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# Fixed Exchange Rate Regimes, Real Undervaluation, and Economic Growth*

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**Abstract.** This paper empirically studies how the fixed exchange rate regime (FERR) may promote economic growth by way of undermining the Balassa-Samuelson effect. When the industrial sector has faster growth of total factor productivity (TFP) than the nontradable sectors relative to the reference country, the FERR can suppress the Balassa-Samuelson effect if adjustment of domestic prices is subject to nominal rigidities. With the World Bank Development Indicators' data of sectoral value added and data of the purchasing power parity converter provided by the Penn World Table, we are able to estimate the home country's industrial-service (quasi-) relative-relative TFP against the United States. Applying those estimates, our econometric exercises then provide robust results showing that the FERR dampens the Balassa-Samuelson effect, and the real undervaluation thus created does promote growth. We also explore the channels for undervaluation to promote growth. Lastly, we compare industrial countries and developing countries and find that the FERR has more significant effects in developing countries than in industrial countries.

**Keywords:** fixed exchange rate regimes, real undervaluation, economic growth
**JEL classification:** F31, F43, O41

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## Fixed Exchange Rate Regimes, Real Undervaluation, and Economic Growth

### 1. Introduction

In theory, the exchange rate regime should not matter for economic performance in a perfect market environment because changes of the nominal exchange rate cannot move any real price (Rose, 2011). There is also empirical evidence showing that the choice of the exchange rate regime does not matter for the real exchange rate (e.g., Chinn and Wei, 2013). In an imperfect market with sticky prices, the fixed exchange rate regime may help stabilize domestic price levels and thus may promote growth. However, even this advantage has to be weighed against a fixed regime's proneness to cause bigger damages than a floating regime when negative shocks hit a country (Levy-Yeyati and Sturzenegger, 2003). On balance, empirical studies do not find a robust link between exchange rate regimes and economic growth (Rose, 2011); Levy-Yeyati and Sturzenegger (2003) even find that the fixed regime, defined by their own classification system based on countries' de facto exchange rate regimes, systematically hurts growth in developing countries.

However, the existing literature studies only the average effect of the fixed regime because most of the empirical studies treat the fixed regime as a stand-alone dummy variable in a growth equation. That approach may ignore the economic fundamentals that could differentiate the roles of the fixed and floating regimes.

In this paper, we consider one of such fundamentals, namely, faster rates of growth of the total factor productivity (TFP) in the industrial sector than in the rest of the economy relative to a reference country (the United States). When that happens, the Balassa-Samuelson effect (Balassa, 1964; Samuelson, 1964) dictates that the home country's currency will experience real appreciation against the reference country's currency. When the domestic market is free of frictions, that effect holds regardless of the choice of the exchange rate regime. However, domestic nominal prices may not adjust quickly to TFP shocks. In addition, the central bank may intervene to stabilize domestic nominal prices if it aims to maintain the fixed exchange rate when appreciation pressures come. As a result, a fixed exchange rate regime (FERR) may perform differently from a floating regime.

Under a floating regime, the nominal exchange rate would adjust in response to the efficiency gains in the industrial sector, regardless of whether domestic prices adjust; the Balassa-Samuelson effect dictates that real appreciation stops only after those gains are eliminated. When the nominal exchange rate is fixed, however, the Balassa-Samuelson effect may be dampened because the economy loses a fast-adjusting parameter. Real undervaluation thus may happen, and faster growth is possible (Dollar, 1992; Rodrik, 2008; Gluzmann, Levy-Yeyati, and Sturzenegger, 2008). Specifically, we study three drivers that are created by real undervaluation to promote overall growth.

The first driver is a structural effect that allows the industrial sector to absorb more labor. Because the industrial sector improves its efficiency faster than the rest of the economy, the whole economy may grow faster. The second driver is exports. Real undervaluation makes it more profitable for domestic firms to produce for external demand. To the extent that external demand is autonomous to domestic income, more exports may have a direct effect that causes higher growth. The third driver is investment. In addition to their direct effect, exports may create higher domestic savings (Dollar, 1992), which in turn lead to a higher rate of domestic investment (Horioka and Feldstein, 1980).

The above mechanism may apply more to developing countries than to industrial countries. Developing countries are still on the way to industrialization, so their industrial sectors tend to experience faster efficiency improvement than their nontradable sectors. In the meantime, markets tend to be less perfect in developing countries than in industrial countries. As a result, the FERR is more likely to cause undervaluation. In addition, the three drivers may play a more prominent role in developing countries than in industrial countries, so undervaluation is more likely to promote overall growth in developing countries.

To conduct our empirical tests, we estimate home countries' industrial-service (quasi-) relative-relative TFPs against the United States by combining the sectoral value-added data provided by the World Bank Development Indicators (WDI) data set and the purchasing power parity (PPP) converters provided by the Penn World Table 8.0. To the best of our knowledge, this is the first attempt to do such an estimation in the literature.

We compare our estimates with the TFP estimates of the countries covered by the EU KLEMS Growth and Productivity Accounts and find that our estimates are reasonably aligned with the EU KLEMS estimates. Using our estimates, we are able to provide a fine estimate for the Balassa-Samuelson effect and to study how the FERR dampens that effect. Then we study whether the real undervaluation created in this manner promotes economic growth.

We also study how growth is obtained through the three channels of higher shares of industrial employment, higher shares of exports, and a higher rate of investment, respectively. Lastly, we conduct a comparative study for industrial and developing countries.

It is widely acknowledged that different definitions of the FERR can lead to very different research results (Rose, 2011). We test real undervaluation under five prevailing definitions of the FERR provided, respectively, by the International Monetary Fund (IMF), Ilzetzki, Reinhart, and Rogoff (2008; hereafter "IRR"), Reinhart and Rogoff (2002; "RR"), Levy-Yeyati and Sturzenegger (2003; "LS"), and Shambaugh (2004; "JS").[1] The FERR is found to cause real undervaluation relative to the floating regime under all five definitions.

Our emphasis on a country's economic fundamentals in determining the performance of the FERR concurs Eichengreen's (2007, 9) comments about real exchange rate management:

> A stable and competitive real exchange rate … enable[s] a country to exploit its capacity for growth and development—to capitalize on a disciplined labor force, a high savings rate, or its status as a destination for foreign investment. Absent these fundamentals, policy toward the real

[1] For better exposure, we would like to use at least two letters to indicate one type of categorization. So in this case, we add the first letter of Shambaugh's first name.

exchange rate will accomplish nothing.

The fundamental in our paper is faster technological progress in the industrial sector than in the rest of the economy. Rodrik (2008) identifies another kind of economic fundamental. In his model, the tradable sector is assumed to face more policy distortions than the nontradable sector. Real exchange rate management thus is a way to overcome those distortions. In contrast, real undervaluation is useful in our case because the industrial sector is technologically better prepared than the rest of the economy to promote growth. In addition, instead of treating real undervaluation as a ready policy tool, we empirically study whether the FERR can cause real undervaluation with the economic fundamental we consider.

