Does the version of the Penn World Tables matter? An analysis of the relationship between growth and volatility

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Abstract. The Penn World Tables (PWT) are an important data source for cross-country comparisons in economics. The PWT have undergone several revisions over time. This paper documents how countries' output growth rates change across four publicly available versions of the PWT. We show that for some countries the magnitude of the differences is significant and/or the sign of the growth rates changes across versions. Using as an example Ramey and Ramey (1995), who found growth volatility has a significant negative effect on growth, we demonstrate that conclusions based on one version of the PWT may not hold under another version. JEL classification: O11, O47, O50

Est-ce que la version qu'on utilise des tableaux mondiaux de Penn porte à conséquence? Une analyse de la relation entre croissance et volatilité. Les tableaux mondiaux de Penn (Penn World Tables ou PWT) sont une source importante de données comparatives entre pays dans le monde économique. Les PWT ont subi plusieurs révisions dans le temps. Ce mémoire montre d'abord comment les taux de croissance du produit des pays changent selon les quatre versions des PWT disponibles au public. On montre que pour certains pays la taille des différences est significative et que même le signe de ces taux change d'une version à l'autre. Utilisant comme exemple Ramey et Ramey (1995) qui ont montré que la volatilité de la croissance a un effet négatif sur la croissance, les auteurs montrent que les conclusions fondées sur une version des PWT peuvent ne pas être fondées dans une autre version.

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1. Introduction

The Penn World Tables (hereafter PWT), a popular data source containing an expanded set of international comparisons, have been extensively used in various fields of economics, including growth, development, and international trade. Data in the PWT are measured at purchasing power parity and have covered a large number of countries from all regions for more than 50 years. This allows researchers to make real quantity comparisons both across countries and over time.

The PWT have been revised and updated since the first release in the early 1990s. PWT5 was made publicly available in 1991, along with the description provided by Summers and Heston (1991). PWT5.5, a revised and updated version of PWT5, became available in 1993. Subsequently, version 5.6 (PWT5.6) was released in January 1995. Version 6.1 (PWT6.1) became available in 2002. Despite the importance of the PWT, however, these revisions have not been explored so far.

This paper examines how countries' growth rates, one of the most frequently used variables, change across the four versions. We provide evidence that the magnitude of the difference is not negligible for some countries. Moreover, for 13% of all countries, even the sign of the growth rates changes across different versions. It is also found that the correlation between the growth rates of PWT5.0 and PWT6.1 is only 53%, a surprisingly low number. This has significant implications for numerous empirical results obtained from the PWT. Given that variables in one version are not identical to those in another, owing to revisions, some conclusions based on the former may not hold when the latter is used instead. In other words, evidence could be version dependent. Such a possibility has not been explored before because researchers typically use only one version of the PWT (usually the most recent one when the research is conducted) for analysis and, therefore, the robustness of their results across versions has not been examined.

We illustrate that these could be legitimate concerns, using the study of Ramey and Ramey (1995) as a particular example. Using PWT5.0, Ramey and Ramey (1995) examined the link between growth and growth uncertainty and found that growth is significantly and negatively related to growth volatility. We use all four versions of the PWT and analyze whether or not their evidence is version dependent. We find that their results are not robust across versions of the PWT: growth and uncertainty are negatively and significantly related in some but not all versions.

We also conduct a similar exercise for a simple Solow growth model, the basis for cross-country growth regression studies. In particular, we estimate the standard growth regression model by using Arellano and Bond's (1991) GMM estimator. We show that the results appear to be version dependent, like those for the relationship between growth and uncertainty. Although we use the same set of instruments for all four versions, the overidentifying restrictions are rejected in two versions of the PWT. For the two versions where the overidentifying restrictions are not rejected, the results are qualitatively but not quantitatively similar: the point estimate of the rate of convergence obtained from one version is twice as small as that from the other. These results, together with those for the growth-uncertainty relationship, suggest that the version appears to matter in general but the extent may depend on applications.

Besides revisions, there is another data issue in the PWT that has received little attention to date. As noted in the technical documentation to the PWT, the data quality varies across countries. That is, data on some countries are measured relatively accurately, while data on others are not.[1] We address this issue by building on Dawson et al. (2001). To examine whether data quality affects the evidence by Ramey and Ramey (1995), Dawson et al. (2001) ran the same regressions as those in Ramey and Ramey (1995) with additional regressors, such as countries' data quality dummies (created from a quality index provided by the PWT). They found that the evidence by Ramey and Ramey (1995) does not hold when controlling for those data quality dummies. We extend the study of Dawson et al. (2001) by (1) controlling for more factors, (2) examining several versions of the PWT, and (3) allowing the relationship between growth and uncertainty to vary with data quality. Our findings suggest that data quality indeed matters but not in the manner found by Dawson et al. (2001); growth and uncertainty are negatively and significantly related only for countries with the worst data quality.

2. Penn World Tables

2.1. Construction

The PWT are constructed using data from the International Comparison Program (ICP). The ICP conducted so-called benchmark studies in 1970, 1975, 1980, 1985, 1990 (only partial), 1993/1996, and 2005. In a benchmark study, each participating country provides national annual average prices of goods and services. The characteristics of items are closely specified to ensure that countries are pricing the same items adjusted for quality. Item prices are expressed as ratios of the corresponding item prices of the numeraire country (i.e., the United States). For example, if the price for fresh milk is \$2 per litre in the U.S., while that in Australia is AU\$3, then the price ratio is 1.5AU\$/\$. Price ratios are grouped by expenditure categories[2] and averaged within a category to obtain the price parity for that category.

The expenditure-category parities (p_{ij}) are aggregated by using data on local currency expenditures $(pq)_{ij}$, where i and j denote expenditure category and country, respectively.[3] Data on $(pq)_{ij}$ are provided by participating countries.

1 Dowrick (2005) reported that PWT5.6 appears to contain errors in the demographic data for some countries.

2 They are called 'basic headings,' which are the lowest aggregate levels for which national expenditure data are available.

3 Hereafter, we rely heavily on PWT6 Technical Documentation.

The local currency expenditures and the price parities are divided by the exchange rate, and hence all input values are expressed in the nominal U.S. dollars. Given these inputs, the aggregate price levels, pl_j, are obtained as follows. First, notional quantities (q_{ij}) are obtained by dividing the expenditures by the price parities, that is, $q_{ij} = (pq)_{ij}/p_{ij}$.[4] Then, the Geary multilateral method (Geary 1958) is used along with $(pq)_{ij}$ and q_{ij} as inputs. The procedure is based on the two equations:

$$\pi_i = \sum_j \frac{(pq)_{ij}}{pl_j} \times \frac{1}{\sum_j q_{ij}} \tag{1}$$

$$pl_j = \frac{\sum_i (pq)_{ij}}{\sum_i \pi_j q_{ij}}, \tag{2}$$

where π_i is the international price for expenditure category i and, thus, $\pi_i q_{ij}$ represents the real expenditure for category i in country j. The equations are iteratively solved for π_i and pl_j with initial values of 1s for all pl_j. Given $(pq)_{ij}$, q_{ij}, π_i, and pl_j, it is possible to compute the price levels of consumption (plC_j), investment (plI_j), government expenditure (plG_j), and their sum (i.e., domestic absorption) as well as their real aggregate values.

Importantly, not all of the countries participated in the benchmark studies, and the number of participating countries varies across the rounds: 10 countries in 1970; 34 in 1975; 60 in 1980; 64 in 1985; 117 in 1993/1996; and 147 in 2005. For countries not participating in the benchmark study, the price levels of consumption, investment, and government expenditure are estimated using 'post-adjustment indexes' created from three price surveys in capital cities around the world. First, regressions of the following type are run using data on participating countries:

$$\ln(RDA) = \theta_0 + \sum_{k=1}^{3} \theta_k \ln\left(\frac{NDA}{PAI_k}\right) + \theta_4 AFRICA + \theta_5 ASIA + \epsilon, \tag{3}$$

where RDA (NDA) is the real (nominal) per capita domestic absorption, $AFRICA$ ($ASIA$) is a dummy variable for the sub-Sahara African (Central Asian) countries, and PAI_k are the post-adjustment indexes on the basis of the three surveys conducted by (1) the United Nations International Civil Service Commission ($k = 1$); (2) the Employment Conditions Abroad, a British organization with members

4 More precisely, expenditures are adjusted by 'super-country weights,' so that $q_{ij} = (pq)_{ij} \cdot scw_j/p_{ij}$, where scw_j is the super-country weight for country j. The objective of using this weight is to minimize the difference in results that may occur from adding or removing countries from an aggregation. For more details on super-country weights, see PWT6 Technical Documentation.

including multinational firms, governments, and non-profit international agencies ($k = 2$); and (3) the U.S. State Department ($k = 3$). Using the coefficients and national accounts series, short-cut regression estimates of the real per capita domestic absorption are obtained for non-participating countries.

Subsequently, the following set of equations is estimated using data on participating countries:

$$RSHC = \alpha_1 NSHC + \beta_1 NSHI + \gamma_1 NSHG + \delta_1 RDA + u_1 \tag{4}$$

$$RSHI = \alpha_2 NSHC + \beta_2 NSHI + \gamma_2 NSHG + \delta_2 RDA + u_2 \tag{5}$$

$$RSHG = \alpha_3 NSHC + \beta_3 NSHI + \gamma_3 NSHG + \delta_3 RDA + u_3, \tag{6}$$

where $RSHC$ ($NSHC$), $RSHI$ ($NSHI$), and $RSHG$ ($NSHG$) are the real (nominal) shares of consumption, investment, and government expenditure, respectively. Using the coefficients and national accounts series, a set of estimated real shares are obtained for non-participating countries. Finally, the price level for consumption in country j is computed as

$$plC_j = \frac{NSHC_j}{RSHC_j} \times \frac{NDA_j}{RDA_j}, \tag{7}$$

and similarly for investment (plI_j) and government expenditure (plG_j).

