# Absolute purchasing power parity in industrial countries

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**Abstract:** Different from popular studies that focus on relative purchasing power parity, we study absolute purchasing power parity (APPP) in 21 main industrial countries. A new method in testing APPP is used. The empirical proof shows that the phenomenon that APPP holds is common, and the phenomenon that APPP does not hold is also common. In addition, some country pairs and the pooled country data indicate that the nearer the GDPPs of two countries are, the more valid APPP between the two countries is.

**Keywords**: Absolute purchasing power parity; Real exchange rate; Coefficient restriction test
**JEL Classification**: F30; F31

## 1. Introduction

The Purchasing power parity (PPP) theory has been playing an important role in research, exchange rate policy and the foreign exchange market (Officer, 1976, Section III; MacDonald, 2007, Chapter 2), and has been one of the core theories in international finance (Krugman et al., 2010, Chapter 16; Melvin and Norrbin, 2012, Chapter 7). Thus, whether PPP holds or not has been extensively studied (Rogoff, 1996; Taylor and Taylor, 2004).

In popular papers that study PPP in industrial countries (e.g., Lothian and Taylor, 1996; Taylor et al., 2001; Karoglou and Morley, 2012; Macchiarelli, 2013; Huang and Yang, 2015), the real exchange rates (RERs) are constructed by consumer, producer, and wholesale price indexes rather than actual price levels. Such constructed RER is used in testing relative PPP rather than absolute PPP (Cheung et al., 2005, p. 1153). Given that if absolute PPP holds then relative PPP must hold, but not vice versa (Taylor and Taylor, 2004, p. 137), absolute PPP is more basic and important. In addition, though some economists (e.g., Bergin, et al., 2006; Broda, 2006) construct the RER by the price level, they discuss other topics rather than absolute PPP. Thus, it is necessary to construct RERs by actual price levels and to study absolute PPP.

Recently, Zhang and Zou (2014) discuss which econometric method should be used in testing absolute PPP (APPP), and analyze APPP of the 40 biggest countries in a panel data. However, the panel data dimension cannot tell us whether or not APPP holds in each pair of countries. That is, the validity of APPP in industrial countries is beyond their scope. Thus, in this paper, we use the time series method to discuss the validity of APPP in the main industrial countries. In addition, we use different method and data from Zhang and Zou (2014).

The rest of the paper is organized as follows. Section 2 gives the concept, method and data. Sections 3 and 4 investigate the validity of APPP based on various databases. Section 5 discusses whether or not the GDPP influences the validity of APPP. Section 6 concludes the paper.

## 2. Concept, method and data

It is useful to introduce APPP by using the term RER. In this paper, the RER is defined by Eq. (1), where $P_i$ is the domestic price level of country $i$, $P^*$ is the price level of a foreign country, $PPP_i$ rate is $P_i$ divided by $P^*$, and the nominal exchange rate $NER_i$ is expressed as the domestic currency units per foreign currency unit. In this definition, a greater value of $RER$ represents the local currency's appreciation against the foreign country. The RER in this definition also measures the relative price level between two countries in terms of a common currency. Thus, it is also called "the price level (of one country relative to the base country)" in popular databases.

$$RER_i = \frac{P_i}{NER_i \times P^*} = \frac{P_i/P^*}{NER_i} = \frac{PPP_i}{NER_i} \tag{1}$$

*2.1. APPP and the Penn effect*

APPP says that a bilateral nominal exchange rate should be equal to its PPP rate or two countries' price levels should be equal when denominated in the same currency. In other words, if the RER defined in Eq. (1) is one, APPP holds; if the RER defined in Eq. (1) is not one, APPP does not hold. In practice, APPP was once used to anchor the nominal exchange rate in some countries, for example in the period between the two World Wars in the UK, Czechoslovakia, and Belgium (Officer, 1976, p. 26).

However, since Balassa (1964) and relevant studies, it is now well known that APPP often does not hold between a rich and a poor country because of the existence of the empirical regularity depicted in Fig. 1. Fig. 1 tells us that, from a global view, there is a systematic relationship between the income level and the RER: the RER tends to be positive with the income level (the RER in a low-income country is often smaller and that in a high-income country is often greater). This regularity is called the "(long-run) deviations from PPP" (Rogoff, 1996), "Balassa–Samuelson effect" (Bergin et al., 2006, Frankel, 2006), "Harrod–Balassa–Samuelson effect" (Taylor and Taylor, 2004), "Penn effect" (Samuelson, 1994, Isard, 2007), or others; The regularity and its explanations are often not differentiated. In this paper, we use the term "Penn effect."

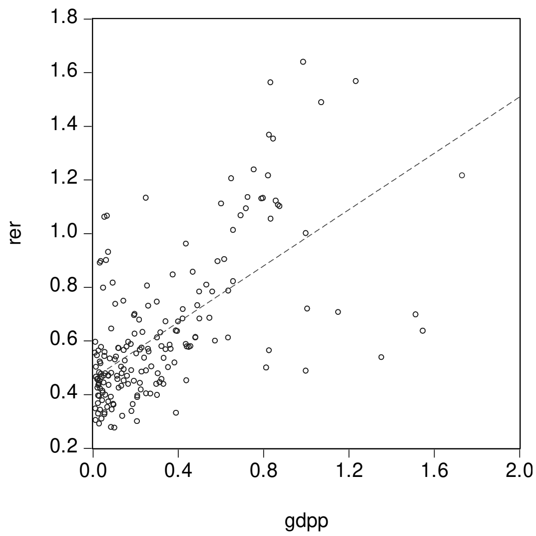


**Fig. 1**. Penn effect for 187 countries and areas in 2013.

Notes：Both the real exchange rate (RER, defined by Eq. (1)) and GDP per capita (GDPP, PPP (constant 2011 international $)) are normalized, with the US = 1. A cross-section regression gives RER = 0.460 + 0.525 GDPP, with both constant and slope terms being significant at the 1% level.

Sources: World Development Indicators and the authors' calculations.

Seen from the Penn effect, except for the outliers, the nearer the GDPPs of two countries are, the nearer the RERs of the two countries are. As the GDPPs in the industrial countries are relatively nearer to each other, it is expected that APPP may hold between some pairs of these countries, which is a reason for us to write this paper.

