Economic Review* 94(4): 813-35.

Schonger, Martin (2002), The curse of natural resources. Diplomarbeit, Rheinische Friedrich-Wilhelms-Universität at BONN.

Stijns, Jean-Philippe C. (2005), Natural resource abundance and economic growth revisited, *Resources Policy* 30: 107-30.

Appendix 1: Country list and data, Table I, Sachs and Warner (1997a), including outliers.*

	Country	DTT7090	GEA7090	LGDPEA70	LINV7089	RL	SOPEN	SXP
1	ALGERIA	6.09	1.48	8.25	3.30	2.00	0.00	0.19
2	BENIN	-3.11	-0.80	7.68	1.49	.	0.04	0.08
3	BURKINA FASO	-0.61	1.72	6.54	2.25	.	0.00	0.04
4	BURUNDI	-6.46	2.80	6.43	1.82	.	0.00	0.10
5	CAMEROON	-2.54	2.56	7.29	2.36	3.00	0.00	0.18
6	CENTRAL AFR.R.	0.09	-1.11	7.20	1.67	.	0.00	0.09
7	CONGO	7.44	1.74	8.03	2.22	.	0.00	0.08
8	EGYPT	-0.52	2.23	7.67	1.64	1.00	0.00	0.07
9	GAMBIA	-2.04	0.61	7.17	1.80	.	0.19	0.36
10	GHANA	-3.26	-0.73	7.62	1.62	1.00	0.19	0.21
11	IVORY COAST	-1.20	-1.29	8.07	2.31	.	0.00	0.29
12	KENYA	-0.80	2.24	7.11	2.68	2.00	0.12	0.18
13	MADAGASCAR	-2.15	-2.37	7.67	0.33	.	0.00	0.12
14	MALAWI	-1.05	0.87	6.76	2.42	1.00	0.00	0.21
15	MALI	0.25	1.42	6.68	1.77	.	0.08	0.08
16	MAURITANIA	-2.50	-0.32	7.38	2.84	.	0.00	0.41
17	MAURITIUS	1.39	3.39	8.41	2.34	.	1.00	0.29
18	MOROCCO	1.71	1.59	7.93	2.42	1.00	0.23	0.11
19	NIGERIA	5.95	1.30	7.32	2.71	1.00	0.15	0.14
20	RWANDA	-2.86	0.86	7.16	1.55	.	0.00	0.11
21	SENEGAL	0.77	0.25	7.67	1.63	1.00	0.00	0.14
22	SIERRA LEONE	-2.52	-2.09	7.87	0.31	.	0.00	0.09
23	SOUTH AFRICA	-2.20	-0.23	8.68	2.92	.	0.00	0.17
24	SUDAN	-0.13	-0.32	7.34	1.88	1.00	0.00	0.16
25	TOGO	-0.26	0.47	7.06	2.91	2.00	0.00	0.19
26	TUNISIA	4.04	2.76	7.97	2.68	3.00	0.04	0.10
27	UGANDA	-3.82	-0.80	7.16	0.92	1.00	0.08	0.27
28	ZAMBIA	-4.40	-2.18	7.68	2.77	3.00	0.00	0.54
29	ZIMBABWE	-3.47	0.02	7.72	2.70	1.00	0.00	0.17
30	CANADA	-0.68	2.19	9.70	3.19	6.00	1.00	0.10
31	COSTA RICA	-2.45	0.13	8.65	2.85	4.00	0.15	0.19
32	DOMINICAN REP.	-1.31	0.85	8.04	2.88	3.00	0.00	0.13
33	EL SALVADOR	-2.51	-0.12	8.18	2.10	1.00	0.04	0.16
34	GUATEMALA	-2.40	0.23	8.28	2.22	1.00	0.08	0.11
35	HONDURAS	-1.63	0.36	7.81	2.60	1.00	0.00	0.23
36	JAMAICA	-0.45	-1.35	8.63	2.94	1.00	0.38	0.14
37	MEXICO	1.78	1.06	8.99	2.84	4.00	0.15	0.02
38	NICARAGUA	-3.61	-3.09	8.47	2.50	1.00	0.00	0.19
39	TRINIDAD&TOBAGO	1.42	-0.01	9.45	2.57	4.00	0.00	0.08
40	U.S.A.	-1.41	1.34	9.95	3.13	6.00	1.00	0.01
41	ARGENTINA	-2.74	-0.69	9.09	2.83	2.00	0.00	0.05
42	BOLIVIA	1.17	-0.01	8.04	2.73	1.00	0.73	0.18
43	BRAZIL	-2.45	1.99	8.41	2.98	4.00	0.00	0.05
44	CHILE	-4.56	0.26	8.77	2.90	5.00	0.58	0.15
45	COLOMBIA	-1.81	1.43	8.33	2.75	2.00	0.19	0.09
46	ECUADOR	5.37	1.64	8.16	3.13	4.00	0.73	0.11
47	PARAGUAY	-1.12	1.58	7.93	2.74	1.00	0.04	0.10
48	PERU	-2.59	-1.63	8.56	2.86	2.00	0.12	0.15
49	URUGUAY	-0.95	0.59	8.78	2.66	3.00	0.00	0.09
50	VENEZUELA	4.80	-1.85	9.62	3.10	3.00	0.04	0.24
51	BANGLADESH	-2.75	0.14	7.83	1.14	1.00	0.00	0.01