When a country has participated in one or more previous benchmark studies, the PWT incorporate price levels from earlier studies in the following manner. Suppose that the PWT were using the 1996 benchmark. Then, the PWT extrapolate price levels from the previous study, that is, 1985 to 1996, using the national accounts deflators. Consequently, the PWT have extrapolated price levels from the 1985 benchmark, in addition to actual price levels from the 1996 benchmark, and predicted price levels from the short-cut regression estimates. Generally, one or two sets of price levels are averaged with prespecified weights to obtain the final price levels for 1996.

After the benchmark year's price levels for consumption, investment, and government expenditure have been obtained for both participating and non-participating countries, the next step is multilateral aggregation of all countries that uses equations (1) and (2) where i goes from 1 to 3. Here, $(pq)_{1j}$, $(pq)_{2j}$, and $(pq)_{3j}$ are replaced with nominal consumption expenditure ($NOMC_j$), nominal investment expenditure ($NOMI_j$), and nominal government expenditure ($NOMG_j$), respectively, in current prices divided by country j's exchange rate relative to the U.S. Also, q_{1j}, q_{2j}, and q_{3j} are replaced with notional quantities $qC_j(=NOMC_j/plC_j)$, $qI_j(=NOMI_j/plI_j)$, and $qG_j(=NOMG_j/plG_j)$, respectively. This provides a set of international price levels for consumption (π_C), investment (π_I), and government expenditure (π_G). Similarly, a multilateral aggregation is implemented for each year other than the benchmark year.

As before, the inputs are the national expenditures on consumption, investment, and government as well as the corresponding price levels. The price levels are extrapolated from the benchmark year by the change in the component deflator relative to the U.S. change.

Given all of these, the chain GDP series (i.e., the ones that are often used for making intertemporal cross-country growth comparisons) are constructed as follows. First, the real current expenditure for each component is obtained by multiplying the international price of the component by the notional quantity. For example, the real current consumption expenditure ($REALC_j$) equals $(\pi_{Ct})\left(qC_{jt}\right)$. Then, the growth rate of domestic absorption ($DAGR_{jt}$) is computed as follows:

$$DAGR_{jt} = RSHC_{jt} \times \frac{NOMC^{const}_{jt+1}}{NOMC^{const}_{jt}} + RSHI_{jt} \times \frac{NOMI^{const}_{jt+1}}{NOMI^{const}_{jt}} + RSHG_{jt} \times \frac{NOMG^{const}_{jt+1}}{NOMG^{const}_{jt}},$$

where $NOMC^{const}$, $NOMI^{const}$, and $NOMG^{const}$ are constant price values of consumption, investment, and government expenditure, respectively, in the national accounts data. Using $DAGR_{jt}$ and $REALDA_{jt}$ (i.e., the sum of real current consumption, investment, and government expenditure), the chain domestic absorption ($CHAINDA_{jt}$) is obtained by

$$CHAINDA_{jt} = \frac{REALDA_{jt+1}}{DAGR_{jt}},$$

for years before the benchmark year and by

$$CHAINDA_{jt} = REALDA_{jt-1} \times DAGR_{jt-1,}$$

for years after the benchmark year. Finally, the chain GDP series are obtained as the sum of $CHAINDA_{jt}$ and the constant price net foreign balance.

2.2. Why are the data different across versions of the PWT?

There may be several potential sources of differences across the PWT. Measurement errors associated with the collection of prices in benchmark studies may be one source, but it is hard to make any judgments about their importance because of a lack of any information about these measurement errors. Revisions of the national data can be another source of differences, as identified in the PWT documentation. However, it does not seem to be very important, since revisions of national data usually take place during the relatively short period of time after the initial data release, and by the time of the release of a subsequent version of the PWT, all revisions are generally completed. Finally, differences across the

PWT may come from the way of constructing the PWT. Each benchmark study provides an additional set of prices for a benchmark year that is used to calculate a set of international prices as well as national aggregate price levels. The extrapolated prices from the previous version of the PWT generally differ from those obtained from a new benchmark study, and, as described earlier, one or two sets of prices are averaged with appropriate weights to get the final set of prices for the benchmark year for a new version of the PWT. This final set of prices, together with national deflators, is then used to get the price sets for the whole period considered. So it is not surprising that some differences are observed even for developed countries that participated in all benchmark studies. In the case of countries that didn't participate in some or all benchmark studies (for which a short-cut regression had to be used) it is natural to expect that the differences across versions can be quite substantial.

One might expect that the PWT data derived from more recent benchmark studies have better quality, as they consist of more participating countries for which the price levels need not to be estimated. However, this is not necessarily the case. As noted on the PWT Web site (http://pwt.econ.upenn.edu/icp.html), the quality of PWT6 derived from the 1993/1996 benchmark study is not necessarily better than that of PWT5 from the 1985 study. Price levels reported in PWT6 may not well represent actual ones because the number of expenditure categories used for PWT6 is substantially smaller than that for PWT5: 32 categories for PWT6 and about 150 for PWT5. In the 1993 round, reduced information surveys on the 32 categories were conducted in a number of countries with limited resources and/or statistical capability, while information on many more categories was gathered for other participating countries. Though this increased the number of participating countries dramatically (i.e., from 64 in 1985 to 117 in 1993/1996), price levels in PWT6 needed to be computed based only on the 32 categories despite the availability of information on more categories for other countries. Moreover, those countries for which the reduced surveys were conducted might have had little experience in the survey, and hence the results might have been relatively unreliable.

3. Data description

In this section we examine properties of the growth rate of GDP per capita (log difference) in four versions of the Penn World Tables: PWT5.0, PWT5.5, PWT5.6, and PWT6.1. Table 1 presents the mean and standard deviation of the growth rates over the period from 1962 to 1985 for 110 countries. When countries do not have data for the whole period, the period over which the mean and standard deviation are calculated is shown in parentheses.

Several findings immediately emerge from table 1. First, the mean and standard deviation of growth rates of a country in one version differs from those in another. For example, the mean (standard deviation) of growth rates of Canada

TABLE 1
Mean and standard deviation of the growth rate (%) of GDP per capita

Country	*mgr*50	*mgr*55	*mgr*56	*mgr*61	*stdgr*50	*stdgr*55	*stdgr*56	*stdgr*61
Algeria	3.34	2.56	2.61	3.36	11.64	7.67	7.99	9.17
Angola	−1.88	−1.39	−1.32	−1.39	10.13	9.72	9.48	10.2
Argentina	0.41	0.42	0.45	0.55	4.24	4.74	5.11	5.22
Australia	2.45	2.40	2.43	2.33	2.57	2.71	2.56	2.47
Austria	3.27	3.01	3.02	3.24	1.9	1.96	1.86	2.27
Bangladesh	0.39	1.33	0.93	0.55	8.17	7.47	9.98	5.31
Barbados	2.47	3.26	3.27	4.15	4.83	4.37	4.37	6.06
Belgium	2.72	2.76	2.81	3.02	2.5	2.62	2.4	2.41
Benin	0.06	−0.27	−0.03	0.36	4.65	4.56	4.91	4.1
Bolivia	1.31	1.72	1.76	0.26	4.08	3.64	3.6	4.64
Botswana	6.85	5.68	5.96	5.93	7.39	7.44	7.21	7.62
Brazil	2.89	3.17	3.18	3.57	4.79	4.68	4.63	4.04
Burkina Faso (66-85)	1.50	1.43	1.42	1.37	4.15	3.94	4.43	3.81
Burundi	0.70	−0.46	−0.64	2.06	8.57	10.2	9.79	8.48
Cameroon	3.57	2.87	3.38	2.15	4.18	4.07	4.36	6.49
Canada	2.76	3.19	3.18	2.88	2.98	2.56	2.48	2.66
Cape Verde	1.81	3.54	3.14	3.56	10.38	8.39	9.74	9.85
Central African Rep.	−0.72	−0.54	−0.57	−1.51	4.12	4.48	4.51	4.94
Chad	−1.79	−2.25	−2.55	−0.70	8.17	9.74	12.1	14.87
Chile	0.63	0.32	0.59	1.01	6.16	8.04	6.88	6.35
China (69-85)	6.27	6.28	4.92	4.11	5.74	5.3	5.15	3.66
Colombia	2.23	2.22	2.24	2.14	3.04	2.75	2.69	2.03
Congo, Dem. Rep.	0.04	−0.11	−0.19	−1.14	7.51	7.28	7.31	6.34
Congo, Rep. of	3.62	3.65	3.65	6.25	5.57	6.89	6.92	9.68
Costa Rica	2.14	1.95	1.71	1.41	3.76	4.08	4.17	3.82
Cote d'Ivoire	1.33	1.70	1.21	1.49	5.39	4.78	6.67	6.19
Cyprus	4.62	4.47	4.51	4.54	10.02	9.42	9.06	9.14
Denmark	2.72	2.46	2.49	2.31	2.83	3.05	2.89	3.06
Dominican Rep.	2.44	2.60	2.56	2.70	6.77	6.78	6.96	4.86
Ecuador	2.67	2.90	2.86	2.85	4.94	4.98	4.99	4.59
Egypt	5.20	3.66	3.64	2.47	5.92	3.26	3.29	5.38
El Salvador	1.34	1.02	1.10	0.36	4.9	4.72	4.64	4.76
Ethiopia	0.82	0.50	0.57	−0.23	2.07	2.49	2.49	4.85
Fiji	1.54	1.66	1.73	1.92	5.42	5.54	5.48	5.12
Finland	3.31	3.11	3.14	3.23	3.12	3.2	3.04	2.86
France	2.97	2.76	2.90	3.11	2.04	2.25	2.05	2.07
Gabon	4.13	3.02	3.01	3.32	15.07	9.79	9.48	10.47
Gambia, The	2.50	1.26	1.30	2.31	9.22	9.94	10.59	7.27
Ghana	−0.97	−0.73	−0.71	0.87	5.08	6.9	7.57	10.21
Greece	4.17	4.10	4.12	3.80	3.84	3.87	3.74	4.73
Guatemala	1.11	0.87	0.90	1.64	2.86	3.38	3.32	2.7
Guinea	0.31	−0.39	0.70	−0.84	3.39	4.27	7.01	4.55
Guinea-Bissau	1.29	1.15	1.19	0.71	9.51	10.78	10.44	15.19
Guyana	−1.12	−1.01	−1.06	0.39	9.67	10.57	11.41	7.55
Haiti (68-85)	0.62	0.47	0.47	0.09	4.32	4.08	4.1	3.95
Honduras	1.36	1.10	1.24	1.24	3.6	3.38	3.14	3.99
Hong Kong	5.97	6.36	6.27	6.59	4.05	4.36	4.21	4.91
Hungary (71-85)	3.66	3.01	3.02	3.56	3.56	3.36	3.18	3.21
Iceland	3.37	3.61	3.83	3.59	4.09	4.78	4.27	4.59
India	0.75	1.44	1.40	1.91	3.62	4.76	5.45	3.64
Indonesia (63-85)	3.65	4.07	4.03	3.81	4.8	4.3	4.18	3.44