Next, in Section 2, we form our strategy to estimate the (quasi-) relative-relative TFPs and present our econometric models to test the Balassa-Samuelson effect and the relationship between real undervaluation and growth. Section 3 discusses our data sources and the definitions of the FERR. The baseline empirical results are presented in Section 4. Then in Section 5, we explore the three channels for real undervaluation to promote growth, and in Section 6, we compare developing countries with industrial countries. Section 7 concludes the paper and discusses the policy implications of our results.

## 2. Econometric Strategies

### 2.1 Estimating (quasi-) relative-relative TFPs

Let us consider a small open economy that comprises two sectors: industry and services. Industrial products are traded in both domestic and international markets. They are produced by capital and labor by the following production function of constant returns to scale:

$$Y_I = A_I K_I^{\alpha_I} L_I^{1-\alpha_I}, \tag{1}$$

where $Y_I$ is output; $A_I$ is the TFP index of industry; $K_I$ and $L_I$ are the amount of capital and the number of workers hired, respectively; and $\alpha_I$ is the output elasticity of capital.

Services are produced in a similar manner with the following production function:

$$Y_S = A_S K_S^{\alpha_S} L_S^{1-\alpha_S} \ , \tag{2}$$

where $Y_S$ is output; $A_S$ is the TFP index of services; $K_S$ and $L_S$ are the amount of capital and the number of workers hired, respectively; and $\alpha_S$ is the output elasticity of capital in services. Services cannot be traded internationally, and their output has to be balanced by domestic demand.

Capital is perfectly mobile across borders. The rental rate of capital, $r^*$, in the international capital market, measured in the international currency, is fixed for domestic firms. The same is true for the price of the industrial product in the international market, $P_I^*$, also measured in the international currency. Let the nominal exchange rate (indirect quote) be $e$. Denote the domestic nominal prices of industrial and service products by $P_I$ and $P_S$, respectively. Note that $P_I = eP_I^*$.

Firms in the industrial and service sectors choose the amounts of capital and labor to maximize their profits. Their maximization exercises yield the following first-order conditions:

$$P_I \alpha_I A_I K_I^{\alpha_I - 1} L_I^{1-\alpha_I} = P_S \alpha_S A_S K_S^{\alpha_S - 1} L_S^{1-\alpha_S} = r \ , \tag{3}$$

$$P_I \beta_I A_I K_I^{\alpha_I} L_I^{-\alpha_I} = P_S \beta_S A_S K_S^{\alpha_S} L_S^{-\alpha_S} = w \ , \tag{4}$$

where $r = er^*$ is the nominal rate of return of capital measured in domestic currency. The same is also true for the wage rate $w$. Let $V_{IS} = \frac{P_I Y_I}{P_S Y_S}$ be the ratio of (real) value added between the industrial sector and the service sector. Then, combining the two first-order conditions in (3) and (4), we have

$$\ln V_{IS} = \phi + \ln \frac{A_I}{A_S} + \ln \frac{P_I}{P_S} + \Lambda \ , \tag{5}$$

where $\phi$ is a constant, and $\Lambda = (\alpha_I - \alpha_S) \ln \frac{w}{r} + \ln \frac{L_I}{L_S}$.

The WDI provides data for sectoral value added, so $V_{IS}$ is known. It also provides data for sectoral labor allocations, so potentially we could replace $V_{IS}$ by the ratio of labor productivity between the two sectors. However, labor data are highly unreliable, especially in developing countries, either because the statistical method is not robust enough or because a large part of the labor force is employed in the informal sector, which is not subject to rigorous national statistical surveillance. In addition, significant rigidities often exist in the labor market. They even occur in industrial countries. So labor productivity data do not necessarily reflect the relative technological strengths of the two sectors.

In addition, the WDI does not provide data for wages. Realizing those data issues, we assume that $\Lambda$ is proportional to the logarithm of gross domestic product (GDP) per capita (ln*GDPPC*). Needless to say, this approximation will introduce noises into our estimation, but it makes sense with regard to economic theory and empirical regularities.

The relative price of labor and capital, *w*/*r*, is ultimately determined by factor endowments in a country, which is highly correlated with its per capita GDP. On the other hand, in the medium- and long-run sectoral labor allocations are consequences of structural change of an economy, which is also correlated with a country's per capita income (Ngai and Pissarides, 2008; Mao and Yao, 2012). The proportionality between $\Lambda$ and ln*GDPPC* can be thought of as a result of first-order approximation.

Data for sectoral relative prices are scant; complete data are available only for industrial countries. But they can be estimated from the PPP converter provided by the Penn World Table 8.0. When it is used to convert GDP measured by domestic prices to GDP measured by the dollar, the PPP converter can be expressed as

$$PPP = \left(\frac{P_I^*}{P_I}\right)^{\theta_I} \left(\frac{P_S^*}{P_S}\right)^{\theta_S} = \frac{1}{e}\left(\frac{P_I}{P_S}\right)^{\theta_S} \left(\frac{P_S^*}{P_I^*}\right)^{\theta_S},$$

where $\theta_I$ and $\theta_S$ are the respective shares of industrial products and services in national consumption, $\theta_I + \theta_S = 1$, and $P_I^*$ and $P_S^*$ are the domestic prices of industrial products and services in the reference country (the United States). To obtain the second equality, $P_I = eP_I^*$ is used. Taking log on both sides and rearranging terms, we obtain

$$\ln\frac{P_I}{P_S} = \frac{1}{\theta_S}\left(\ln PPP + \ln e\right) - \ln\frac{P_S^*}{P_I^*}. \tag{6}$$

Plugging this equation into Equation (5) gives us

$$\ln V_{IS} = \phi + \frac{1}{\theta_S}\left(\ln PPP + \ln e\right) + \beta \ln GDPPC + \left(\ln\frac{A_I}{A_S} - \ln\frac{P_S^*}{P_I^*}\right), \tag{7}$$

where $\beta$ is the ratio between $\Lambda$ and ln*GDPPC*. The term $\left(\ln\frac{A_I}{A_S} - \ln\frac{P_S^*}{P_I^*}\right)$, abbreviated to $\ln A_{IS}$ thereafter, is what we are most interested in. Note that $\frac{P_S^*}{P_I^*}$ is the internal real exchange rate of the United States, which should be highly correlated with the country's sectoral relative TFPs. As a result, $\ln A_{IS}$ can be conveniently interpreted as the sectoral relative-relative TFP of the home country against the United States. Because the relative price, not the relative TFP, of the reference country is used, "quasi-relative-relative TFP" is probably a more appropriate name for it. In the subsequent text, though, we will often simply use $\ln A_{IS}$ to denote it.