*2.2. Method*

It is now well known that even when the GDPP of a country is very near to that of the other country (e.g., Canada and the US), APPP does not hold strictly or perfectly because of some factors such as the transportation costs, tariffs, and nontariff barriers (Rogoff, 1996, pp. 653–654). In other words, we cannot find a RER between two countries in the actual world whose value is invariably one. Further, if we test the APPP theory in accordance with whether a RER's value is invariably one, we will get the conclusion that APPP does not hold for any pair of countries. But actually, in any textbook of international finance (e.g., Krugman et al., 2010; Melvin and Norrbin, 2012), APPP is introduced as one of the most basic and important exchange rate theories. Thus, it is wrong to test the theory in accordance with whether a RER's value is invariably one. The meaningful thing is to use some econometric method to investigate *how closely* APPP holds (how close the RER is to one) in the real world.

Zhang and Zou (2014) have proven that the popular unit root and cointegration tests used in relative PPP studies are invalid in testing APPP, and they suggest using the coefficient restriction and the RER misalignment distribution tests. In this paper, we use a test based on Eq. (2), where the RER is defined in Eq. (1), $C$ is a constant, and no logarithmic transformation for the RER is used. Such an equation as Eq. (2) has been used to analyze the behavior of the U.S. real interest rate (e.g., Bai and Perron, 2003a; Rapach and Wohar, 2005). Concretely, we use OLS with Newey–West robust standard error to estimate Eq. (2), and then examine whether the constant, $C$, is equal to one. If the constant is equal to one, we think that the RER fluctuates around its equilibrium value and APPP holds. Otherwise, APPP does not hold. For the coefficient restriction test in Eq. (2), we use the Wald test. If the $p$-value for the Chi-squared statistic in the Wald test is greater than a usual significant level (1%, 5%, or 10%), we think that this test accepts the null hypothesis $C = 1$ and APPP holds. If the $p$-value is less than a usual significant level, we think that this test rejects the null hypothesis and APPP does not hold.

$$RER_t = C + u_t \tag{2}$$

For the sub-period analysis, we use the least squares with breakpoints by Bai and Perron (1998, 2003a, 2003b). The Bai and Perron method can not only identify the breakpoints but also estimate the coefficients in all sub-periods. Concretely, three tests are used: the Sup$F_T(k)$, the double maximum statistics ($UD_{max}$ and $WD_{max}$), and the sequential Sup$F_T(l + 1/l)$. The $SupF_T(k)$ tests the null hypothesis of no structural breaks ($m = 0$) against the alternative hypothesis that there are $m = k$ breaks. The double maximum test considers the null hypothesis of no structural breaks ($m = 0$) against the alternative hypothesis of at least 1 through to M structural breaks. The double maximum test takes two forms, $UD_{max}$ and $WD_{max}$. The $UD_{max}$ statistic is the maximum value of the Sup$F_T(k)$ statistic while the $WD_{max}$ statistic weights the individual statistics. The sequential Sup$F_T(l + 1/l)$ procedure tests the null hypothesis of $l$ breaks against the alternative hypothesis of ($l$ + 1) breaks. We first conduct the double maximum test to examine whether or not the breaks exist. If the double maximum test ($UD_{max}$ and/or $WD_{max}$) confirms that at least one break exists, we examine the actual, fitted, and residual graphs in the three tests and choose the test whose result seems to be most reasonable. Following Bai and Perron (2003a, Section 6) and Rapach and

Wohar (2005), the unit root test is not needed before applying OLS to Eq. (2), which reduces the econometric work.

Finally, we can see that the method based on Eq. (2) has some relationships and differences with the coefficient restriction and the RER misalignment distribution tests in Zhang and Zou (2014). (1) It also uses the Wald test to test the coefficient (it is also a coefficient restriction test). However, the coefficient restriction test in Zhang and Zou (2014) tests whether the nominal exchange rate is equal to its PPP rate, and the method based on Eq. (2) tests whether the RER is equal to its equilibrium value (one). (2) It also examines the mean of the RER as used in the RER misalignment distribution test. However, the RER misalignment distribution test examines the RER mean using a simple statistic, and the method based on Eq. (2) examines the RER mean in a regression analysis. (3) Compared with the coefficient restriction test in Zhang and Zou (2014), one does not need to do the preliminary unit root and cointegration tests before performing equation estimation when using the method based on Eq. (2), and the econometric steps in this method are fewer.

*2.3. Data*

The core data in constructing the RER defined in Eq. (1) is the PPP rate. Different from the price index that can be obtained from a country's statistics department, the PPP rate can only be obtained by an international price level comparison, which is often conducted by the international organizations. The two databases that supply the RER defined in Eq. (1) are the Penn World Table (PWT) and the World Bank's World Development Indicators (WDI). The PWT 7.1 and earlier versions are made by the Center for International Comparisons at the University of Pennsylvania. The PWT 8.0 and later versions are made by economists at the University of California, Davis and the University of Groningen. Both the PWT 7.1 and PWT 8.1 are based on the 2005 International Comparison Program, while the WDI is based on the 2011 International Comparison Program. In addition, some calculation methods in the PWT 8.1 are different from those in the PWT 7.1; See Feenstra et al. (2013) for the details. These factors lead to the different values for the same variable in the three databases: the PWT 7.1, the PWT 8.1, and the WDI (the June 2015 version), which are all considered in this paper.

Concretely, only the RER and GDP per capita (GDPP) for each country are needed in this paper. In the PWT 7.1, the RER is the "Price Level of GDP, G-K method (US = 100)" (the variable "p" in the database), and the GDPP is the "PPP Converted GDP Per Capita (Chain Series), at 2005 constant prices" (the variable "rgdpch" in the database). In the WDI, the RER is the "Price level ratio of PPP conversion factor (GDP) to market exchange rate" (the code "PA.NUS.PPPC.RF" in the database), and the GDPP is the "GDP per capita, PPP (constant 2011 international $)" (the code "NY.GDP.PCAP.PP.KD" in the database). In the PWT 8.1, the RER is the "Price level of CGDPo (PPP/XR), price level of USA GDPo in 2005 = 1" (the variable "pl_gdpo" in the database), and the GDPP is derived from the "Output-side real GDP at chained PPPs (in mil. 2005US$)" (the variable "rgdpo" in the database) and the "Population (in millions)" (the variable "pop" in the database). Though the WDI supplies both the PPP-converted and market exchange rate-converted GDPPs, the PWTs only supply the PPP-converted GDPP, thus we use the PPP-converted GDPP. Though the PWT 8.1 supplies the name "Price level of CGDPe (PPP/XR), price level of USA GDPo in 2005 = 1" (the variable "pl_gdpe"), the values for this variable are blank, thus there isn't another choice for the RER besides the variable "pl_gdpo" in this database.