Continued

TABLE 1 *Continued*

Country	*mgr*50	*mgr*55	*mgr*56	*mgr*61	*stdgr*50	*stdgr*55	*stdgr*56	*stdgr*61
Iran	2.64	2.07	1.48	2.10	11.21	9.91	10.01	9.6
Ireland	2.39	3.20	3.07	2.92	2.87	3.07	2.36	2.12
Israel	3.22	3.27	3.28	2.87	4.48	4.08	4.14	5.2
Italy	3.35	3.25	3.28	3.29	2.76	2.98	2.84	2.58
Jamaica	1.09	0.73	0.93	0.64	4.99	5.29	5.37	4.93
Japan	5.24	5.21	5.24	5.19	3.62	3.61	3.55	3.75
Jordan	2.47	3.13	4.17	2.39	7.35	7.89	10.14	8.04
Kenya	1.76	1.41	1.43	1.76	5.58	7.61	7.73	6.39
Korea, Rep. of	5.84	6.39	6.35	6.04	4.49	4.44	4.3	3.78
Lesotho	5.35	4.77	4.73	2.62	8.46	7.49	7.54	7.43
Luxembourg	2.26	1.83	1.90	2.14	3.45	4.68	4.52	3.72
Madagascar	−1.65	−1.81	−1.78	−1.03	3.79	4.33	4.66	3.21
Malawi	0.88	0.90	0.95	1.65	5.31	5.33	5.23	6.27
Malaysia	3.92	4.30	4.30	3.78	4.33	4.77	4.63	2.63
Mali	−0.27	0.28	0.13	−0.37	5.43	5.34	5.57	6.62
Mauritania	−0.11	−0.37	−0.11	2.91	8.49	7.38	7.37	12.65
Mauritius	2.19	0.99	1.00	2.24	5.87	8.05	8.03	5.64
Mexico	2.55	2.60	2.81	2.74	3.88	4.27	4.28	2.97
Morocco	2.74	2.82	2.82	3.04	4.62	4.69	4.68	4.2
Mozambique	−2.06	−2.02	−1.81	−2.97	7.91	7.45	7.32	9.35
Nepal	0.89	1.69	1.78	1.14	4.14	7.22	7.72	3.78
Netherlands	2.70	2.55	2.57	2.51	2.41	2.33	2.33	2.23
New Zealand	1.46	1.44	1.46	1.25	3.29	3.46	3.16	3.95
Nicaragua	0.10	0.20	0.25	0.01	13.35	9.74	9.48	7.17
Niger	0.09	0.12	0.05	−2.53	8.46	8.51	10.7	7.67
Nigeria	0.00	1.88	2.73	0.14	9.09	10.79	12.08	10
Norway	3.61	3.66	3.68	3.33	1.84	1.65	1.63	1.65
Pakistan	2.21	2.71	2.71	3.44	3.82	4.73	4.68	2.96
Panama	3.28	3.03	3.03	3.50	3.45	3.46	3.36	3.85
Papua New Guinea	1.34	0.91	0.81	0.85	5.72	4.13	4.04	5.01
Paraguay	2.68	2.47	2.25	2.23	5.15	5.61	6.55	3.7
Peru	0.84	0.84	0.77	1.06	4.95	4.93	5	4.63
Philippines	1.53	1.21	1.21	1.20	3.78	4.08	3.88	3.42
Portugal	4.01	3.83	3.87	3.85	4.66	4.52	4.37	4.27
Rwanda	1.53	1.67	1.78	0.88	9.82	9.43	9.48	6.84
Senegal	−0.06	0.28	0.34	−0.75	4.59	4.73	4.72	6.09
Seychelles (77-85)	2.69	4.71	4.97	1.81	6.67	7.77	7.62	10.55
Sierra Leone	0.47	0.80	0.13	0.51	5.99	6.31	9.46	6.97
Singapore	5.90	6.30	6.67	7.50	4.46	4.57	5.21	10.21
South Africa	1.64	1.89	1.69	1.77	4.87	3.89	3.98	2.1
Spain	3.08	3.12	3.21	3.37	3.51	3.29	3.2	3.32
Sri Lanka	1.72	2.54	2.47	2.19	5.09	4.78	4.37	2.21
Sweden	2.49	2.20	2.19	2.33	1.81	1.95	1.87	2.17
Switzerland	1.53	1.61	1.62	1.52	2.44	2.85	2.68	2.95
Syria	4.13	4.04	4.05	3.03	10.25	11.98	11.98	14.34
Taiwan	6.29	5.85	5.98	6.75	3.03	2.83	2.81	3.02
Tanzania	2.56	1.68	1.86	2.31	5.38	5.82	5.88	6.24
Thailand	3.82	3.92	3.93	4.48	2.97	3.26	3.19	2.24
Togo	1.96	2.16	2.31	1.10	6.61	6.98	6.68	9
Trinidad and Tobago	1.57	1.93	1.92	2.88	8.8	8.05	7.94	5.84
Tunisia	3.18	3.67	3.70	3.66	3.43	3.66	3.39	4.02
Turkey	2.66	2.67	2.65	2.45	3.6	3.51	3.46	3.3

Continued

TABLE 1 *Continued*

Country	*mgr*50	*mgr*55	*mgr*56	*mgr*61	*stdgr*50	*stdgr*55	*stdgr*56	*stdgr*61
Uganda	0.83	−1.44	−0.25	0.77	12.59	10.06	17.67	9.35
United Kingdom	2.06	2.12	1.99	1.99	2.2	2.91	2.21	2.26
United States	2.14	2.17	2.13	2.71	2.59	2.91	2.67	2.88
Uruguay	0.13	−0.08	0.06	0.22	5.04	5.22	4.93	4.92
Venezuela	1.51	−0.15	−0.11	−0.72	6.51	3.9	3.66	4.37
Zambia	−1.73	−0.82	−0.73	−0.56	7.11	7.2	7.07	6.35
Zimbabwe	1.68	0.66	0.79	3.08	6.19	5.42	5.78	8.11

NOTE: *mgr* and *stdgr* denote the mean and standard deviation of growth rates, respectively. Numbers after *mgr* and *stdgr* represent versions of the PWT. The sample is over the period 1962–85 except for five countries (for which the sample period is shown in parentheses). Countries for which the average growth rates change sign over versions are shown in bold.

is 2.76% (2.98%), 3.19% (2.56%), 3.18% (2.48%), and 2.88% (2.66%) in versions 5.0, 5.5, 5.6, and 6.1, respectively. Second, the country that has the largest mean growth rate alters across versions: Botswana (6.85%), Korea (6.39%), Singapore (6.67%), and Singapore (7.50%) in versions 5.0, 5.5, 5.6, and 6.1, respectively. A similar finding is observed for the countries that have the smallest mean growth rates: Mozambique (−2.06%), Chad (−2.25%), Chad (−2.55%), and Mozambique (−2.97%) in versions 5.0, 5.5, 5.6, and 6.1, respectively. Third, a significant percentage (13%) of countries, most of which are African, have experienced sign changes in the mean growth rates across different versions. For example, the growth rate of Mauritania is negative in versions 5.0, 5.5, and 5.6, while being positive in version 6.1. Likewise, Uganda has positive growth rates in versions 5.0 and 6.1, while having negative growth rates in the other versions.

We also look at the maximum absolute and the maximum percentage differences between the pairs of the mean growth rates in four versions of the PWT. Results can be seen in table A1 in the online appendix. In almost all of the OECD countries in the old definition (23 countries shown in bold) GDP data were not severely affected by the PWT revisions. However, a majority of countries experience the maximum absolute differences of more than 0.5 percentage points. An extreme case is Mauritania; the maximum difference is more than three percentage points where the mean growth rates are −0.37% and 2.91% in PWT5.5 and PWT6.1, respectively. It is also noteworthy that in 24 countries the maximum relative differences are no smaller than 100%. Overall, the results in table 1 and table A1 indicate that revisions of the PWT have resulted in nonnegligible changes in the mean growth rates of countries.