Then Equation (7) suggests that we can first estimate the following equation county by country:

$$\ln V_{IS,t} = \phi + \kappa \ln P_t + \beta \ln GDPPC_t + \varepsilon_t, \tag{8}$$

where the newly added subscript is an index for the calendar year, $P_t = PPP_t \times e_t$ is the real exchange rate (indirect quote), $\kappa$ is a parameter to be estimated, and $\varepsilon_t$ is an error term. Then we can estimate country *i*'s $\ln A_{IS}$ for each year, by

$$\ln A_{IS,it} = \ln V_{IS,it} - \ln V_{IS,it}\,. \tag{9}$$

Note that by definition, $\ln A_{IS,it}$ has zero mean. That can be understood as the result of a demeaning exercise. Ignoring the noises, the mean should be the constant $\phi$ estimated from Equation (8). It is noteworthy that demeaning does not affect within-country variations of the data. Therefore, our results will not be affected if our regressions adopt the country fixed-effect model.

Also note that by Equation (6), $\kappa$ has a theoretical value of $1/\theta_S$. In reality, the relationship between the real exchange rate and the sectoral ratio of value added can be influenced by many other factors not modeled here, and the value of $\kappa$ can substantially deviate from its theoretical value.

## 2.2 Real undervaluation and growth

With the estimates for $\ln A_{IS}$, we can then study whether the fixed regime leads to real undervaluation relative to the floating regime in the framework of the Balassa-Samuelson effect. Because our key explanatory variable $\ln A_{IS}$ is equivalent to the relative-relative TFP,[2] we define the left-hand variable by the logarithm of the home country's real exchange rate net of that of the reference country (the United States),[3] and conveniently denote it by $\ln RER_{it}$. Then our specification for the study of real undervaluation is

$$\ln RER_{it} = \eta_0 + \eta_1 \ln A_{IS,it} + \eta_2 \ln A_{IS,it} \times FERR_{it} + \eta_3 FERR_{it} + \delta_i + e_{it}, \tag{10}$$

where the $\eta$'s are parameters to be estimated, *FERR* is a dummy variable for the FERR, $\delta_i$ is country *i*'s fixed effect, and $e_{it}$ is an independent and identically distributed error term.

To facilitate interpretation, in actual regressions we use the direct quote of the real exchange rate, i.e., $1/P_t$, so a larger value of it means appreciation. We do not control the year fixed effect because $\ln RER_{it}$ contains the reference country's real exchange rate, which is the same for all countries in the same year. The parameter $\eta_1$ is the elasticity of the Balassa-Samuelson effect under the floating regime, and $\eta_1 + \eta_2$ is the elasticity of the Balassa-Samuelson effect under the fixed regime. The Balassa-Samuelson effect requires that $\eta_1$ be positive. If the fixed regime causes real undervaluation relative to the floating regime, then $\eta_2$ must be negative. We add the

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[2] We could have obtained each country's sectoral relative TFP, $\ln(A_I / A_S)$, because data can be obtained from the Bureau of Economic Analysis for the prices of industrial goods and services in the United States. However, that extra calculation may introduce more noises into our estimation. In addition, using relative-relative TFPs as the explanatory variable is more consistent with the modern formulation of the Balassa-Samuelson effect (Tica and Druzic, 2006).

[3] In PWT 8.0, the PPP converter is constructed taking 2005 as the base year. So for the United States, its real exchange rate of each year is just its price level of that year relative to its price level of 2005.

FERR dummy as a stand-alone variable to allow for the possibility that the exchange rate regime itself has a direct effect on the level of the real exchange rate.

Let $RER_{it}^{float}$ and $RER_{it}^{fixed}$ denote the home country's real exchange rates relative to the reference country's under the floating and fixed regimes, respectively, estimated from Equation (10). Then the rate of real undervaluation caused by the fixed regime relative to the floating regime can be measured by

$$UNDERVALUE_{it} = \frac{RER_{it}^{float} - RER_{it}^{fix}}{RER_{it}^{float}}.$$

When the difference between $RER_{it}^{float}$ and $RER_{it}^{fixed}$ is not large, we can approximate it by

$$UNDERVALUE_{it} = \ln RER_{it}^{float} - \ln RER_{it}^{fix} = -\eta_3 - \eta_2 \ln A_{IS,it}. \qquad (11)$$

The rate of real undervaluation under the floating regime is zero. The rate of real undervaluation under the fixed regime comprises two parts. One is measured by $-\eta_3$, which is directly linked to the choice of the exchange rate regime. The other is measured by $-\eta_2 \ln A_{IS,it}$, which is linked to the Balassa-Samuelson effect. Its sign depends on whether a country can grow its industrial TFP faster than its service TFP relative to the United States. Provided we have the expected estimate for $\eta_2$, the amount of real undervaluation increases (or real overvaluation decreases) if a country's industrial TFP grows faster than its service TFP relative to the United States.

Note that here our definition of "real undervaluation" differs from that of most others. The conventional approach is to estimate a linear relationship between the relative TFP or GDP per capita and the real exchange rate and then define real undervaluation by a country's deviation from this average relationship. We are concerned with the difference between the floating regime and the fixed regime. So for a country with the floating regime, real undervaluation is set to zero. For a country with the fixed regime, real undervaluation is defined by the gap between its rate of response to an increase in $\ln A_{IS}$ (i.e., the elasticity of the Balassa-Samuelson effect) and its counterfactual rate of response in the hypothetical case that it adopted the floating regime.

A direct way to study the effect of the fixed regime on growth through real undervaluation is to put $UNDERVALUE_{it}$ as an explanatory variable in a growth equation. But to compare our results with the existing results, we estimate the following growth equation:

$$GR\_GDPPC_{it} = b_0 + b_1 \ln GDPPC_{it-1} + b_2 \ln A_{IS,it} \times FERR_{it} + b_3 FERR_{it} + \delta_i' + \delta_t' + e_{it}', \quad (12)$$

where $GR\_GDPPC_{it}$ is the growth rate of real GDP per capita of country $i$ in year $t$; $GDPPC_{it-1}$ is its lagged real GDP per capita; the $b$'s are parameters to be estimated; and, to abuse notations, $\delta_i'$, $\delta_t'$, and $e_{it}'$ are the country fixed effect, year fixed effect, and error term, respectively. The effect of real undervaluation on growth comprises two parts: one is related to the choice of the exchange rate regime, measured by $b_3$; and the other, measured by $b_2$, is related to the fixed regime's ability to dampen the Balassa-Samuelson effect. If $b_2$ is positive, the dampening effect is conducive for growth.