Finally, some notes about the data should be given. (1) In the following sections when the US is treated as the foreign country in Eq. (1), the RERs and GDPPs are normalized to those of the US = 1 in each year respectively. Likewise, when the UK is treated as the foreign country in Eq. (1), the RERs and GDPPs are normalized to those of the UK = 1 in each year respectively. (2) The longest whole period is 1950–2010 in the PWT 7.1, 1990–2013 in the WDI, and 1950–2011 in the PWT 8.1, respectively. For some concrete countries, however, the available periods are shorter because of the blank data in some years. (3) We chose 21 traditional, main industrial countries, the same countries as in Papell (1997) in his relative PPP studies; see Table 1 for details. (4) In the following sections, we first analyze the validity of APPP based on the PWT 7.1 (that is more traditional), then based on the WDI (that is more updated), and then based on the PWT 8.1.

## 3. Based on the PWT 7.1

In this section, we analyze the validity of APPP between each country and the US, and the validity of APPP between each country and the UK, both based on the PWT 7.1.

### *3.1. APPP between each country and the US: The whole period*

In this section we use the US as the foreign country in Eq. (1) and analyze APPP between each country and the US. The main econometric results are given in Table 1. The coefficient estimation and test in the sub-period are the same as those in the whole period except the breakpoint analysis, thus we only give the conclusion about the breakpoint analysis for the sub-period.

**Table 1**. APPP between each country and the US based on the PWT 7.1.

| Country | In the whole period | | | In the sub-period | |
|---|---|---|---|---|---|
| | *C* | $\chi^2$ statistic | APPP | Breakpoint | APPP holds for |
| Australia | $0.88^{***}$ | $7.24^{***}$ | Doesn't hold | 1973, 1983 | 1983–2010 |
| Austria | $0.78^{***}$ | $15.38^{***}$ | Doesn't hold | 1973, 1987 | 1987–2010 |
| Belgium | $0.89^{***}$ | $6.12^{**}$ | Holds | 1973 | 1973–2010 |
| Canada | $0.95^{***}$ | $7.21^{***}$ | Doesn't hold | 1993, 2002 | 1950–1992, 2002–2010 |
| Denmark | $1.06^{***}$ | 0.68 | Holds | 1972, 1987 | 1972–1986 |
| Finland | $0.98^{***}$ | 0.09 | Holds | 1974, 1987 | 1974–1986 |
| France | $0.92^{***}$ | $4.26^{**}$ | Holds | 1973 | 1973–2010 |
| Germany | $1.00^{***}$ | 0.00 | Holds | 1981, 1987 | 1970–1980, 1987–2010 |
| Greece | $0.66^{***}$ | $85.68^{***}$ | Doesn't hold | 1990, 2002 | 2002–2010 |
| Ireland | $0.79^{***}$ | $13.96^{***}$ | Doesn't hold | 1986, 2002 | None |
| Italy | $0.75^{***}$ | $25.54^{***}$ | Doesn't hold | 1972, 1987 | 1987–2010 |
| Japan | $0.90^{***}$ | 1.26 | Holds | 1973, 1986 | 1973–1985 |
| Netherlands | $0.77^{***}$ | $13.12^{***}$ | Doesn't hold | 1973 | 1973–2010 |
| New Zealand | $0.79^{***}$ | $53.27^{***}$ | Doesn't hold | 1973, 1987 | None |
| Norway | $1.00^{***}$ | 0.00 | Holds | 1973, 2002 | None |
| Portugal | $0.64^{***}$ | $84.55^{***}$ | Doesn't hold | 1990, 2002 | 2002–2010 |
| Spain | $0.63^{***}$ | $56.61^{***}$ | Doesn't hold | 1973, 1988 | None |
| Sweden | $1.05^{***}$ | 0.67 | Holds | 1964, 1973 | None |
| Switzerland | $0.99^{***}$ | 0.02 | Holds | 1973, 1987 | 1973–1986 |
| UK | $0.85^{***}$ | $13.67^{***}$ | Doesn't hold | 1974, 1988 | 1988–2010 |

Notes: *, **, and *** indicate that the coefficient $C$ (in Eq. (2)) or the $\chi^2$ statistic (in the Wald test with $H_0$: $C = 1$) is significant at the 0.1, 0.05, and 0.01 levels, respectively. No subscript indicates that the coefficient $C$ or the $\chi^2$ statistic is not significant at the 0.1 level. The whole periods for Germany and Greece are 1970–2010 and 1951–2010, respectively; those for the other countries are all 1950–2010. The coefficient $C$ in each sub-period is significant at the 0.01 level.

Sources: The PWT 7.1 database and the authors' calculations.

We first analyze the whole period. Seen from Table 1, the constant $C$ in each country is significant at the 0.01 level, spans from 0.6 to 1.1, and is not far from 1, which indicates the validity of APPP in each country to some extent. However, when we examine the Wald test to differentiate the validity, the countries are divided into three groups.

(1) For Australia, though the constant (0.88) is not far from 1, the Wald $\chi^2$ statistic (7.24) is significant at the 0.01 level and strongly rejects the null hypothesis that the constant is 1, thus APPP does not hold between this country and the US. Similar conclusions also appear in Austria, Canada, Greece, Ireland, Italy, the Netherlands, New Zealand, Portugal, Spain, and the UK. That is, for all 11 countries, APPP does not hold.

(2) For Belgium, the Wald $\chi^2$ statistic (6.12) is not significant at the 0.01 level (though it is significant at the 0.05 level), thus the null hypothesis that the constant is 1 is accepted at the 0.01 level (though rejected at the 0.05 level). A similar conclusion also appears in France. We think that APPP also holds for the two countries (though weakly).

(3) For Denmark, the Wald $\chi^2$ statistic (0.68) is not significant at the 0.1 level, thus the null hypothesis that the constant is 1 is strongly accepted and APPP holds. Similar conclusions also appear in Finland, Germany, Japan, Norway, Sweden, and Switzerland. That is, APPP (strongly) holds for the seven countries.

Fig. 2 gives the RERs of Austria (left part) and Germany (right part), which can help us to understand the econometric results for the two countries. We can see that the RER of Austria is mostly smaller than 1 before 1980 (though with fast increases in this period) and only fluctuates around the horizontal line of 1 after 1985, which leads APPP not to hold in the whole period. In contrast, the RER of Germany basically fluctuates around the horizontal line of 1 in its whole period, which leads APPP to hold.