To analyze similarity of data it is useful to look at their correlation. The correlations between the growth rates[5] in different versions of the PWT range from 53% to 78% except for the pair PWT5.5 and PWT5.6, where the correlation

5 The results are available in table A2 in online appendix.

TABLE 2
Mean equality test for growth rates across PWT versions

$m = 50$ $n = 55$	$m = 50$ $n = 56$	$m = 50$ $n = 61$	$m = 55$ $n = 56$	$m = 55$ $n = 61$	$m = 56$ $n = 61$
The null hypothesis for the equality of the means is rejected at 1% level					
Tunisia	Costa Rica Ireland	Costa Rica India USA	Costa Rica South Africa	Canada Costa Rica Taiwan USA	Canada El Salvador Taiwan USA
The null hypothesis for the equality of the means is rejected at 5% level					
Austria Ireland Mali Taiwan Zambia	Austria China Nigeria Tunisia Zambia	Belgium Brazil Denmark El Salvador Niger	China Netherlands Spain	El Salvador Niger Spain Uganda	
The null hypothesis for the equality of the means is rejected at 10% level					
Cameroon Panama Philippines	Panama Philippines Sweden	Guinea Mauritania Spain Taiwan	Cameroon El Salvador Papua New Guinea Senegal Taiwan	Austria Mauritania Uruguay	Belgium Costa Rica Niger

NOTE: *m* and *n* are the versions of the PWT.

is as high as 93%. These numbers are surprisingly low, given that we are dealing with the same variable. It is also important to note that the correlations become smaller as more revisions take place, suggesting that information in past versions becomes less relevant for newer versions.

Table 2 refers to the results of the t-test with the null hypothesis that the mean of the growth rate in one version of the PWT is the same as in the other version. For each pair of versions, the table presents the countries for which the null is rejected at 1%, 5%, and 10% levels of significance. It is demonstrated that for 30 countries (27% of all countries considered) the null is rejected at the 10% level of significance for at least one pair of the PWT versions. Most of those countries are developing ones; however, countries such as Canada, USA, and Spain are also among them.

Scatter plots of the growth rates in different versions of the PWT are provided in figures 1–3. Figure 1 illustrates that the difference in growth rates is smallest between versions 5.5 and 5.6. There is relatively large diversity between growth rates in version 6.1 and all other versions. As can be seen in figures 2 and 3, the difference in growth rates of the OECD countries is much smaller across different versions compared with non-OECD countries.

We perform the two-sample Kolmogorov-Smirnov (K-S) test for each pair of versions, thereby examining whether the distributions of growth rates significantly differ across versions. For the two sample K-S tests, the null hypothesis is that

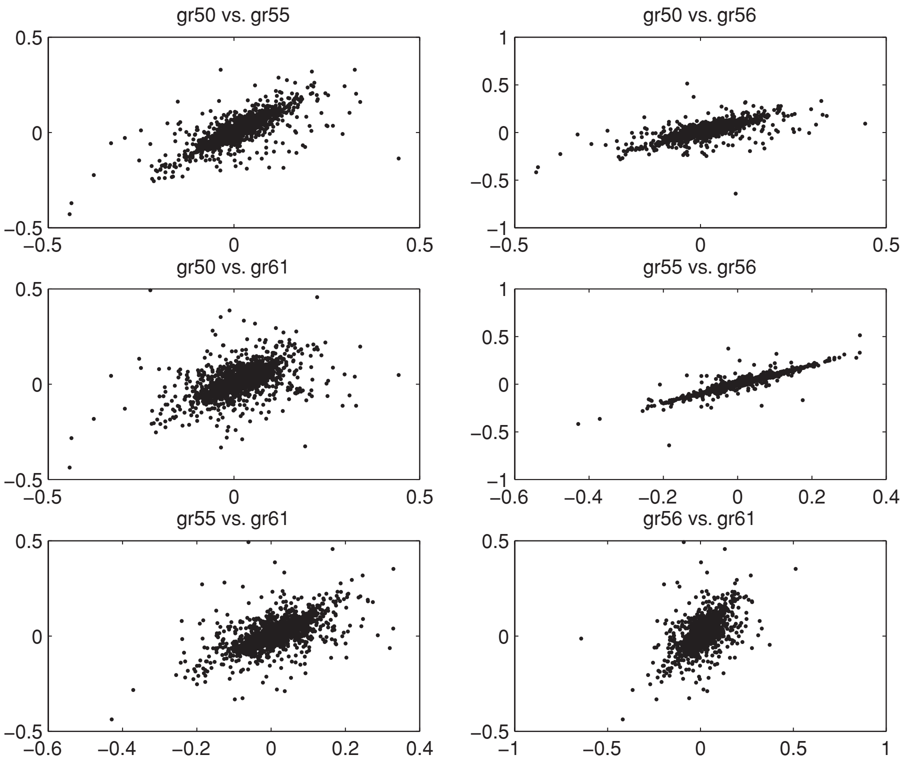

FIGURE 1 Scatter plots for the sample including all available countries

the true distribution functions of growth rates in two versions are the same. The results show that the null hypothesis cannot be rejected for all pairs of the PWT. For instance, we cannot reject the null hypothesis that growth rates in versions 5.0 and 5.5 come from the same distribution. These results are in line with Kernel density estimates of the growth rates[6] and do not change even when we use subsamples such as OECD countries and non-OECD countries.

The PWT has a data quality index that divides countries by data quality in four broad groups: A, B, C, and D, where A characterizes the best quality of data and D the worst. For each group, we further conduct K-S tests. The distributions are not found to differ across versions except in one case: when we analyze growth rates in version 5.6 and version 6.1 for data quality D (using version 6.1 data quality index), the null hypothesis is rejected at the 10% level. Overall, our results suggest that although growth rates differ across versions, the distribution of growth rates appears to be the same.

6 Selected Kernel density plots are available in the online appendix.

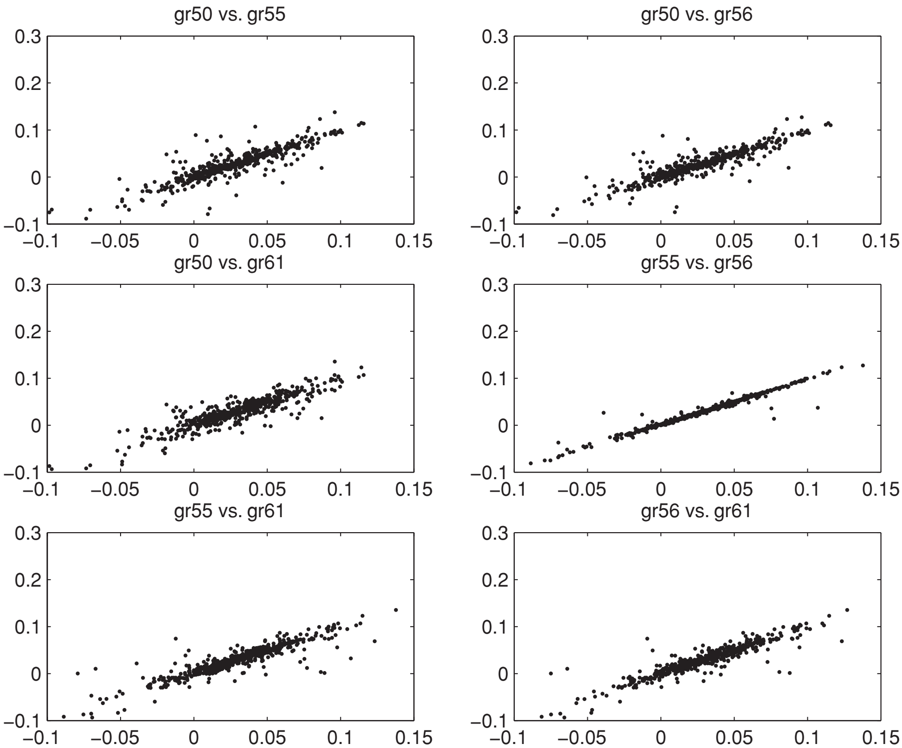

FIGURE 2 Scatter plots for the OECD sample

4. Does the version affect results in previous studies?

In the previous section, we have shown that the growth rate of a country differs across different versions of the PWT. This suggests that growth rates (and output) reported in three or potentially all versions are measured with error. Since measurement error leads to econometric problems such as inefficiency and/or inconsistency, it is possible that evidence from one version of the PWT does not hold when another version is used instead. In other words, evidence is potentially version dependent.

If measurement error is 'classical,' then it would not be hard to tell in what kind of applications evidence is likely to be version dependent. For example, consider a simple linear regression model where the dependent variable is the country's growth rate. Then, measurement error will result only in inefficiency. Instead, if one of the explanatory variables is the country's growth rate, then measurement error will lead to inconsistency. In this case, it may be possible to correct for endogeneity by using the country growth rate computed in some other version of the PWT as an instrument for that used for estimation.