## 3. Data and Variables

Our sample includes annual data of 159 countries from 1960 to 2010. In general, the number of countries in the sample increased over time, from an average of 40 countries each year in the 1960s to an average of 148 countries in the 2000s. The time span is long enough to enable us to overcome the power problem (Tica and Druzic, 2006). To estimate $\ln A_{IS}$, the ratio of value added between industrial and service sectors ($V_{IS}$), the PPP converter and per capita GDP will be used. Data for the PPP converter are obtained from the Penn World Table 8.0. Data for the other two variables come from the WDI, with per capita GDP measured in thousands of constant 2000 US dollars.

The estimated quasi-relative-relative TFPs, $\ln A_{IS}$, will then be used to test whether the adoption of the FERR dampens the Balassa-Samuelson effect. Since this effect of the FERR may depend on the flexibility of price levels and monetary policies, we will control how quickly the money supply changes. When a central government loses control of its pace to issue money, the growth rate of M2 will sharply increase. The difference in the growth rate of M2 from the previous year, denoted by GGR_M2, which is calculated from the data of M2 provided by the WDI, will thus be used as a measure.

As to the growth equation, we calculate the growth rate in per capita GDP and use it as the dependent variable. To identify growth channels, the share of industrial employment in total employment, the share of exported goods and services in GDP, and the share of investment (measured by fixed capital formation) in GDP will be considered as potential intermediaries for real undervaluation to promote growth. We will also control the share of the population between ages 15 and 64 and the share of general government expenditure in GDP as two conventional growth determinants. Data for all these variables are provided by the WDI. A descriptive summary of these variables is available in Panel A of Table 1.

[Table 1 about here]

The definition of "FERR" is crucially important to this paper. Different classifications usually lead to different empirical outcomes. Concerning this issue, we construct five definitions of the FERR from five popular categorizations of the exchange rate regime. The first is the IMF's de jure classification system. It used to be a typical method to identify whether a country had a fixed exchange rate regime (e.g., Baxter and Stockman, 1989). However, it has been widely acknowledged that the regime a country actually adopts may differ from the one it officially claims. Recently, alternative coding criteria have been proposed to revise the classification based on de facto behavior. We consider four prevailing alternatives along with the IMF's categorization.

The first two, RR (Reinhart and Rogoff, 2002) and IRR (Ilzetzki, Reinhart, and Rogoff, 2008), are related to each other. They are de facto classifications created from the same complicated algorithm taking into consideration parallel currency markets.

Briefly speaking, the presence of dual or multiple exchange rates are first identified according to country chronologies. If a country had a unified rate and an officially alleged regime, the official regime would be verified on the basis of the real exchange rate movements. If the country did not have a unified rate, or had a unified rate but the regime was not announced or failed to be confirmed, then a statistical classification would be performed. However, when the 12-month inflation rate exceeded 40 percent, the exchange rate regime is labeled as "freely falling." The original coverage of RR ranges from 1970 to 2007; whereas the coverage of IRR, which is an update to RR, extends to 1940. IRR also provides finer grids than RR does.

The third alternative is LS proposed by Levy-Yeyati and Sturzenegger (2003). This de facto classification system is based on cluster analysis according to three indicators: (a) exchange rate volatility as measured by the absolute change in the nominal exchange rate, (b) volatility of exchange rate changes as measured by the standard deviation of percentage changes, and (c) volatility of reserves as measured by the absolute change in dollar denominated reserves relative to the dollar value of the base money. Exchange rate regimes are categorized into three groups: fixed, intermediate, and floating. The original coverage of LS ranges from 1974 to 2004.

The fourth classification system, JS, is constructed by Shambaugh (2004) and is based on the de facto degree of exchange rate movements over a period. JS considers two groups of regimes: the group of "pegs," in which the monthly exchange rate stayed within $\pm 2$ percent bands (i.e., the difference between the max and min of the log of the month-end exchange rate was within 0.04) for at least two years; and the group of "nonpegs" if otherwise. The original coverage of JS ranges from 1970 to 2004.

Rose (2011) provides updates for the RR, LS, and JS classifications. Data of those three classifications and the IMF classification are obtained from Rose's personal website.[4] Reinhart's website provides updates for IRR.[5] The FERR dummy then is defined in the following way.

For the IMF and RR classifications, we follow Rose (2011) to define FERR = 1 if

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[4] http://faculty.haas.berkeley.edu/arose.
[5] http://www.carmenreinhart.com/data/browse-by-topic/topics/11/.

a regime is categorized in the group of “currency union/fix,” and to define FERR = 0 if a regime is categorized in the group of “narrow crawl,” “wide crawl/managed floating,” or “float.” Note that cases of “freely falling” classified by IMF and RR are excluded as in Rose (2011).

For the LS classification, we define FERR = 1 if a regime is categorized in the group of “fixed,” and we define FERR = 0 if it is categorized in the group of “intermediate” or “floating.” For the JS classification, FERR = 1 is defined for the group of pegs, and FERR = 0 is defined for the group of nonpegs.

Lastly, for the IRR classification, we define FERR according to its fine grid. In particular, we define FERR = 1 if a regime is in grids 1–4 (which range from cases of “no separate legal tender” to cases of “de facto peg”) and define FERR = 0 if it is in grids 5–13 (which range from cases of “preannounced crawling peg” to cases of “freely floating”). But cases of “freely falling” are excluded again.

Panel B of Table 1 provides a descriptive summary of the five thus-defined FERR regimes (for simplicity, we label them by the names of the classification systems from which they are created). The correlation coefficients among these definitions are exhibited in Table 2. Not surprisingly, the IMF definition has low correlation coefficients with the other four definitions. A coefficient of 0.9 indicates that the RR and IRR coding systems are highly correlated. As a result, we expect to find similar empirical results when these two definitions are used. However, IRR is more distinctive from the other three definitions than RR. It seems that IRR’s finer grids help it distinguish itself from the other categorizations.

[Table 2 about here]

## 4. Baseline Results

### 4.1 Estimates of ln$A_{IS}$

We first estimate Equation (8) for each country and obtain the logarithm of the sectoral quasi-relative-relative TFP, $\ln A_{IS,it}$, by Equation (9). To gauge the reliability of our estimation, we compare our estimates with those provided by EU KLEMS. We first note that EU KLEMS reports only sectoral TFP growth rates, so we need to convert our estimates into growth rates. Recall that

$$\ln A_{IS,it} = \ln \frac{A_{I,it}}{A_{S,it}} - \ln \frac{P_{St}^{*}}{P_{It}^{*}}.$$

So the growth differential of TFP between the industrial sector and the service sector is

$$\hat{A}_{I,it} - \hat{A}_{S,it} = \left( \ln A_{IS,it} - \ln A_{IS,it-1} \right) + \left( \ln \frac{P_{St}^{*}}{P_{It}^{*}} - \ln \frac{P_{St-1}^{*}}{P_{It-1}^{*}} \right). \qquad (13)$$

Data for the industrial and service prices in the United States are obtained from the Bureau of Economic Analysis's National Income and Product Account. The growth differentials of TFP in EU KLEMS are obtained directly from its sectoral TFP growth rates.