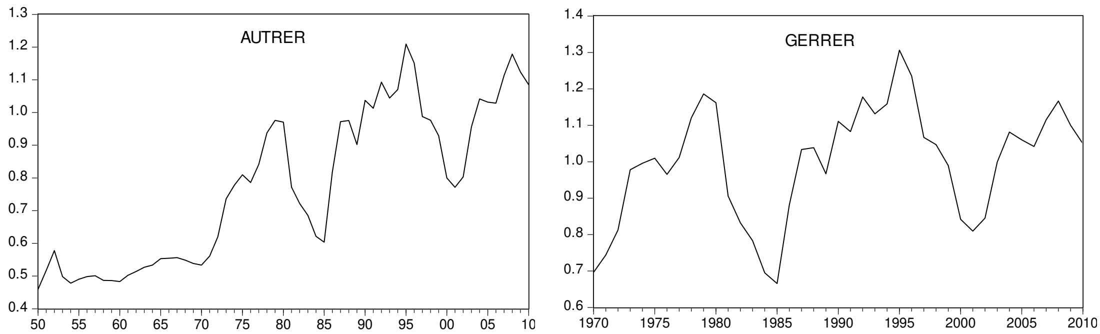


**Fig. 2.** The RERs of Austria (denoted AUTRER) and Germany (denoted GERRER).

Notes: The RER of the US = 1 in each year.

Sources: The PWT 7.1 and the authors' calculations.

*3.2. APPP between each country and the US: The sub-period*

For the sub-period, we use the Bai and Perron method as introduced in Section 2.2 to analyze the structure change. As there are only 61 observations in the whole period 1950–2010, we allow up to 2 breakpoints and use a trimming $\varepsilon = 0.15$. We use Austria to illustrate the breakpoint analysis; the results are listed in Table 2. We can see that the double maximum tests indicate there is at least one breakpoint at the 0.05 level (in detail, they suggest two breakpoints). Both the Sup$F_T(k)$ and the Sup$F_T(l + 1/l)$ tests indicate there are two breakpoints. The Sup$F_T(k)$ tests indicate that the two breakpoints are 1973 and 1987 (which is also confirmed by the double maximum tests), while the Sup$F_T(l + 1/l)$ tests suggest two different breakpoints: 1964 and 1987. By examining the actual, fitted, and residual graphs, we choose the breakpoints decided by the Sup$F_T(k)$ tests and the double maximum tests (1973 and 1987). They divide the whole period 1950–2010 into three regimes (sub-periods): 1950–1972, 1973–1986, and 1987–2010. In 1950–1972, the Wald test strongly rejects the null hypothesis that the constant (0.53) is equal to 1. Likewise, the null hypothesis that the constant (0.79) is equal to 1 in 1973–1986 is also strongly rejected. However, in 1987–2010, the constant (1.01) is very near 1, and the null hypothesis that the constant is equal to 1 is also confirmed by the Wald test at the 0.1 level. Thus, APPP only holds for Austria in its period 1987–2010.

**Table 2.** The breakpoint analysis for Austria.

| | | | | |
|---|---|---|---|---|
| Global L breaks vs none: | Sup$F_T(1)$ | Sup$F_T(2)$ | $UD_{max}$ | $WD_{max}$ |
| | 78.84$^{**}$ | 87.85$^{**}$ | 87.85$^{**}$ | 104.40$^{**}$ |
| Sequential L+1 breaks vs. L: | Sup$F_T(1\|0)$ | Sup$F_T(2\|1)$ | | |
| | 78.84$^{**}$ | 27.12$^{**}$ | | |
| Breakpoints: | 1973, 1987 | | | |
| Regimes: | 1950–1972 | 1973–1986 | 1987–2010 | |
| $C$: | 0.53$^{***}$ | 0.79$^{***}$ | 1.01$^{***}$ | |
| $\chi^2$ statistic: | 1777.88$^{***}$ | 20.86$^{***}$ | 0.10 | |

Notes: $^{*}$, $^{**}$, and $^{***}$ indicate that the coefficient $C$ (in Eq. (2)) or the statistic (in the Bai and Perron test and the Wald test) is significant at the 0.1, 0.05, and 0.01 levels, respectively. No subscript indicates there is no significance at the 0.1 level.

The right part of Table 1 gives the conclusions about each country's sub-periods. We can see that there is at least one breakpoint in each whole period for all the 20 countries, and the year 1973 (1972, or 1974) is confirmed as a breakpoint in most countries, which indicates the influence of the change of the exchange rate regime on the RER. Among the 20 countries, APPP holds for at least one sub-period for 15 countries (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, the Netherlands, Portugal, Switzerland, and the UK). For the remaining 5 countries (Ireland, New Zealand, Norway, Spain, and Sweden), APPP does not hold in none of the sub-periods.

Conclusively, in the whole period or in at least one sub-period of 17 countries, APPP holds. However, from a different view, for each of the 20 countries, APPP does not hold either in the whole period or in at least one sub-period. Thus, the econometric analysis gives us this conclusion: the phenomenon that APPP holds is common, and the phenomenon that APPP does not hold is also common.

### *3.3. APPP between each country and the UK*

After knowing APPP between each country and the US, we then investigate whether the conclusion that is obtained by using the US as the numeraire is robust when another country is used as the numeraire. Some relative PPP studies choose Germany as another numeraire besides the US, but the whole period for Germany in the PWT 7.1 begins from 1970 and is obviously shorter than those of the other countries which begin from 1950 or 1951. Considering that the UK is also much influential in the world economy and is also located in Europe, we choose the UK as the new numeraire, and analyze APPP between each country and the UK in this section. Each country's RER against the UK can be obtained from this RER against the US divided by the UK's RER against the US.

As in Sections 3.1 and 3.2, we analyze both the whole period and the sub-period. The results are listed in Table 3. As the econometric result for the APPP between the US and the UK has been given in Table 1, we don't list the result for the same pair of countries in Table 3 anymore.