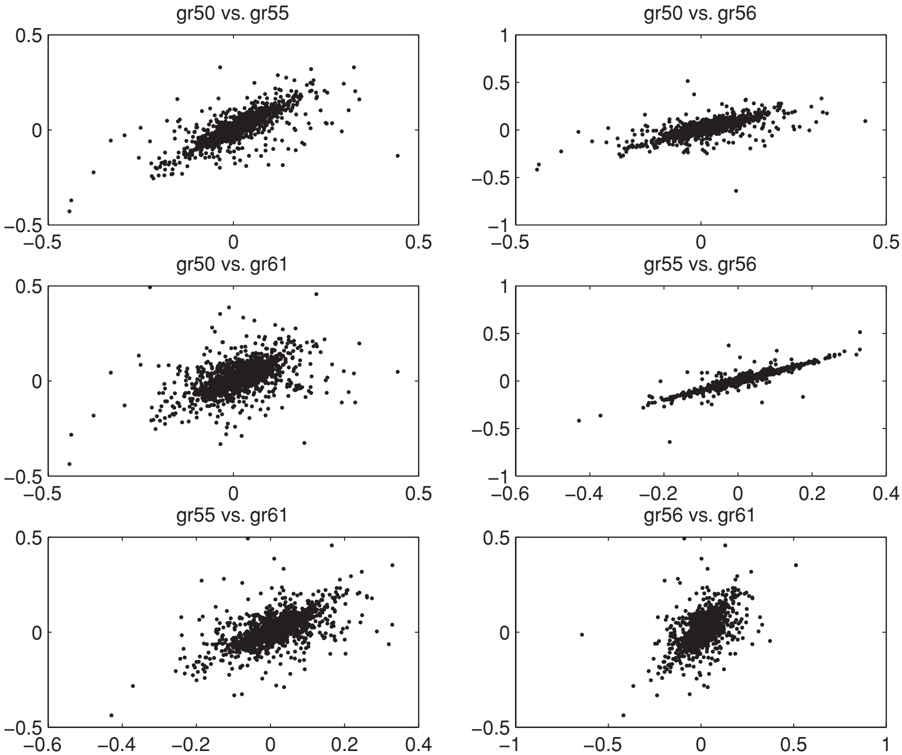

FIGURE 3 Scatter plots for the non-OECD sample

Note, however, that measurement error is not necessarily classical. Indeed, there is a reason to suspect that measurement error is not classical; the PWT report that data quality is likely to differ across countries. Moreover, as discussed earlier, owing to the construction of the PWT, measurement error in one version is likely to be correlated with that in another. Furthermore, as there is no 'validation' data, it is not possible to know the exact properties of measurement error in the PWT. This makes it difficult to see in what kind of applications results are severely affected by measurement error in the PWT.

Consequently, we consider several examples. We first consider the study by Ramey and Ramey (1995) (RR hereafter) in which the link between growth and growth uncertainty is examined in the multi-country panel framework.[7] The choice of this study is motivated by Dawson et al. (2001), who found that RR's results are not robust once controlling for or conditioning on data quality. Importantly, however, RR and Dawson et al. (2001) used different data sets: the

7 For recent discussion of the empirical relationship between growth and growth uncertainty, see Kroft and Lloyd-Ellis (2002), Grier et al. (2004), and Fountas, Karanasos, and Kim (2006).

former used PWT5.0, while the latter used PWT5.5.[8] This raises the possibility that Dawson et al.'s findings are not due to controlling for data quality but due to using a different version of the PWT. The second example we consider is a simple growth regression model. We believe this should be the most informative application, given that the PWT have been used by many growth regression studies.

4.1. Replication of Ramey and Ramey (1995)

To examine the link between growth and growth uncertainty, RR estimated the following equation:

$$\Delta \ln Y_{it}^* = \lambda\sigma_i + \theta \ln X_{it}^* + \epsilon_{it}, \ \epsilon_{it} \sim N\big(0, \sigma_i^2\big), \tag{8}$$

where Y_{it}^* is output per capita for country i in year t and X_{it}^* is a set of control variables. In this model, growth uncertainty, measured by the standard deviation of ϵ_{it}, σ_i, is allowed to be directly related to the growth rate. Using data from PWT5.0, RR found that growth uncertainty is significantly and negatively associated with growth for both a sample of 24 OECD countries and a broader sample of 92 countries.[9]

Dawson et al. (2001) showed that in the presence of measurement error in Y_{it}^* and X_{it}^*, parameter estimates are generally inconsistent. To see this, assume $Y_{it} = Y_{it}^* U_{it}$ and $X_{it} = X_{it}^* V_{it}$, where Y_{it} and X_{it} are the measured levels of Y_{it}^* and X_{it}^*, respectively, and U_{it} and V_{it} are the corresponding measurement errors. Also, it is assumed that U_{it} and V_{it} are log-normally distributed. Specifically, $\ln U_{it} \sim N(0, \sigma_{Ui}^2)$, $\ln V_{it} \sim N(0, \sigma_{Vi}^2)$, and $\ln U_{it}$ and $\ln V_{it}$ are assumed to be serially uncorrelated.

Expressing equation (8) using observables Y_{it} and X_{it}, one obtains

$$\Delta(y_{it} - u_{it}) = \lambda\sigma_i + \theta(x_{it} - v_{it}) + \epsilon_{it},$$

where lowercase letters indicate log values. It immediately follows that

$$\Delta y_{it} = \lambda\sigma_i + \theta x_{it} + w_{it}, \tag{9}$$

where $w_{it} = (\epsilon_{it} + u_{it} - u_{it-1} - \theta v_{it})$ is a composite error term. As discussed in Dawson et al. (2001), when one estimates equation (9), σ_i is replaced by the

8 Dawson et al. (2001) do not appear to be aware that the version that they used is different from the one in RR. They mentioned that 'except for this grouping by data quality, the *data*, sample periods, and countries included are identical to those used by Ramey and Ramey' (emphasis added; 999).

9 However, it should be noted that when RR estimate the panel data model that uses government spending volatility and controls for time and country-fixed effects, the effect of growth uncertainty on growth is found to be insignificant in the 92-country sample while still holds for the OECD sample.

estimated standard error of w_{it}, $\widehat{\sigma_i} = (\sigma_i + s_i)$. This causes an error-in-variables problem with σ_i, and hence an estimate of λ is expected to be inconsistent. Note also that even if x_{it} is correctly measured (i.e., $v_{it} = 0$), s_i will not be zero in general, resulting in an inconsistent estimate of λ. In this sense, the model differs from a linear model where measurement error in the dependent variable does not lead to inconsistency (if it is uncorrelated with explanatory variables).

Dawson et al. (2001) show that the asymptotic bias in the estimate of λ is

$$plim(\hat{\lambda} - \lambda) = -\frac{\lambda VAR(s_i)}{VAR(\sigma_i) + VAR(s_i)} + \Psi, \tag{10}$$

where Ψ is a set of additional terms. Equation (10) along with findings in the previous section essentially suggest that RR's results are likely to be subject to bias. However, the direction of the bias is hard to determine, owing to the second term in equation (10). See Dawson et al. (2001) for details on Ψ.

4.1.1. Results – a broad sample

This section analyzes the results of the replication of RR using different versions of the PWT. Table 3 presents estimates of the coefficient on growth volatility, λ, for different samples and different versions of the PWT.[10] All estimations are made using a maximum likelihood method. Column 1 shows the estimates of λ from RR. First, we replicate results of RR using a sample of 91 countries (Tanzania was excluded from the sample because the human capital variable was not available for this country). As can be seen from the table, the results of RR ($\hat{\lambda} = -0.211$) and replication using PWT5.0 ($\hat{\lambda} = -0.2051$) are very similar. Then, we examine a sample of 78 countries[11] available in all four versions of the PWT. This allows us to compare results across different versions.

When we use PWT5.0, the estimate of λ for *LR* specification including Levine-Renelt variables (the average investment fraction of GDP, initial log GDP per capita, initial human capital, and the average growth rate of population) is found to be negative and significant. This is consistent with the evidence provided by RR, though the size of the effect in RR is more pronounced. A similar finding is obtained for PWT6.1. Note, however, that PWT5.5 and PWT5.6 provide substantially different results. The estimate of λ is insignificant at any conventional level of significance. Moreover, the magnitude of the coefficient becomes much smaller in absolute terms. This suggests that RR's results do not hold even without controlling for data quality, as Dawson et al. (2001) do.

In addition, we estimate specification *F*, where we also control for forecasting variables, including lags of GDP per capita and time trend.[12] Our findings do

10 Detailed estimation results are available in tables A3–A6 in the online appendix.

11 The 78-country sample excludes the following countries from RR: Liberia, Sierra Leone, Sudan, Swaziland, Tanzania, Tunisia, Zaire, Haiti, Afghanistan, Burma, Iraq, West Germany, Malta, and Yugoslavia.

12 The full list of covariates in this specification includes initial investment, initial population growth, initial human capital, and initial GDP per capita, two lags of GDP per capita, time trend, time trend squared, post-1973 dummy, and post-1973 trend.

TABLE 3
Estimated coefficient on volatility for different versions of the PWT

Specification	Sample	(1) RR	(2) PWT5.0	(3) PWT5.5	(4) PWT5.6	(5) PWT6.1
	Broad:					
LR	92	−0.211** (−2.61)				
LR	91		−0.2051** (−2.29)			
LR	78		−0.1544* (−1.74)	−0.1011 (−1.22)	−0.0619 (−0.62)	−0.1547** (−2.37)
F	92	−0.178** (−2.43)				
F	91		−0.144* (−1.95)			
F	78		−0.1261 (−1.28)	−0.1089 (−1.21)	−0.0902 (−1.22)	−0.175*** (−2.58)
	OECD:					
LR	24	−0.385* (−1.92)				
LR	24		−0.3923* (−1.85)			
LR	23		−0.3994** (−2.14)	−0.212 (−1.43)	−0.2069 (−1.43)	−0.0083 (−0.21)
F	24	−0.949*** (−4.09)				
F	24		−0.9336*** (−3.29)			
F	23		−0.9110*** (−3.47)	−0.7789*** (−3.577)	−0.7618*** (−2.61)	−0.4599** (−2.46)

NOTES: *LR*-specification with Levine-Renelt variables (the average investment fraction of GDP, initial log GDP per capita, initial human capital and the average growth rate of population). *F*-specification with additional forecasting variables including lags of GDP per capita, and time trend. Column (1) contains the estimation results of Ramey and Ramey (1995).

not change even when these additional control variables are included; the version matters to the results. The estimate of λ is found to be significant for PWT6.1 but not for the other versions. Two aspects of the results are worth mentioning. First, the coefficient on σ_i becomes insignificant when we use the 78-country sample from PWT5.0, suggesting that the evidence provided by RR may be sensitive to the choice of countries included in the sample. Second, with regard to the absolute magnitude of the growth-uncertainty effect, we observe a similarity between the models with and without additional controls: PWT6.1 provides the largest effect, PWT5.0 the second, PWT5.5 the third, and PWT5.6 the smallest. This result is somewhat puzzling, as the correlation between growth rates in PWT6.1 and PWT5.0 is the smallest among any other pair, as shown in the previous section.