Figure 1 then presents our estimates of the TFP growth differentials against those calculated from the EU KLEMS estimates for each country covered by EU KLEMS. Except for the Czech Republic, Denmark, Luxembourg, Slovenia, and the United Kingdom, countries have positive correlation coefficients between the two series. The average correlation coefficient for all 19 countries is 0.25. If we exclude the five countries with negative correlation coefficients, the average is increased to 0.40. Austria, Germany, Ireland, the Netherlands, and Portugal have coefficients higher than 0.5. Portugal has the highest, at 0.67. Because both our estimates and the EU KLEMS estimates contain noises, we believe that the degree of match between the two series is in a reasonable range.

[Figure 1 about here]

Our hypothesis states that the FERR regime dampens the Balassa-Samuelson effect, which creates an undervaluation in real exchange rate when the TFP of the industrial sector increases relative to the TFP of the service sector. This undervaluation can give a higher growth rate to an economy. When the relative TFP decreases, however, the adoption of the FERR renders an overvalued real exchange rate. The economic growth rate may be lower instead. That is, under the FERR, we expect the growth rate to move together with the relative TFP.

In contrast, under the floating regime, the Balassa-Samuelson effect is in full play, thus, the co-movement between the growth rate and the relative TFP may not exist. As an example, Figure 2 describes the relationship between the growth rate of per capita GDP and the estimated quasi-relative-relative TFPs under different exchange rate regimes for China. The FERR here is defined according to the IRR classification. The history of China's exchange rate regime is divided into two phases according to IRR. Before 1994, China adopted a de facto floating regime; afterward, the regime was fixed. Consistent with our hypothesis, in the first phase when the regime was floating, there was no observable trend in China's growth rate, whereas the quasi-relative-relative TFP experienced a downward trend in general. In the second phase in contrast, the two variables were moving together as they both exhibited a W-shaped trajectory.

[Figure 2 about here]

Another way to validate our estimates is to compare industrial countries with developing countries. Industrialization means the growth of the industrial sector, to which technological progress is a significant contributor. As a result, it is reasonable to expect that industrial countries have higher ratios of TFP between their industrial sectors and service sectors than developing countries.

To confirm that expectation, we add the constant $\phi$ estimated from Equation (8) to each country's estimates of $\ln A_{IS}$ to get their levels in the sample period. The left panel of Figure 3 then shows the means of those levels for industrial and developing countries, respectively. It is indeed the case that industrial countries have higher levels of $\ln A_{IS}$ than developing countries in all years. However, consistent with the fact that industrial countries are deindustrializing, their average $\ln A_{IS}$ was declining over time. For developing countries, $\ln A_{IS}$ exhibited an M curve.

The right panel of Figure 3 compares the growth rates of the average $\ln A_{IS}$ in industrial and developing countries. Note that the growth rate of $\ln A_{IS}$ is the gap of TFP growth rate between the industrial sector and the service sector relative to that of the United States. In the early 1990s and early 2000s, developing countries had higher growth rates than industrial countries. The average growth rate of developing countries in the whole sample period was 0.02 percent, two percentage points higher than the average growth rate of industrial countries. Because developing countries are in general experiencing industrialization, this result makes sense.

[Figure 3 about here]

### 4.2 Testing real undervaluation

Then we estimate Equation (10) to test real undervaluation under the five definitions of the FERR. The results are presented in Table 3. In Column (1), we present the results with only ln$A_{IS}$ on the right-hand side in addition to the country dummies. This regression is intended to confirm the existence of the Balassa-Samuelson effect. It is shown by the significant and positive coefficient of ln$A_{IS}$. This coefficient indicates that the elasticity of the Balassa-Samuelson effect is 0.052. Compared with the results of the empirical studies gathered by Tica and Druzic (2006) that use sectoral TFPs as the independent variable, this elasticity is not small. In fact, several of those studies obtain negative coefficients.

[Table 3 about here]

In Columns (2)–(6), we estimate the full model of Equation (10) under different definitions of the FERR. The coefficient of ln$A_{IS}$ is significantly positive in all the regressions, meaning that the Balassa-Samuelson effect holds for the floating regime under all the definitions. In addition, its size is larger than 0.052 in all the regressions. Except under JS, the coefficient of the interaction term ln$A_{IS}$ × FERR is significantly negative, indicating that the fixed regime does lead to significant real undervaluation.

The categorization of JS returns a different result; the fixed regime is not shown to perform significantly differently from the floating regime. The reason may be because JS has a coarse categorization system. It is noteworthy that the elasticity of the Balassa-Samuelson effect becomes negative under the fixed regime defined by IRR and RR. Because those two classifications are the most sophisticated in capturing a country's de facto choice of the exchange rate regime, this result is indicative for the role played by the fixed regime to cause real undervaluation when the Balassa-Samuelson effect is supposed to work.

The coefficient of the stand-alone dummy FERR is significantly positive under all definitions. That is, the fixed regime itself causes real overvaluation if its impact on the Balassa-Samuelson effect is controlled for. The overall effect of the fixed regime defined by Equation (11) depends on the gap between the level of the TFP of the industrial sector and the level of the TFP of the service sector. Because by construction the average of this gap is zero, the average level of undervaluation caused by the fixed regime depends completely on the estimate of the stand-alone dummy FERR. Because this estimate is consistently positive across all the definitions, we conclude that on average the FERR causes real overvaluation. The size of overvaluation is not small.

By the LS definition, the real exchange rate on average is 13.1 percent higher under the fixed regime than under the floating regime. That is followed by the IMF and JS definitions, which return a rate of overvaluation of 12.9 percent and 11.2 percent, respectively. The effects are much smaller under the IRR and RR definitions, which are 4.5 percent and 2.9 percent, respectively. That probably explains why most empirical studies do not find a growth effect of the FERR because they in effect estimate the average contribution of the FERR.

Because the role of the fixed regime highly depends on the flexibility of domestic prices, the central bank's intervention, or both, it would be a good idea to control for the growth of money supply, which is what we show in Columns (7)–(11). In the regressions, GGR_M2 is measured in decimals. Except under the IMF definition, higher growth rates of money supply are found to cause real appreciation of the home country's currency, which is an expected result. However, the estimated effects are all very small.

The Balassa-Samuelson effect is still there under the floating regime by all definitions. It is noteworthy that its elasticity becomes larger under all five definitions. That means that the growth of money supply and $\ln A_{IS}$ are negatively correlated under the floating regime.[6] The coefficients of $\ln A_{IS} \times$FERR become significantly negative under all definitions. In addition, their sizes all become larger than their corresponding figures when the growth of M2 is not controlled. So the growth of money supply and $\ln A_{IS}$ are positively correlated under the fixed regime.[7] The coefficients of the stand-alone dummy FERR are still significantly positive under all definitions, and their magnitudes do not change much.