**Table 3**. APPP between each country and the UK based on the PWT 7.1.

| Country | In the whole period | | | In the sub-period | |
|---|---|---|---|---|---|
| | *C* | $\chi^2$ statistic | APPP | Breakpoint | APPP holds for |
| Australia | $1.05^{***}$ | 1.38 | Holds | 1973, 1986 | 1950–1972, 1986–2010 |
| Austria | $0.90^{***}$ | $10.31^{***}$ | Doesn't hold | 1973 | 1973–2010 |
| Belgium | $1.05^{***}$ | $2.76^{*}$ | Holds | 1972, 1981 | 1950–1971, 1981–2010 |
| Canada | $1.17^{***}$ | $7.53^{***}$ | Doesn't hold | 1961, 1978 | 1978–2010 |
| Denmark | $1.23^{***}$ | $28.54^{***}$ | Doesn't hold | 1971, 1980 | 1950–1970 |
| Finland | $1.16^{***}$ | $29.63^{***}$ | Doesn't hold | 1959, 1973 | None |
| France | $1.09^{***}$ | $13.90^{***}$ | Doesn't hold | 1959, 1997 | 1997–2010 |
| Germany | $1.07^{***}$ | $4.68^{**}$ | Holds | 1980 | 1980–2010 |
| Greece | $0.78^{***}$ | $82.11^{***}$ | Doesn't hold | None | |
| Ireland | $0.91^{***}$ | $10.40^{***}$ | Doesn't hold | 1985, 2002 | None |
| Italy | $0.88^{***}$ | $31.86^{***}$ | Doesn't hold | 1986 | 1986–2010 |
| Japan | $1.02^{***}$ | 0.12 | Holds | 1968, 1984 | 1968–1983 |
| Netherlands | $0.89^{***}$ | $6.99^{**}$ | Holds | 1968 | 1968–2010 |
| New Zealand | $0.94^{***}$ | $5.44^{**}$ | Holds | 1960, 1998 | None |
| Norway | $1.16^{***}$ | $20.11^{***}$ | Doesn't hold | 1970 | 1950–1969 |
| Portugal | $0.76^{***}$ | $114.07^{***}$ | Doesn't hold | 1979, 1992 | None |
| Spain | $0.73^{***}$ | $98.11^{***}$ | Doesn't hold | 1986 | None |
| Sweden | $1.23^{***}$ | $43.29^{***}$ | Doesn't hold | 1968, 1980 | None |
| Switzerland | $1.13^{***}$ | $4.94^{**}$ | Holds | 1973 | None |

Notes: $^{*}$, $^{**}$, and $^{***}$ indicate that the coefficient *C* (in Eq. (2)) or the $\chi^2$ statistic (in the Wald test with $H_0$: $C = 1$) is significant at the 0.1, 0.05, and 0.01 levels, respectively. No subscript indicates that the coefficient *C* or the $\chi^2$ statistic is not significant at the 0.1 level. The whole periods for Germany and Greece are 1970–2010 and 1951–2010, respectively; those for the other countries are all 1950–2010. The coefficient *C* in each sub-period is significant at the 0.01 level.

Sources: The PWT 7.1 and the authors' calculations.

We can see that the validity of APPP against the UK is similar to that against the US. Concretely, in the whole period, APPP holds for 7 countries, and does not hold for the other 12 countries. In the sub-period, there is no breakpoint in Greece. In the other 18 countries where the breakpoints exist, APPP holds in at least one sub-period for 11 countries. For the other 7 countries, however, APPP does not hold in any sub-period. Thus we still conclude: the phenomenon that APPP holds is common, and the phenomenon that APPP does not hold is also common.

## 4. Based on other databases

After knowing APPP in the 20 countries based on the PWT 7.1, we next analyze APPP based on other databases (the WDI and the PWT 8.1) to check for robustness.

### *4.1. Based on the WDI*

In this section, we analyze the validity of APPP based on the WDI database. As in Section 3, both APPPs in each country against the US and the UK are investigated. As the whole period for each country is 1990–2013 (with only 24 observations), we don't analyze the sub-period. The econometric results are listed in Table 4.

**Table 4**. APPP between each country and the US or the UK based on the WDI.

| Country | APPP against the US | | | APPP against the UK | | |
|---|---|---|---|---|---|---|
| | $C$ | $\chi^2$ statistic | APPP | $C$ | $\chi^2$ statistic | APPP |
| Australia | 1.05*** | 0.40 | Holds | 0.98*** | 0.08 | Holds |
| Austria | 1.08*** | 4.70** | Holds | 1.02*** | 0.30 | Holds |
| Belgium | 1.08*** | 3.92** | Holds | 1.01*** | 0.22 | Holds |
| Canada | 0.99*** | 0.04 | Holds | 0.93*** | 3.81* | Holds |
| Denmark | 1.35*** | 58.60*** | Doesn't hold | 1.27*** | 63.63*** | Doesn't hold |
| France | 1.13*** | 10.19*** | Doesn't hold | 1.06*** | 3.07* | Holds |
| Finland | 1.20*** | 18.73*** | Doesn't hold | 1.13*** | 11.88*** | Doesn't hold |
| Germany | 1.10*** | 7.24** | Holds | 1.04*** | 0.88 | Holds |
| Greece | 0.81*** | 23.79*** | Doesn't hold | 0.76*** | 92.75*** | Doesn't hold |
| Ireland | 1.09*** | 4.06** | Holds | 1.02*** | 1.01 | Holds |
| Italy | 0.99*** | 0.03 | Holds | 0.93*** | 7.37** | Holds |
| Japan | 1.33*** | 24.53*** | Doesn't hold | 1.27*** | 9.72*** | Doesn't hold |
| Netherlands | 1.08*** | 4.71** | Holds | 1.02*** | 0.26 | Holds |
| New Zealand | 0.93*** | 1.63 | Holds | 0.87*** | 10.47*** | Doesn't hold |
| Norway | 1.37*** | 52.46*** | Doesn't hold | 1.29*** | 57.55*** | Doesn't hold |
| Portugal | 0.80*** | 70.52*** | Doesn't hold | 0.75*** | 243.13*** | Doesn't hold |
| Spain | 0.90*** | 7.99*** | Doesn't hold | 0.85*** | 34.44*** | Doesn't hold |
| Sweden | 1.25*** | 26.56*** | Doesn't hold | 1.18*** | 17.42*** | Doesn't hold |
| Switzerland | 1.38*** | 75.95*** | Doesn't hold | 1.30*** | 45.77*** | Doesn't hold |
| UK | 1.06*** | 5.95** | Holds | | | |

Notes: *, **, and *** indicate that the coefficient $C$ (in Eq. (2)) or the $\chi^2$ statistic (in the Wald test with $H_0$: $C = 1$) is significant at the 0.1, 0.05, and 0.01 levels, respectively. No subscript indicates that the coefficient $C$ or the $\chi^2$ statistic is not significant at the 0.1 level. The period for each country is 1990–2013.

Sources: The WDI database (June 2015) and the authors' calculations.