Overall, these findings do not support the robustness of the results in Ramey and Ramey (1995). Their conclusions do not necessarily survive when the number of countries in the sample is slightly reduced. More important, the results are not robust across the versions of the PWT. In other words, RR would have reached different conclusions, depending on the version of the PWT used.

4.1.2. Results – OECD countries

This section discusses the results of the replication of RR using a sample of 24 western industrialized countries.[13] Because of the Germany's reunification, the data for Western Germany are unavailable in some versions of the PWT. We excluded this country from the analysis, as our purpose is comparing across versions. The second lag of the growth rate of GDP per capita for PWT6.1 is unavailable for Sweden and Greece in 1952. Thus, for these countries the data start from 1953. Since the population growth rate for these countries is also unavailable between 1950 and 1951 in PWT6.1, it was replaced with the one from PWT5.6.[14] This does not seem to generate a large difference, since the population growth rate from 1950 to 1951 cannot be revised substantially from one version of the PWT to the other.

The bottom half of table 3 shows the estimates of λ for a set of 24 OECD countries (23 when Germany is excluded). Column 1 shows the coefficients from RR. As can be seen from the table, the estimate of λ is negative and significant for PWT5.0. However, for the later versions of the PWT, the coefficient is found to be insignificant. It becomes smaller in absolute value over versions; surprisingly, it is almost zero for PWT6.1. The results again suggest that the version significantly affects the results.

The effects of the versions are milder when we include additional control variables in the regression. As table 3 indicates, for all versions of the PWT, the coefficient on σ_i is found to be significant at least at the 5% level. This suggests that the researcher would reach the same conclusion qualitatively; growth uncertainty is negatively associated with growth. Nonetheless, the results are substantially different quantitatively. As in the model without the additional controls, the estimate of λ is the highest for PWT5.0, monotonically decreasing in absolute value for the later versions. Note that the magnitude of the coefficient for PWT6.1 is approximately half of that for PWT5.0.

To summarize the results, the significant negative effect of growth uncertainty on growth is robust across different versions only when we control for the forecasting variables. With simpler specifications, the significant relationship

13 The countries in the sample are Australia, Austria, Belgium, Canada, Switzerland, Denmark, Spain, Finland, France, the United Kingdom, West Germany, Greece, Ireland, Iceland, Italy, Japan, Luxembourg, Netherlands, Norway, New Zealand, Portugal, Sweden, Turkey, and the United States.

14 We use the population growth between 1950 and 1951 as the initial population growth.

TABLE 4
Effect of government-spending-induced volatility

	(1)	(2) Version of the PWT	(3)	(4)	(5)
	RR	5.0	5.5	5.6	6.1
78-country sample					
volatility on growth λ	−1.666	NA	−0.159	−0.08	−0.221
	(−1.36)		(−1.38)	(−1.23)	(−1.55)
Government volatility	0.658***	NA	0.258***	0.338***	0.194***
on output volatility α_1	(18.5)		(13.93)	(15.67)	(11.33)
OECD (23 country) sample					
volatility on growth λ	−0.426*	−0.336*	−0.186	−0.206	NA
	(−1.93)	(−1.90)	(−1.024)	(−1.20)	
Government volatility	0.624***	0.336***	0.253***	0.310***	NA
on output volatility α_1	(7.5)	(7.53)	(6.95)	(7.39)	

NOTES: Time and country fixed effects are included. *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively. Numbers in parentheses are *t* statistics. Forecasting variables such as first and second lags of log GDP per capita are controlled for. Column (1) contains the estimation results of Ramey and Ramey (1995). NA stands for results unavailable due to convergence problems.

between the growth uncertainty and growth is observed only for PWT5.0. In either specification, the magnitude of the effect considerably varies across different versions.

4.1.3. Robustness checks

RR also extended their model in such a way that shocks to government spending are a source of the volatility:

$$\epsilon_{it} \sim N\big(0, \sigma_{it}^2\big),\ \sigma_{it}^2 = \alpha_0 + \alpha_1 \hat{\mu}_{it}^2,$$

where $\hat{\mu}_{it}^2$ is the square of the estimated residual for country *i* in period *t* from the government-spending forecasting equation.[15] We also estimate this model to see whether our results remain unchanged. Table 4 presents the results where the set of control variables includes two lags of log GDP per capita as well as country and year dummies.[16] The results show that the version used matters to the results especially when we use the OECD sample. The coefficient on the volatility is significant at the 10% level for PWT5.0, while it is insignificant for PWT5.5 and PWT5.6.

15 The forecasting equation relates government spending growth to a constant term, two lags of log level of GDP per capita, two lags of the log level of government spending per capita, a quadratic time trend, a post-1973 trend, and a dummy variable for the post-1973 period.

16 We experienced a convergence problem in the case of PWT5.0 (78-country sample) and PWT6.1 (OECD sample); hence, the results for these versions are not reported.

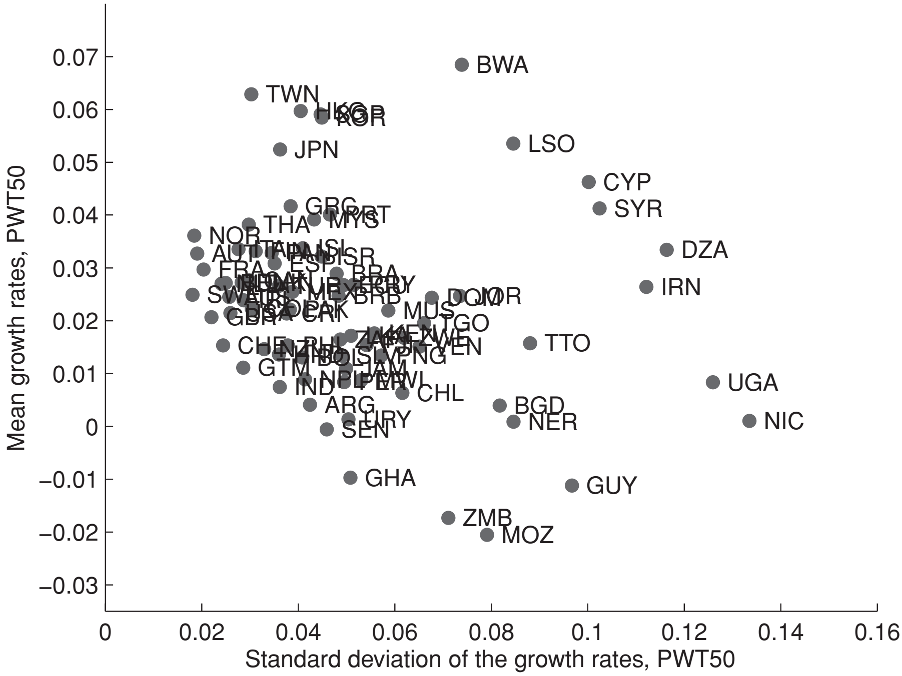

FIGURE 4 Mean and standard deviation of the growth rates for PWT5.0

One might wonder if the presence of outliers is a major reason for our results. To examine this possibility,[17] we attempt to detect potential outliers by using several approaches. First, we conduct a visual analysis. Figures 4–7 present the scatter plots for the mean and standard deviation of the growth rates for different versions of the PWT. Second, we run a simple linear regression of mean growth rates on standard deviation, thereby nominating a country as a potential outlier if the studentized residual is in excess of ±2 (especially ±2.5). Third, we look at the leverage that allows us to assess how influential the country is to the results. Furthermore, we use two diagnostic statistics such as Cook's D and DFITS.[18]

Given the results from all these methods, we treat a country as an outlier (1) if most of the methods indicate so and (2) if the statistics are very different from those for other countries. According to these criteria, Syria is identified as an outlier in PWT5.5, PWT5.6, and PWT6.1, while Mozambique and Singapore are identified as outliers for PWT6.1.

17 We are grateful to an anonymous referee for suggesting this possibility.

18 Cook's D or Cook's distance is an influence measure proposed by Cook (1977), and it measures the difference between the fitted values obtained using the full sample and fitted values obtained by removing one of the observations. DFITS proposed by Welsch and Kuh (1977), is similar to Cook's D and measures the scaled difference between the *i*th fitted value obtained from the full data and *i*th value obtained by excluding the *i*th observation from estimation.