### 4.3 Real undervaluation and growth

Next we estimate Equation (12) to study whether real undervaluation caused by the fixed regime leads to higher rates of growth. The results are presented in Table 4. The first five columns are the results of the original two-way fixed-effect model. The coefficients of lagged per capita GDP are all significantly negative, implying strong convergence. Except under the IMF categorization, the coefficient of $\ln A_{IS} \times$FERR is significantly positive. That is, when defined by de facto choice of the exchange rate regime, the fixed regime promotes growth by dampening the Balassa-Samuelson effect.

The insignificant result of the IMF definition implies that how a country actually manages its exchange rate is probably more important than what it announces. A curious result, though, is that the direct effect of the fixed regime, measured by the coefficient of the stand-alone dummy FERR, is also positive under RR, LS, and JS. That seems to contradict the results of the Balassa-Samuelson effect, which show that the fixed regime causes overvaluation when its dampening effect on the Balassa-Samuelson effect is controlled for.

[Table 4 about here]

However, it is possible that a country chooses the exchange rate regime to promote economic growth. The contrasting results between the de jure regimes and the de facto regimes reinforce that possibility. If that is the case, the estimation of Equation

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[6] The reason may be that the nominal exchange rate tends to overreact to increases in $\ln A_{IS}$ so the growth of money can be slowed to achieve the right level of the real exchange rate.

[7] The reason is that the nominal exchange rate is fixed so money supply has to grow faster to respond to a larger $\ln A_{IS}$ to accommodate the appreciation pressure.

(12) is subject to the challenge of endogeneity.[8]

To deal with that challenge, we adopt the method introduced by Levy-Yeyati and Sturzenegger (2003) to instrument the FERR. In particular, five instrumental variables will be used for the FERR dummy: (a) the surface area of a country measured in square kilometers, (b) the relative economic size measured by the ratio of a country's GDP over that of the United States, (c) the island dummy indicating whether a country is an island,[9] (d) the ratio of total reserves to the monetary base for the earliest year when a country became observed, and (e) the average of exchange rate regimes among other countries in the IMF department to which a country belonged. Most variables are obtained from or calculated with the WDI data.

The results are presented in Columns (6)–(10) of Table 4. Now the coefficient of the dummy FERR is not significant in any regression, but the coefficient of $\ln A_{IS} \times$ FERR remains significantly positive under IRR, RR, and LS. Therefore, the direct effect of the fixed regime is not robust, and its positive effect is mainly created by dampening the Balassa-Samuelson effect.

We then consider only the contribution of real undervaluation for growth via the fixed regime's dampening effect. The amount of real undervaluation created this way is equal to $-\eta_2 \ln A_{IS,it}$. But we put $\ln A_{IS,it} \times FERR_{it}$ in the growth equation. So to recover the contribution of real undervaluation, we need to divide $b_2$ by $-\eta_2$.

Using the results provided by Table 3 and the IV results provided by Table 4, we then get the coefficients for real undervaluation for IRR, RR, and LS: 0.09, 0.12, and 0.15, respectively. Following Rodrik (2008), those coefficients imply that a 50 percent undervaluation would increase the growth rate by 4.5, 6.0, and 7.5 percentage points, respectively. Those numbers are much larger than the numbers obtained by Rodrik (2008) and Gluzmann, et al. (2008) which are in the range of one to two percentage points. That can probably be explained by the different ways that those two studies and our study have taken to define "real undervaluation."

[8] The estimation of Equation (8) is less likely so. A country does not change its exchange rate regime often, so the FERR is a slow variable. On the other hand, the real exchange rate can change very quickly. As a result, the exchange rate regime can be seen as predetermined when the real exchange rate is considered.

[9] For the list of island countries, see: https://en.wikipedia.org/wiki/List_of_island_countries.

In those two studies, undervaluation is defined by the gap between a country's actual real exchange rate and its counterfactual that is fully explained by the country's per capita GDP. That is, real undervaluation is defined on the level of the real exchange rate. In contrast, we define real undervaluation on the rate of response of the real exchange rate to respond to the changes in $\ln A_{IS}$. So our measure is more sensitive than the measure of the other two studies. As a result, the "intensity" of undervaluation is higher by our measure than by their measures, and our measure arrives at a larger growth effect than their measures for the same amount of undervaluation.

## 5. Exploring the Growth Channels

In this section, we explore possible channels for real undervaluation to promote economic growth. Because IRR is the most sophisticated categorization of de facto real exchange rate regimes and, together with RR, it consistently performs better than other categorizations in our study, we will focus on IRR for the time being.

Following our arguments in the introduction, we explore three channels: industrial employment, exports, and investment. Table 5 presents the results when we regress the share of industrial employment in total employment, the share of exports in GDP, and the share of investment in GDP, respectively, on $\ln A_{IS} \times$ FERR and the FERR, as well as lagged per capita GDP.

For each share, we conduct two regressions: one adopts the fixed-effect (FE) model, and the other instruments FERR on the basis of the FE model. Except in the two-stage regression for industrial employment, we yield significant and positive results for the coefficient of $\ln A_{IS} \times$ FERR. So by dampening the Balassa-Samuelson effect, adopting the fixed regime increases the share of industrial employment, the share of exports, and the share of investment, and the effect is more robust for the latter two shares. Using the method that we used to recover the effect of undervaluation on growth, we obtain the following result based on the FE regressions: a 10 percent real undervaluation increases the shares of industrial employment, exports, and investment by 1.71, 4.28, and 1.93 percentage points, respectively.

[Table 5 about here]

The level effects of the fixed regime, though, are generally negative. The two-stage FE model shows that, compared with countries adopting the floating regime, countries adopting the fixed regime have lower shares of industrial employment, exports, and investment. That seems to contradict the results found in Table 4 that show that the choice of the exchange rate regime alone does not have an effect on growth.

To further explore the channels of growth, we run several regressions for the growth equation and present their results in Table 6. In Column (1) of the table, we include as explanatory variables the shares of industrial employment, exports, and investment, as well as two other usual suspects of growth determinants: the share of government spending in GDP and the share of the population between the ages of 15 and 64 (the working-age population). As expected, higher shares of government spending strongly hurt growth, and higher shares of the working-age population strongly promote growth. The share of industrial employment is not significant, but higher shares of exports and investment are associated with higher rates of growth.

In Column (2), we leave out the shares of industrial employment, exports, and investment but add the two variables measuring undervaluation of the fixed regime, $\ln A_{IS} \times$ FERR and FERR. The results of government spending and working-age population do not change qualitatively, and the coefficients of both $\ln A_{IS} \times$ FERR and the FERR are significantly positive.