We can see that the constant $C$ in each country (whether against the US or the UK) is significant at the 0.01 level, spans from 0.8 to 1.4, and is not far from 1, which indicates the validity of APPP in each country to some extent as in Section 3. Concretely, for the 20 countries against the US, APPP holds for 10 countries, and it does not hold for the other 10 countries. For the 19 countries against the UK, APPP holds for 9 countries, and it does not hold for the other 10 countries. For 9 countries (Denmark, Finland, Greece, Japan, Norway, Portugal, Spain, Sweden, and Switzerland) where APPP does not hold whether against the US or the UK, we find APPP holds between these pairs: Denmark and Norway, Finland and Japan, Greece and Portugal, Spain and New Zealand, Sweden and Japan, and Switzerland and Norway.

### *4.2. Based on the PWT 8.1*

In this section, we analyze the validity of APPP based on the PWT 8.1 database. The validity of APPP between each country and the US is listed in Table 5, while the validity of APPP between each country and the UK is listed in the Appendix Table.

**Table 5**. APPP between each country and the US based on the PWT 8.1.

| Country | In the whole period | | | In the sub-period | |
|---|---|---|---|---|---|
| | *C* | $\chi^2$ statistic | APPP | Breakpoint | APPP holds for |
| Australia | 0.98*** | 0.22 | Holds | 1973, 1983 | 1983–2011 |
| Austria | 0.96*** | 0.31 | Holds | 1973, 1997 | 1997–2011 |
| Belgium | 1.05*** | 0.90 | Holds | 1973 | None |
| Canada | 1.00*** | 0.09 | Holds | 1994, 2003 | 1950–1993 |
| Denmark | 1.13*** | 2.34 | Holds | 1973, 1987 | None |
| Finland | 1.11*** | 3.55* | Holds | 1974, 1997 | 1997–2011 |
| France | 1.05*** | 1.41 | Holds | 1973, 1987 | 1973–1986 |
| Germany | 1.02*** | 0.07 | Holds | 1972, 1998 | 1998–2011 |
| Greece | 0.82*** | 39.86*** | Doesn’t hold | 1973, 2003 | 2003–2011 |
| Ireland | 0.91*** | 3.62* | Holds | 1972 | 1972–2011 |
| Italy | 0.87*** | 9.44*** | Doesn’t hold | 1963, 1987 | 1987–2011 |
| Japan | 1.04*** | 0.15 | Holds | 1972, 1986 | 1972–1985 |
| Netherlands | 0.93*** | 1.01 | Holds | 1964, 1973 | 1973–2011 |
| New Zealand | 0.89*** | 15.11*** | Doesn’t hold | 1973, 2003 | 2003–2011 |
| Norway | 1.16*** | 5.73** | Holds | 1970, 1997 | 1997–2011 |
| Portugal | 0.70*** | 66.18*** | Doesn’t hold | 1973, 1990 | None |
| Spain | 0.76*** | 18.00*** | Doesn’t hold | 1973, 1987 | 1987–2011 |
| Sweden | 1.29*** | 19.97*** | Doesn’t hold | 1972, 1997 | 1950–1971 |
| Switzerland | 1.03*** | 0.07 | Holds | 1973, 1987 | 1973–1986 |
| UK | 0.93*** | 2.22 | Holds | 1972, 1987 | 1972–1986 |

Notes: *, **, and *** indicate that the coefficient *C* (in Eq. (2)) or the $\chi^2$ statistic (in the Wald test with $H_0$: $C = 1$) is significant at the 0.1, 0.05, and 0.01 levels, respectively. No subscript indicates that the coefficient *C* or the $\chi^2$ statistic is not significant at the 0.1 level. The whole period for Greece is 1951–2010, and those for all other countries are all 1950–2010. The coefficient *C* in each sub-period is significant at the 0.01 level.

Sources: The PWT 8.1 and the authors’ calculations.

We can see that the PWT 8.1 seems to be more favorable for APPP. In the whole period, APPP holds in 14 countries. In the sub-period, APPP holds for 17 countries in at least one sub-period. Conclusively, APPP holds for 19 countries (the 20 countries except Portugal) in the whole period or at least one sub-period. The validity of APPP between each country and the UK is a bit weaker than that between each country and the US (see the Appendix Table for details), but the main conclusion keeps to be unchanged.

## 5. Does the GDPP matter?

Now we turn to the question of why APPP holds for some countries while not for the other countries. Concretely, we will investigate whether or not the GDPP influences the validity of APPP. As APPP is a long-run concept (Rogoff, 1996; Taylor and Taylor, 2004), the whole period is more important than the sub-period; so we only analyze the whole period in this section.

### *5.1. APPP in three lower-income industrial countries*

Table 6 concludes the results in Sections 3 and 4. We can see that for most countries in Table 6, though APPP does not hold in some situations, it holds in at least one situation. For example for Australia, APPP does not hold when against the US and based on the PWT 7.1, but it holds in the other four situations. For Austria, APPP does not hold in two situations (against the US and against the UK, both based on the PWT 7.1), but it holds in the other three situations. For these countries, as APPP holds in at least one situation, we think the invalidity of APPP is not obvious and do not discuss these countries further. In contrast, for the three countries APPP does not hold in all five situations. They are Greece, Portugal, and Spain. For these three countries we think the invalidity of APPP is obvious and discuss them further.

**Table 6**. The invalidity of APPP in some countries in various situations.

| Situation | APPP does not hold for |
|---|---|
| Against the US and based on the PWT 7.1 | Australia, Austria, Canada, Greece, Ireland, Italy, the Netherlands, New Zealand, Portugal, Spain, and the UK |
| Against the US and based on the WDI | Denmark, France, Finland, Greece, Japan, Norway, Portugal, Spain, Sweden, and Switzerland |
| Against the US and based on the PWT 8.1 | Greece, Italy, New Zealand, Portugal, Spain, and Sweden |
| Against the UK and based on the PWT 7.1 | Austria, Canada, Denmark, Finland, France, Greece, Ireland, Italy, Norway, Portugal, Spain, and Sweden |
| Against the UK and based on the WDI | Denmark, Finland, Greece, Japan, New Zealand, Norway, Portugal, Spain, Sweden, and Switzerland |

Notes: The whole period is used.

Sources: Sections 3 and 4.

We list the validity of APPP among Greece, Portugal, and Spain in Table 7. As the econometric process is trivial, we only give the conclusions based on the WDI and the PWT 8.1. We can see that APPP holds for each pair of the three countries in the PWT 7.1, and holds for each pair in one of the other two databases (the WDI and the PWT 8.1). Thus, though APPP does not hold between the three countries and the US (or the UK), it commonly holds among these countries themselves.