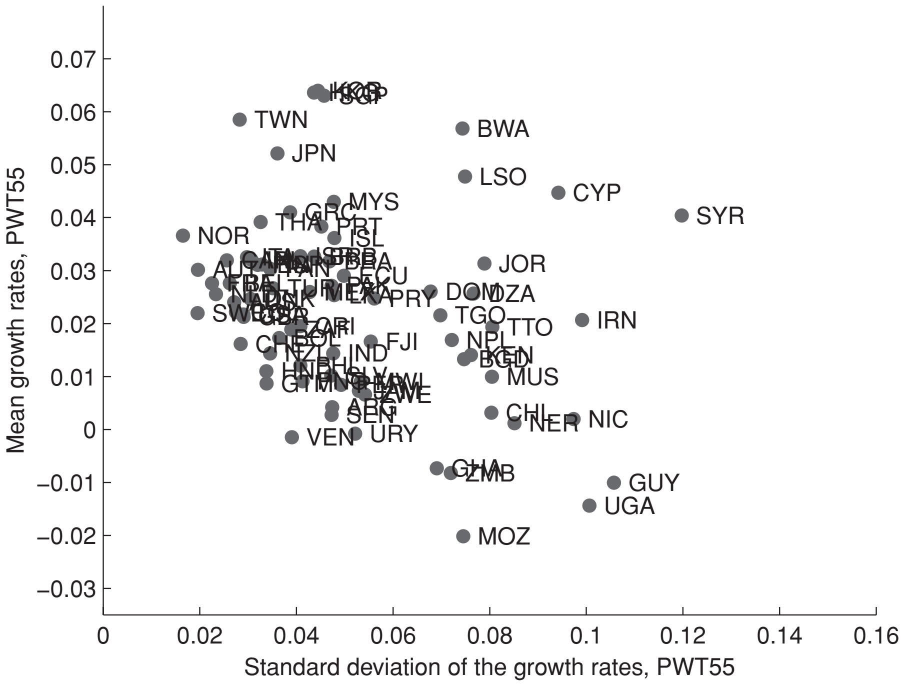

FIGURE 5 Mean and standard deviation of the growth rates for PWT5.5

PWT5.0 is the most difficult case. The scatter plot (see figure 4) suggests that 8 countries[19] can be treated as outliers. Cook's D and DFITS diagnostics suggest that 7 and 13 countries, respectively, can be considered as outliers. However, statistics values are not very different for these countries. Therefore, either all of these countries or none of them should be treated as outliers. As 7 countries constitute about 10% of the sample, we are inclined to treat these countries as non-outliers in PWT5.0.

Excluding identified outliers from the sample, we re-estimate the model with the forecasting variables for each version except PWT5.0. The results are presented in table 5. The coefficient on the volatility is found to be significant only for PWT6.1. Recall that the same pattern has been observed for the sample with outliers (see table 3 as well as tables A3 and A4 in the online appendix). Moreover, for each version, the magnitude of the coefficient is similar to that from the sample with outliers. Our main results, therefore, do not seem to be affected by outliers either qualitatively or quantitatively.

4.1.4. Does data quality matter?

As mentioned earlier, the PWT provides a data quality index that ranks countries by data quality in four broad groups, A, B, C, and D. Dawson et al. (2001)

19 These countries are Botswana, Lesotho, Cyprus, Syria, Algeria, Iran, Uganda, and Nicaragua.

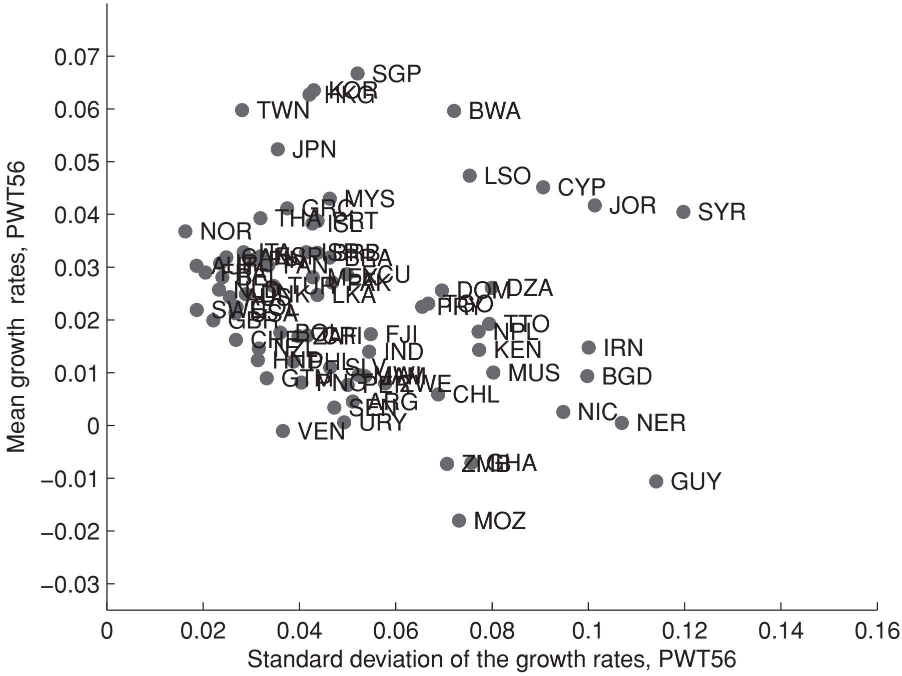

FIGURE 6 Mean and standard deviation of the growth rates for PWT5.6

made an attempt to look at the effect data quality of the PWT has on several relationships found in literature, one of which is the relationship between growth and uncertainty identified by RR. Specifically, they added data quality dummies to RR's specification with Levine-Renelt variables. They found that the coefficient on σ_i becomes insignificant, thereby casting doubts on the evidence by RR.

We extend Dawson et al. (2001) in three dimensions. First, we examine RR's specification with forecasting variables where more variables are controlled for than in Dawson et al. (2001). This is important to correctly measure uncertainty. Second, we explore two versions of the PWT (PWT5.0 and PWT6.1), while only one version (PWT5.5) was used in Dawson et al. (2001). By so doing, we ask whether their findings survive in different versions of the PWT. Third, we include the cross terms of volatility and quality dummies in the model, allowing the relationship between growth and uncertainty to vary across data with different quality. With this specification, we examine how the relationship is related to data quality. As will be clear, the cross terms appear to play an important role in the empirical relationship between growth and uncertainty.

Table 6 presents the estimation results when quality dummies are included. Columns 2 and 3 show the results for a sample of 91 countries in PWT5.0. Without the cross terms we obtain similar results with those of Dawson et al. (2001). As

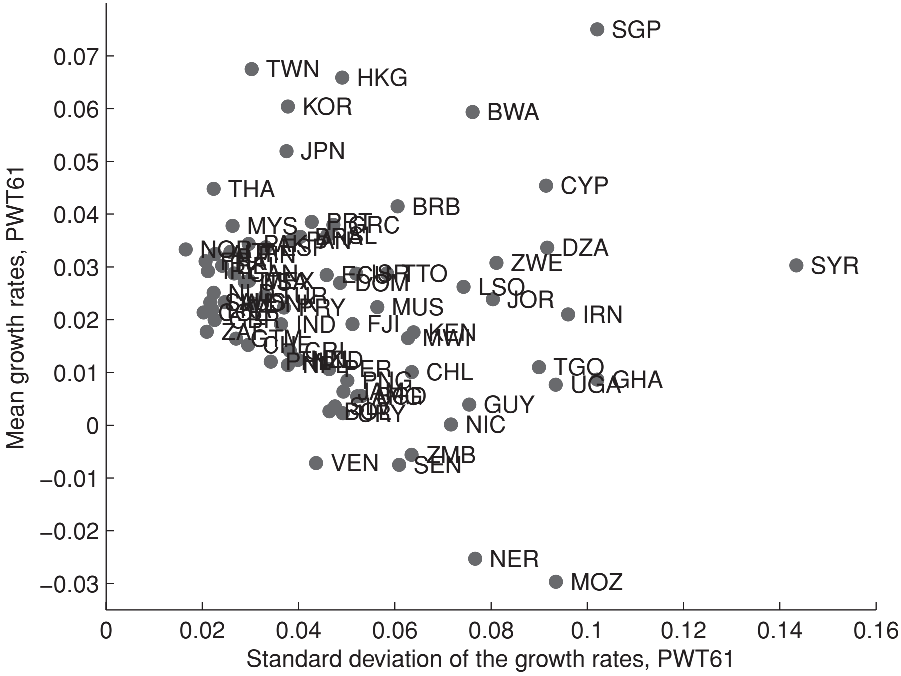

FIGURE 7 Mean and standard deviation of the growth rates for PWT6.1

column 2 indicates, quality C and D dummies are negatively and significantly related to growth rates. That is, countries for which data quality is lower tend to experience lower growth rates. It is also important to note that the estimate of λ becomes insignificant, which is consistent with Dawson et al. (2001). These results do not change, even when we include the cross terms of volatility and data quality dummies (column 3). Given that quality dummies partially control for the variation of measurement error, our results suggest that the standard error of measurement errors, not the 'true' uncertainty, is associated with growth rates. This provides a possible reason for the significance of σ_i found by RR; in RR, σ_i captures the 'true' uncertainty and the standard deviation of measurement error, and the significance of σ_i may be attributed mainly to the latter.