	Country	DTT7090	GEA7090	LGDPEA70	LINV7089	RL	SOPEN	SXP
52	CHINA	-0.34	2.25	7.13	3.02	.	0.00	0.02
53	HONG KONG	-2.00	5.12	8.94	3.03	6.00	1.00	0.03
54	INDIA	-2.02	1.99	7.27	2.65	3.00	0.00	0.02
55	INDONESIA	4.62	4.56	7.18	3.07	1.00	0.77	0.11
56	IRAN	7.68	-1.91	9.16	3.02	1.00	0.00	0.12
57	ISRAEL	-0.05	2.22	9.21	3.20	1.00	0.19	0.04
58	JAPAN	-0.96	3.31	9.27	3.54	6.00	1.00	0.01
59	JORDAN	-0.21	2.93	7.93	2.82	1.00	1.00	0.09
60	KOREA, REP.	-0.83	5.71	8.03	3.29	3.00	0.85	0.02
61	PAKISTAN	-2.63	1.15	7.62	2.26	1.00	0.00	0.03
62	PHILIPPINES	-2.35	0.68	7.90	2.80	1.00	0.08	0.13
63	SINGAPORE	1.14	5.77	8.56	3.58	6.00	1.00	0.03
64	SRI LANKA	-1.18	1.92	7.73	2.39	2.00	0.23	0.15
65	SYRIA	6.64	2.40	8.50	2.73	1.00	0.04	0.08
66	TAIWAN	-0.20	5.77	8.25	3.20	6.00	1.00	0.02
67	THAILAND	-1.00	3.15	8.01	2.87	3.00	1.00	0.09
68	AUSTRIA	-0.25	2.16	9.41	3.25	6.00	1.00	0.04
69	BELGIUM	-0.26	2.02	9.49	3.10	6.00	1.00	0.11
70	CYPRUS	-3.18	3.60	8.76	3.28	.	1.00	0.14
71	DENMARK	-0.40	1.59	9.62	3.20	6.00	1.00	0.10
72	FINLAND	0.46	2.66	9.41	3.52	6.00	1.00	0.07
73	FRANCE	0.07	1.77	9.60	3.29	6.00	1.00	0.03
74	GERMANY, WEST	-0.09	1.68	9.60	3.25	6.00	1.00	0.02
75	GREECE	-1.07	2.14	8.80	3.20	3.00	1.00	0.04
76	IRELAND	-0.27	2.73	9.07	3.26	5.00	0.96	0.15
77	ITALY	-0.55	2.19	9.37	3.25	5.00	1.00	0.02
78	NETHERLANDS	-0.29	1.25	9.60	3.15	6.00	1.00	0.15
79	NORWAY	0.40	2.92	9.46	3.48	6.00	1.00	0.10
80	PORTUGAL	1.73	3.75	8.58	3.14	6.00	1.00	0.05
81	SPAIN	-0.64	2.12	9.15	3.22	5.00	1.00	0.03
82	SWEDEN	0.14	1.66	9.71	3.11	6.00	1.00	0.05
83	SWITZERLAND	-0.18	0.99	9.89	3.36	6.00	1.00	0.02
84	TURKEY	-1.14	2.09	8.30	3.11	3.00	0.04	0.04
85	U.K.	-0.14	1.99	9.52	2.90	6.00	1.00	0.03
86	AUSTRALIA	-1.51	1.15	9.75	3.31	6.00	1.00	0.10
87	NEW ZEALAND	0.27	0.51	9.66	3.17	6.00	0.15	0.18
	Outliers							
88	CHAD	2.26	-2.40	7.09	0.79		0.00	0.08
89	GABON	7.97	0.39	8.70	3.34	2.00	0.00	0.33
90	GUYANA	-1.51	-3.64	8.22	3.01	0.00	0.08	0.51
91	MALAYSIA	0.52	3.69	8.33	3.26	4.00	1.00	0.37