**Table 7.** APPP in the three lower-income industrial countries.

| Country pair | APPP based on the PWT 7.1 | | | APPP based on other databases | |
|---|---|---|---|---|---|
| | $C$ | $\chi^2$ statistic | APPP | WDI | PWT 8.1 |
| Greece and Portugal | $1.04^{***}$ | $5.53^{**}$ | Holds | Holds | Doesn’t hold |
| Greece and Spain | $1.09^{***}$ | $4.26^{**}$ | Holds | Doesn’t hold | Holds |
| Portugal and Spain | $1.05^{***}$ | 2.07 | Holds | Doesn’t hold | Holds |

Notes: *, **, and *** indicate that the coefficient $C$ (in Eq. (2)) or the $\chi^2$ statistic (in the Wald test with $H_0$: $C = 1$) is significant at the 0.1, 0.05, and 0.01 levels, respectively. No subscript indicates that the coefficient $C$ or the $\chi^2$ statistic is not significant at the 0.1 level. The whole period is used. The coefficient $C$ in each country pair in the WDI and the PWT 8.1 is significant at the 0.01 level.

Sources: The PWT 7.1, the WDI, the PWT 8.1, and the authors' calculations.

Then, why does APPP not hold between the three countries and the US (or the UK), but holds among the three countries with each other? Based on Fig. 1 of the Penn effect, APPP tends to hold for a pair of countries whose GDPPs are near, and tends not to hold for a pair of countries whose GDPPs are far from each other. Table 8 lists the GDPPs of the 20 countries based on the PWT 7.1 and WDI, where the two databases give the same basic information. We can see that based on the PWT 7.1, the mean GDPPs of the three countries (0.53 for Greece, 0.39 for Portugal, and 0.57 for Spain) happen to be the three lowest among all the 20 countries. The minimum and maximum values give similar conclusions.[1] The three countries' GDPPs are a bit far from the GDPPs of the US and the UK compared with the other countries. This may be a reason for the result that APPP does not hold between the three countries and the US (or the UK) but commonly holds between the other 17 countries and the US (or the UK). In addition, the GDPPs of the three countries are near, which may lead APPP to hold among them.

**Table 8**: The GDPPs of the 20 countries in the whole periods (the US = 1 in each year).

| Country | Based on the PWT 7.1 | | Based on the WDI | |
|---|---|---|---|---|
| | Mean | [Min., Max.] | Mean | [Min., Max.] |
| Australia | 0.91 | [0.79, 1.01] | 0.79 | [0.75, 0.85] |
| Austria | 0.78 | [0.45, 0.93] | 0.85 | [0.82, 0.88] |
| Belgium | 0.76 | [0.56, 0.87] | 0.82 | [0.79, 0.86] |
| Canada | 0.87 | [0.82, 0.95] | 0.81 | [0.80, 0.84] |
| Denmark | 0.80 | [0.60, 0.89] | 0.90 | [0.83, 0.93] |
| Finland | 0.68 | [0.45, 0.83] | 0.75 | [0.67, 0.84] |
| France | 0.74 | [0.52, 0.89] | 0.76 | [0.72, 0.81] |
| Germany | 0.82 | [0.75, 0.90] | 0.83 | [0.76, 0.90] |
| Greece | 0.53 | [0.26, 0.69] | 0.57 | [0.47, 0.64] |
| Ireland | 0.61 | [0.42, 0.97] | 0.83 | [0.61, 0.98] |
| Italy | 0.67 | [0.40, 0.82] | 0.78 | [0.66, 0.85] |
| Japan | 0.64 | [0.21, 0.93] | 0.73 | [0.68, 0.83] |
| Netherlands | 0.87 | [0.67, 0.98] | 0.90 | [0.87, 0.94] |
| New Zealand | 0.74 | [0.60, 0.94] | 0.62 | [0.59, 0.65] |
| Norway | 0.99 | [0.69, 1.25] | 1.26 | [1.15, 1.31] |
| Portugal | 0.39 | [0.21, 0.51] | 0.55 | [0.51, 0.58] |
| Spain | 0.57 | [0.29, 0.69] | 0.66 | [0.62, 0.69] |
| Sweden | 0.86 | [0.74, 0.99] | 0.82 | [0.77, 0.88] |
| Switzerland | 1.15 | [0.87, 1.44] | 1.10 | [1.03, 1.26] |
| UK | 0.72 | [0.64, 0.83] | 0.72 | [0.70, 0.75] |

[1] However, the correlation coefficient cannot give useful information. For example, the correlation coefficients between the GDPPs of Australia, Austria, Greece, Portugal, and Spain and that of the US are 0.987, 0.990, 0.959, 0.991, and 0.991, respectively. They are very near and one cannot tell the difference in the GDPPs.

Sources: The PWT 7.1, the WDI, and the authors' calculations.

However, even though such a rule (the nearer the GDPP is, the more valid APPP is) exists, it is not hard and fast, because there are indeed some country pairs that do not obey this rule. For example, based on the PWT 7.1 and in the whole period, APPP holds between France and the US and does not hold between France and the UK, but the mean GDPP of France (0.74) is nearer to that of the UK (0.72) than to that of the US (1.00). A similar example can also be found in New Zealand in the WDI database. The GDPP of New Zealand is nearer to that of the UK than to that of the US; APPP holds between this country and the US but does not hold between this country and the UK.

*5.2. APPP in the pooled country data*

Besides the above concrete country analysis, we next analyze how the GDPP influences the validity of APPP in all the countries. To do this, we pool the data of all the countries together and apply the least squares with breakpoints to the pooled time series data.

We use the PWT 7.1 and APPP against the US to illustrate our pooled method. Each observation (a country in a year) includes a pair of data: a RER and a GDPP. The observations of the US are firstly excluded because the country is the numeraire. Then we pool all the observations of the other 20 countries together and then sequence them according to the GDPPs, from low to high. Thus, we obtain two new time series, the GDPP and the RER, where the country and the year are mixed. Finally we conduct the least squares with breakpoints for the new RER, with the new GDPP as the order. The econometric conclusion is given in Table 9, where we allow up to 5 breakpoints, as the observations in each situation are large enough.