The same exercise is repeated with the 78-country sample for PWT5.0 and PWT6.1, and the results are presented in columns 4–7. We show that the evidence by Dawson et al. (2001) also does not hold in PWT5.0 and PWT6.1 when we use the 78-country sample. On the one hand, when we use PWT5.0, inclusion of quality dummies does not play any role in the empirical relationship between growth and uncertainty. The estimate of λ is insignificant (see column 4), but recall that it is insignificant even without quality dummies, as presented earlier. On the other hand, in PWT6.1, inclusion of quality dummies indeed increases

TABLE 5
Relationship between growth and volatility with outliers excluded

	(1)	(2) Version of the PWT	(3)
Independent variable	5.5 without Syria	5.6 without Syria	6.1 without Syria Mozambique Singapore
σ_i	−0.1298	−0.1057	−0.1927***
	(−1.46)	(−1.42)	(−2.71)
Constant	0.0854***	0.0905***	0.1008***
	(4.47)	(4.89)	(6.08)
Initial investment fraction	0.0367**	0.0425***	0.0399***
	(2.38)	(2.73)	(3.03)
Initial population growth rate	−0.0452	−0.0747	−0.0816
	(−0.48)	(−0.81)	(−0.89)
Initial human capital)	0.0172**	0.0169***	0.0173***
	(2.55)	(2.68)	(2.66)
Initial log GDP per capita	−0.3015***	−0.3037***	−0.2778***
	(−5.62)	(−5.84)	(−5.18)
First lag of log GDP per capita	1.8812***	1.808***	1.7122***
	(7.78)	(7.46)	(6.94)
Second lag of log GDP per capita	−1.6605***	−1.5921***	−1.5305***
	(−6.50)	(−6.26)	(−5.93)
Trend	−0.0127	−0.012	−0.0046
	(−0.80)	(−1.27)	(−0.42)
Trend squared	0.0062	0.0056	0.0026
	(0.54)	(0.84)	(0.32)
Post-1973 trend	−0.0025	−0.0022	−0.0015
	(−0.89)	(−1.31)	(−0.74)
Post-1973 dummy	−0.0153***	−0.0156***	−0.0151***
	(−4.10)	(−4.56)	(−4.53)
Log-likelihood	3165.3	3169.3	3206.8

NOTES: 78-country sample. Specification with forecasting variables. *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively. Numbers in parentheses are t statistics.

the estimate of λ in absolute terms and hence supports RR's evidence (column 6).

Further, when we include cross terms, the results are reasonably similar between PWT5.0 and PWT6.1 (see columns 5 and 7, respectively). In both versions,

TABLE 6
Estimation results with data quality dummies

Independent variable	(1) RR	(2) 5.0 (91)	(3) 5.0 (91)	(4) 5.0 (78)	(5) 5.0 (78)	(6) 6.1 (78)	(7) 6.1 (78)
		Version of the PWT (number of countries in the sample)					
σ_i	−0.178**	0.0559	−0.0777	0.0233	−0.0579	−0.2957***	0.3276
	(−2.43)	(0.48)	(−0.50)	(−0.06)	(−0.26)	(−3.94)	(1.04)
Constant	0.0607**	0.0824***	0.0757***	0.0753	0.0716**	0.1347***	0.1161***
	(3.58)	(4.266)	(3.641)	(−1.48)	(−2.7)	(−7.18)	(5.71)
Initial investment fraction	0.019	0.0128	0.0178	0.0217	0.0318*	0.036***	0.0394***
	(1.37)	(0.936)	(1.038)	(−1.17)	(−1.89)	(−2.58)	(2.78)
Initial population growth rate	0	0.0832	0.1202	0.2489*	0.2291	0.2248**	0.0626
	(0.13)	(0.508)	(0.936)	(−1.93)	(−1.33)	(−2)	(0.66)
Initial human capital capital	0.012**	0.0092	0.01	0.0059	0.0053	0.0112	0.005
	(2.01)	(1.185)	(1.223)	(−0.34)	(−0.71)	(−1.5)	(0.68)
Initial log GDP per capita	−0.23**	−0.1888***	−0.1955***	−0.1834***	−0.1376**	−0.257***	−0.1888***
	(−4.46)	(−3.313)	(−3.998)	(−2.61)	(−2.17)	(−4.81)	(−3.32)
B		−0.003	−0.0241	−0.005	−0.0297*	0.0008	0.0122
		(−0.852)	(−1.499)	(−0.95)	(−1.73)	(−0.22)	(1.21)
C		−0.0115***	−0.0168**	−0.0148	−0.0207	−0.0146***	−0.0002
		(−2.988)	(−2.364)	(−1.9)	(−1.58)	(−3.16)	(−0.02)
D		−0.0232***	0.0043	−0.0206	0.0187*	−0.0009	0.042***
		(−3.617)	(0.321)	(−1.13)	−1.71	(−0.13)	(3)
B × σ_i			0.6807		0.8167		−0.5373
			(1.331)		−1.5		(−1.58)
C × σ_i			0.2208)		0.2122		−0.5744*
			(1.221)		−0.69		(−1.74)
D × σ_i			−0.3006		−0.5301**		−1.109***
			(−1.194)		(−2.49)		(−2.94)

NOTES: *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively. Numbers in parentheses are *t* statistics. B, C, and D are data quality dummies for PWT5.0 or PWT6.1, depending on the sample considered. Forecasting variables such as first and second lags of log GDP per capita, trend, trend squared, post-1973 trend, and post-1973 dummy are controlled for. Column (1) contains the estimation results of Ramey and Ramey (1995).

σ_i is not significantly related to growth rates, while the coefficient on the interaction term involving quality dummy D is negative and significant at the 5% level. These results provide evidence for a negative relationship between growth and uncertainty only for countries with the worst data quality. Note that this pattern was not identified by Dawson et al. (2001), as they assumed that data quality matters only for the constant term.

In summary, our results suggest that (1) data quality plays some role in the empirical relationship between growth and uncertainty and (2) if there is a negative relationship between the two, it is only for countries with the worst data quality.

4.2. Another application: simple growth regression

Although we have shown that the results for the growth-uncertainty relationship are not robust across the versions of the PWT, it is difficult, if not impossible, to generalize our findings to other applications. In this section, we therefore consider another example, a simple growth regression model:

$$\ln Y_{it} - \ln Y_{it-5} = \alpha \ln Y_{it-5} + \beta \ln s_{it-5} + \gamma \ln(n_{it-5} + g + \delta) + \eta_i + \xi_t + \epsilon_{it}, \tag{11}$$

where Y_{it} is the output per capita for country i in year t; s_{it-5} is the saving rate proxied by the ratio of real domestic investment to GDP, taken as an average over the five years preceding t; n_{it-5} is the average population growth rate between $t-5$ and $t-1$; g is the labour-augmenting technological progress; δ is the depreciation rate; η_i is the country fixed effect; ξ_t is the time effect; and ϵ_{it} is an idiosyncratic error term. As in Mankiw, Romer, and Weil (1992) and Caselli, Esquivel, and Lefort (1996), we assume that 0.05 is a reasonable approximation of the value of $g + \delta$.

We estimate equation (11) using Arellano and Bond's (1991) GMM estimator,[20] as in Caselli, Esquivel, and Lefort (1996), and this is repeated for all four versions of the PWT.[21] The results are presented in table 7. Importantly, the overidentifying restrictions are rejected for PWT5.5 and PWT5.6 despite the fact that we use the *same* set of GMM-style instruments[22] for all versions. This suggests that serial dependence in measurement errors in PWT5.5 and PWT5.6 is different from those in the other versions.[23] For the versions in which the overidentifying restrictions are not rejected (i.e., PWT5.0 and PWT6.1), the results are qualitatively similar but quantitatively different; although the implied rate of convergence is found to be significant for both versions, the point estimate from PWT5.0 is at least twice as large as that from PWT6.1. We therefore conclude that the version of the PWT appears to matter even in the simple growth regression model.[24]

20 More specifically, we use the one-step GMM estimator.

21 We use only the countries marked as non-oil, as in Mankiw, Romer, and Weil (1992).

22 They are lags of log GDP, log saving rate, and log of the sum of population growth, technological progress, and depreciation rate.

23 For PWT5.5 and PWT5.6, we also try a different set of instruments that consist of further lags of the original instruments. For each version, the overidentifying restrictions are rejected at the 10% level.

24 There is a caveat to this result. It is possible that for more realistic specifications of the growth regression the results may be robust across the versions. However, further analysis of the growth regression is beyond the scope of this study.

TABLE 7
Growth regression (dependant variable ΔY)

Independent variable	PWT50	PWT55	PWT56	PWT61
$\ln(Y_{i,t-5})$	-0.4748^{***}	-0.4986^{***}	-0.3172^{**}	-0.2584^{*}
	(−3.52)	(−3.70)	(−2.59)	(−1.95)
$\ln(s_{it})$	0.1808^{**}	0.0530	0.1421^{*}	0.0630
	(2.49)	(0.59)	(1.77)	(0.83)
$\ln(n_{it}+g+\delta)$	-0.6301^{***}	-0.5079^{**}	−0.2804	−0.2027
	(−2.66)	(−2.23)	(−1.59)	(−1.00)
Implied λ	0.1288^{***}	0.1381^{***}	0.0763^{**}	0.0598^{*}
	(2.51)	(2.57)	(2.12)	(1.67)
Number of instruments	26	26	26	26
	Tests of overidentifying restrictions			
Sargan	22.18	40.08	43.17	26.69
P-value	(0.275)	(0.003)	(0.001)	(0.112)
Hansen	18.40	27.76	34.22	20.12
P-value	(0.496)	(0.088)	(0.017)	(0.388)

96 countries sample. One-step difference GMM estimation. GMM-style instruments: log GDP, log saving rate, and log of the sum of population growth, technological progress, and depreciation rate. *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively. Numbers in parentheses are t statistics.

5. Conclusion

This study analyzed the properties of different versions of the Penn World Tables. We provided evidence that countries' growth rates were substantially revised across different versions. We also analyzed the effects of the revisions on the empirical evidence presented in Ramey and Ramey (1995) that growth volatility has a significant negative effect on growth. We found that their evidence is supported in some versions but not in others. Moreover, we showed that the effect of uncertainty on growth tends to be stronger for countries with the worst data quality.

We also examined whether the version matters to the results for a simple growth regression model. Our findings suggest that researchers could have obtained qualitatively similar results, but not necessarily quantitatively.

Two implications can be made from this study. First, there is a possibility that depending on the version of the PWT used, past studies may have reached different conclusions. Second, the presence of measurement error in the PWT may be one of the major driving forces of the existing empirical relationships. Further analysis of the properties of the PWT and the measurement error present in different versions is needed, which is left for future studies.

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