In Columns (3)–(5), we add the share of industrial employment, the share of exports, and the share of investment consecutively in the regression to see if they affect the results of $\ln A_{IS} \times$ FERR and the FERR. It turns out that the coefficient of the FERR becomes insignificant as soon as the share of industrial employment is added, but the coefficient of $\ln A_{IS} \times$ FERR remains significantly positive until the share of investment is added. To be more exact, the coefficient of $\ln A_{IS} \times$ FERR actually becomes larger when only the share of industrial employment is added, but it becomes smaller again when the share of exports is added in addition to the share of industrial employment. And it finally becomes insignificant when the share of investment is also added.

[Table 6 about here]

Two conclusions can be drawn from the above results. First, the dampening effect of the fixed regime on the Balassa-Samuelson effect is more robust than the level effect of the fixed regime. The dampening effect of the fixed regime is related to the higher rates of TFP growth in the industrial sector than in the service sector. The Balassa-Samuelson effect would eliminate any gain of growth caused by this differential of TFP growth. By dampening the Balassa-Samuelson effect, the fixed regime promotes growth. The level effect of the fixed regime is less robust because it is uncertain whether the fixed regime would cause undervaluation or overvaluation.

Second, although dampening the Balassa-Samuelson effect increases all three shares of industrial employment, exports, and investment, the share of exports and the share of investment are the channels for undervaluation to promote growth. However, investment is a stronger channel than exports because the fixed regime's dampening effect vanishes only when investment is controlled in the growth equation.

## 6. Industrial versus Developing Countries

We have found that the fixed regime promotes growth by dampening the Balassa-Samuelson effect. But the Balassa-Samuelson effect arises only when a country's TFP growth is faster in its industrial sector than in its service sector. As Figure 3 shows, that is more likely to happen in developing countries than in industrial countries. In developing countries, the growth effect of a given amount of undervaluation may also be larger because exports and capital accumulation, the two growth channels we have confirmed in the last section, may be more important for growth in those countries than in industrial countries.

In this section, we divide our sample into two subsamples—one for industrial countries and the other for developing countries—using the categorization provided by the World Bank based on gross national income (GNI) per capita.[10] In particular, high-income and higher-middle-income countries are defined as industrial countries, whereas low-income and lower-middle-income countries are defined as developing countries. Because of data availability of per capita GNI, some country-years could not be classified as industrial or developing countries, so they are excluded from analysis.

We first study the fixed regime's undervaluation in the two subsamples. The first two columns of Table 7 present the results using the IRR definition of the fixed regime. The Balassa-Samuelson effect is found in both samples under the floating regime, and its magnitude is much larger in industrial countries than in developing countries. The fixed regime is found to dampen the Balassa-Samuelson effect in both samples, but the dampening effect is much stronger in developing countries. Indeed, although it is insignificantly different from zero in industrial-country fixers, the Balassa-Samuelson effect is significantly negative in developing-country fixers. That is, real depreciation happens when the industrial sector has faster TFP growth than the service sector in developing countries with a fixed regime.

[Table 7 about here]

That result is consistent with the fact that markets are less developed, and thus prices are more rigid in developing countries than in industrial countries. However, the fixed regime alone is not found to have any level effect on the real exchange rate in either sample of countries. This result is different from the significantly positive effects we have found for the whole sample. Because industrial countries have higher real exchange rates than developing countries, the discrepancy is likely to be created by industrial countries' higher tendency to adopt the fixed regime than developing countries. In our sample, the fixed regime is found for 43 percent of country-years among industrial countries, whereas only 38 percent are found among developing countries.[11]

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[10] http://siteresources.worldbank.org/DATASTATISTICS/Resources/OGHIST.xls.

[11] Note that in the full sample, the share of country-years with the FERR is 46 percent under IRR. In both subsamples of industrial and developing countries, that share is lower than 46 percent because this share is 54 percent in the subsample of observations that could not be categorized as industrial or developing countries.

The remaining two regressions presented in Table 7 study how real undervaluation affects economic growth in the industrial-country sample and the developing-country sample, respectively. The contrast is stark. Among industrial countries, the fixed regime does not have a stand-alone effect on growth; nor does it promote growth by dampening the Balassa-Samuelson effect. Among developing countries, the fixed regime is found to promote growth either by itself alone or by dampening the Balassa-Samuelson effect.

However, as before, we should not interpret the growth effect of undervaluation directly from the coefficients of FERR and $\ln A_{IS}$ × FERR. Because the fixed regime alone does not cause real undervaluation, its significantly positive growth effect must come from other sources that are not accounted for in our study. The channel for the fixed regime to affect growth by real undervaluation is still through the Balassa-Samuelson effect. So we rely only on the coefficient of $\ln A_{IS}$ × FERR to interpret the impact of real undervaluation on growth. Like before, this coefficient should be divided by $-\eta_2$ to get the right estimate.

The final result is that a developing-country fixer grows 6.5 percent faster if faster TFP growth in its industrial sector allows it to gain a 50 percent undervaluation on the basis of the developing-country floaters' average real exchange rate. That effect is larger than what we got from the whole sample (4.5 percent).

Then in Table 8, we study how undervaluation affects industrial employment, exports, and investment in industrial countries and developing countries, respectively. Interesting contrasts also emerge from the two subsamples. Among industrial countries, undervaluation increases the share of industrial employment and the ratio of exports, but it significantly reduces the share of investment either by undermining the Balassa-Samuelson effect or by adopting the fixed regime alone. Among developing countries, the stand-alone effect of the fixed regime is unstable, but undervaluation through the Balassa-Samuelson effect is found to have positive effects on the share of exports and capital formation, but no significant effect on the share of industrial employment.

[Table 8 about here]

Summarizing the above results, we conclude that we have found that the industrial-country sample and the developing-country sample share the same result for the share of exports but have diverse results for the share of industrial employment and the share of investment. Real undervaluation raises the prices of tradable goods relative to services, so it is natural to see that it promotes exports.

The diverse results about investment can be explained by the stage of development. A developing country has not yet reached its steady state of growth, so accumulation of capital can still be a significant driver for growth. Real undervaluation can promote capital formation either by increasing savings through exports or by attracting more investment into its export sectors. In contrast, an industrial country has already reached its steady state, and capital accumulation is mostly limited to making up for capital depreciation. The gain from real undervaluation is thus mostly absorbed by more imports and domestic consumption.

The insignificant result of industrial employment in developing countries is harder to comprehend. One tentative explanation is that developing countries are diverse with respect to their efforts spent on industrialization. Real undervaluation stimulates more labor to be allocated to the industrial sector in countries that are striving for industrialization, but it may have no effects in countries that maintain a sluggish pace of industrialization.