**Table 9**. The pooled time series data analysis.

| Database | Against | GDPP range in each interval<br>Does APPP hold in the corresponding interval? | | | | | |
|---|---|---|---|---|---|---|---|
| PWT 7.1 | US | [0.21, 0.72] | [0.72, 1.44] | | | | |
| | | No | Yes | | | | |
| PWT 7.1 | UK | [0.30, 0.88] | [0.88, 1.17] | [1.17, 2.13] | | | |
| | | No | Yes | No | | | |
| WDI | US | [0.47, 0.63] | [0.64, 0.73] | [0.73, 0.79] | [0.79, 0.83] | [0.83, 0.91] | [0.91, 1.31] |
| | | No | Yes | No | Yes | No | No |
| WDI | UK | [0.66, 0.89] | [0.89, 1.03] | [1.03, 1.10] | [1.10, 1.16] | [1.16, 1.29] | [1.29, 1.85] |
| | | No | Yes | Yes | Yes | No | No |
| PWT 8.1 | US | [0.18, 0.44] | [0.44, 0.57] | [0.57, 0.63] | [0.64, 0.70] | [0.70, 0.75] | [0.75, 1.59] |
| | | No | No | No | No | No | No |
| PWT 8.1 | UK | [0.28, 0.68] | [0.69, 0.92] | [0.92, 2.18] | | | |
| | | No | Yes | No | | | |

Notes: "Against the US (or the UK)" means the US (or the UK) is the foreign country in Eq. (1). When against the US, the RER and GDPP of the US = 1 in each year; when against the UK, the RER and GDPP of the UK = 1 in each year. The observations in the PWT 7.1, the WDI, and the PWT 8.1 are 1199, 480, and 1239, respectively.

Sources: The PWT 7.1, the WDI, the PWT 8.1, and the authors' calculations.

We can see that when against the US and in each database, APPP does not hold when the GDPP is smaller than 0.6. But except this common result, no clear conclusion can be obtained. When against the UK, however, a common, clear conclusion can be obtained from the three databases. That is, the nearer the GDPPs of some observations are to the UK's GDPPs, the more valid APPP is for the RERs between these observations and the UK. Concretely, based on the PWT 7.1, APPP does not hold in the GDPP intervals [0.30, 0.88] and [1.17, 2.13], but does hold in the interval [0.88, 1.17]. In other words, APPP holds when the GDPP is between 88% and 117% of the GDPP of the UK, and does not hold when the GDPP is smaller than 88% or greater than 117% of the GDPP of the UK. Likewise, based on the WDI, APPP holds in three continued GDPP intervals [0.89, 1.03], [1.03, 1.10], and [1.10, 1.16], but does not hold in the other intervals where the GDPP is smaller than 0.89 or greater than 1.16. Based on the PWT 8.1, APPP holds in the GDPP interval [0.69, 0.92], and does not hold in the other two intervals where the GDPP values are smaller or greater than those in the interval [0.69, 0.92].

## 6. Conclusion

In this paper we regress the RER on a constant to see whether or not it fluctuates around its equilibrium value (one) by a coefficient restriction test. If the coefficient restriction test confirms that the mean of the RER is equal to its equilibrium value, we think that APPP holds; otherwise, we think that APPP doesn't hold. Then we apply this method to investigate the validity of APPP in 21 industrial countries.

As the values for the RERs in different databases are different, three main databases (the PWT 7.1, the WDI, and the PWT 8.1) are used. In addition, both the whole period and the sub-period are analyzed. Different databases and different period dimensions both show that the phenomenon that APPP holds is common, and the phenomenon that APPP does not hold is also common. For the three lower-income industrial countries (Greece, Portugal, and Spain), APPP does not hold between them and the US (or the UK), but APPP holds among them. The pooled country data also indicates that APPP may tend to hold for a pair of countries whose GDPPs are near. However, as the RER in each concrete country is idiosyncratic, the validity of APPP between a pair of arbitrary two industrial countries can be further studied.

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## Appendix Table

From the appendix table we still can find the general conclusion obtained in the main text: the phenomenon that APPP holds is common, and the phenomenon that APPP does not hold is also common. In addition, APPP still does not hold between each of the three lower-income countries (Greece, Portugal, and Spain) and the UK in the whole period based on the PWT 8.1.

**Table A1**. APPP between each country and the UK based on the PWT 8.1.

| Country | In the whole period | | | In the sub-period | |
|---|---|---|---|---|---|
| | *C* | $\chi^2$ statistic | APPP | Breakpoint | APPP holds for |
| Australia | 1.07*** | 2.01 | Holds | 1973, 1985 | 1985–2011 |
| Austria | 1.02*** | 0.17 | Holds | 1973, 1997 | 1997–2011 |
| Belgium | 1.13*** | 13.49*** | Doesn't hold | 1972, 1981 | 1981–2011 |
| Canada | 1.12*** | 4.15** | Holds | 1979 | 1979–2011 |
| Denmark | 1.19*** | 14.29*** | Doesn't hold | 1972, 1981 | 1950–1971 |
| Finland | 1.19*** | 29.12*** | Doesn't hold | 1974, 1997 | 1997–2011 |
| France | 1.14*** | 26.63*** | Doesn't hold | 1959, 1997 | 1997–2011 |
| Germany | 1.09*** | 4.68** | Holds | 1970, 1997 | 1950–1969, 1997–2011 |
| Greece | 0.89*** | 10.98*** | Doesn't hold | 1980 | 1951–1979 |
| Ireland | 0.98*** | 1.45 | Holds | 1969, 1989 | None |
| Italy | 0.94*** | 9.98*** | Doesn't hold | 1968, 1978 | 1968–1977 |
| Japan | 1.09*** | 1.73 | Holds | 1972, 2003 | 2003–2011 |
| Netherlands | 0.99*** | 0.07 | Holds | 1969, 1980 | 1980–2011 |
| New Zealand | 0.97*** | 0.77 | Holds | 1960, 1990 | 1960–1989 |
| Norway | 1.26*** | 15.29*** | Doesn't hold | 1970, 1979 | None |
| Portugal | 0.75*** | 196.38*** | Doesn't hold | 1979, 1992 | None |
| Spain | 0.81*** | 49.21*** | Doesn't hold | 1960, 1973 | None |
| Sweden | 1.40*** | 43.97*** | Doesn't hold | 1968, 1981 | None |
| Switzerland | 1.07*** | 0.95 | Holds | 1973, 1997 | None |

Notes: *, **, and *** indicate that the coefficient *C* (in Eq. (2)) or the $\chi^2$ statistic (in the Wald test with $H_0$: $C = 1$) is significant at the 0.1, 0.05, and 0.01 levels, respectively. No subscript indicates that the coefficient *C* or the $\chi^2$ statistic is not significant at the 0.1 level. The whole period for Greece is 1951–2010, and those for all other countries are all 1950–2010. The coefficient *C* in each sub-period is significant at the 0.01 level.

Sources: The PWT 8.1 and the authors' calculations.