*The original data is reported up to 16 decimal places.

Appendix 2: Alphabetic list of Sachs and Warner regression variables mentioned in this paper

DTT7080 Average annual growth of the natural logarithm of the external terms of trade between 1970 and 1980.

DTT8090 Average annual growth of the natural logarithm of the external terms of trade between 1980 and 1990.

DTT7090 Average annual growth of the natural logarithm of the external terms of trade between 1970 and 1990.

GEA7080 Average annual growth of purchasing power adjusted GDP per person aged 15-64 (economically active population) between the years 1970 and 1980.

GEA8090 Average annual growth of purchasing power adjusted GDP per person aged 15-64 (economically active population) between the years 1970 and 1980.

GEA7089 Average annual growth of purchasing power adjusted GDP per person aged 15-64 (economically active population) between the years 1970 and 1989.

GEA7090 Average annual growth of purchasing power adjusted GDP per person aged 15-64 (economically active population) between the years 1970 and 1990.

GR6070 Average annual real per-capita growth between 1960 and 1970.

LAND Natural logarithm of the ratio of total land area to population in 1971.

LGDPEA70 Natural logarithm of real GDP per person aged 15-64 in 1970.

LGDPEA80 Natural logarithm of real GDP per person aged 15-64 in 1980.

LGDPNR70 Natural logarithm of GNP produced in sectors other than the natural resource sector in 1970.

LINV7079 Natural logarithm of the ratio of real gross domestic investment (public plus private) to real GDP, averaged over the period 1970-1979.

LINV8089 Natural logarithm of the ratio of real gross domestic investment (public plus private) to real GDP, averaged over the period 1980-1989.

LINV7089 Natural logarithm of the ratio of real gross domestic investment (public plus private) to real GDP, averaged over the period 1970-1989.

M71/EAPOP71 Mineral and energy sales per economically active population in 1971 based on 1971 USD prices.

PXI70 Ratio of primary exports to total merchandise exports in 1970.

RL Index for rule of law ranging from 0 (low) to 6 (high) measured as of 1982.

SOPEN The fraction of years during 1970-1990 in which Sachs and Warner rate an economy as open.

SOPEN7 The fraction of years during 1970-1980 in which Sachs and Warner rate an economy as open.

SOPEN8 The fraction of years during 1980-1990 in which Sachs and Warner rate an economy as open.

SNR Share of mineral production in GNP in 1971.

SXP Share of primary products exports in GNP in 1970.

SXP80 Share of primary products exports in GNP in 1980.