## 7. Conclusion

In this paper, we develop a novel approach to estimate sectoral (quasi-) relative-relative TFPs for countries that have data of sectoral value added in the WDI. Using those estimates, we are able to test whether the fixed exchange rate regime dampens the Balassa-Samuelson effect. We find that under five definitions constructed from five popular classification systems of exchange rate regimes, the FERR does dampen the Balassa-Samuelson effect. Introducing the real undervaluation thus created into a growth equation, we find that real undervaluation leads to higher growth rates. We also explore the channels for that to happen and find that exports and investment are the two most significant channels. Lastly, we compare industrial countries and developing countries and find that the FERR is more likely to cause undervaluation, and undervaluation is more likely to promote growth in developing countries than in industrial countries.

Although our result that real undervaluation causes higher growth is consistent with the results of existing studies, our result that the FERR causes real undervaluation by dampening the Balassa-Samuelson effect is new to the literature. It is widely acknowledged that peripheral countries may fix the exchange rates between their own currencies and the currencies of countries of the Center, notably the U.S. dollar, in a bid to accelerate their economic growth through increased exports (Dooley, Folkerts-Landau and Garber, 2003). Under the Bretton Woods system, the major peripheral countries applying this practice were Japan and Germany; in the 1980s and 1990s, they were the East Asian Tigers; and today, it is China. Other examples are the new European Union members of Eastern Europe that have been admitted to the euro zone. Our empirical results suggest that those countries have been relatively successful because they have had sound economic fundamentals, particularly in their industrial sector. Our results thus pose several policy implications for real exchange rate management.

First, our results confirm Eichengreen's (2007) assessment that real exchange rate management works only when a country is well prepared with regard to economic fundamentals. The success of real undervaluation to promote growth critically depends on the ability of a country's tradable sector, particularly its manufacturing sector, to generate higher rates of growth than the rest of the economy because real undervaluation essentially provides a subsidy to the tradable sector.

Second, because economic fundamentals are important, real exchange rate management has to be formed as a contingent policy. As Figure 3 shows, the industrial sector does not always have faster rates of technological improvement than the service sector, even in developing countries. That suggests that the exchange rate regime should be changed accordingly in order to promote growth. However, in reality, once an exchange rate regime is adopted, it is not easy to change it. That may explain why the FERR is often found to fail to promote growth. Real exchange rate management thus requires fine-tuned policy that adapts to changes in economic fundamentals.

Third, the stage of development is an important factor in determining whether the FERR is useful for creating real undervaluation. Developing countries are in a better position than industrial countries to succeed for two reasons. The first is that developing countries are in the process of industrialization, and, as our estimates of $\ln A_{IS}$ have shown, their industrial sectors tend to experience faster technological progress than the rest of the economy. That is, developing countries are better prepared in their economic fundamentals than industrial countries to benefit from the FERR. The second reason is that domestic markets are less developed in developing countries than in industrial countries. As a result, it is easier for the FERR to cause real undervaluation when a developing country experiences faster technological progress in its industrial sector than in other sectors.

Fourth, our results provide clues for us to assess China's fixed exchange rate policy. As shown by Figure 2, China began to adopt a de facto pegging system in 1994, and its growth rates since have closely followed the change of its $\ln A_{IS}$. Two cycles can be observed. The first cycle happened around the time of the Asian financial crisis, which occurred in 1997. Before that crisis, the fixed exchange rate helped China reap the gains created by faster TFP growth in its industrial sector. However, those gains became negative after the crisis because the industrial sector had a slower rate of TFP growth than the service sector. The fixed exchange rate in effect hurt China's growth.

The second cycle happened around the global financial crisis of 2008. After China joined the World Trade Organization in 2001, the country began a new round of economic expansion, driven largely by unprecedented rates of growth of exports.[12] The fixed exchange rate helped China again. The global financial crisis forced the global economy into a prolonged period of deep adjustment; China's export growth

[12] Between 2001 and 2008, China's export grew by a factor of five. See http://www.stats.gov.cn.

also slowed down.

Reflected on the technological side, the industrial sector began to have slower rates of TFP growth than the service sector again. Accordingly, the fixed regime hurt China’s growth once more. Because the Chinese economy had double-digit growth in the mid-1990s and early 2000s, on balance China might have gained from the fixed rate regime since 1994. However, it is highly unlikely that the growth pattern of the mid-1990s and early 2000s will be repeated in the country because of the adjustments that have happened to the world economy and the structural change that has happened to the Chinese economy as a natural result of economic growth. Therefore, continuing the fixed exchange rate regime may not be a good idea for China.

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Table 1. Summary statistics of variables

| Variables | Obs. | Mean | Std. | Min. | Max. |
|---|---|---|---|---|---|
| | | Panel A | | | |
| $\ln V_{IS}$ | 5,465 | −0.590 | 0.511 | −1.982 | 1.131 |
| $\ln P_{IS}$ | 5,468 | −0.511 | 0.464 | −2.170 | 0.870 |
| ln*GDPPC* | 5,507 | 0.545 | 1.580 | −2.851 | 4.032 |
| GR_GDPPC (%) | 5,433 | 2.002 | 5.751 | −50.290 | 92.586 |
| GGR_M2 (%) | 4,433 | 0.051 | 1.017 | −5.289 | 7.762 |
| Gov. exp.(% GDP) | 5,394 | 15.666 | 6.154 | 2.047 | 64.393 |
| Pop. 15–64 (%) | 5,402 | 58.888 | 6.700 | 44.791 | 79.121 |
| Ind. employment (%) | 2,164 | 24.737 | 7.552 | 2.100 | 48.900 |
| Export (% GDP) | 5,437 | 35.192 | 24.308 | 1.946 | 234.352 |
| Investment (% GDP) | 2,806 | 14.023 | 7.666 | −2.884 | 74.404 |
| | | Panel B | | | |
| IMF | 3,963 | 0.435 | 0.496 | 0 | 1 |
| IRR | 4,118 | 0.461 | 0.499 | 0 | 1 |
| RR | 3,816 | 0.359 | 0.480 | 0 | 1 |
| LS | 3,227 | 0.522 | 0.500 | 0 | 1 |
| JS | 4,116 | 0.422 | 0.494 | 0 | 1 |

Note: Gross domestic product (GDP) per capita is measured in thousands of 2000 US dollars; GR_GDP_PC is the growth rate of GDP per capita; GGR_M2 is the growth in the growth rate of M2; Pop. 15–64 is the share of population ages 15 to 64; Gov. exp. is the share of government expenditure in GDP; Ind. employment is the share of industrial employment in total employment; Export is the share of exports in GDP; Investment is the share of fixed capital formation in GDP; IMF, IRR, RR, LS, and JS are dummy variables for the fixed exchange rate regime defined by the categorizations of the IMF, IRR, RR, LS, and JS.

Table 2. The correlation coefficient matrix of different definitions of the FERR

| | IMF | IRR | RR | LS | JS |
|---|---|---|---|---|---|
| IMF | 1 | | | | |
| IRR | 0.321 | 1 | | | |
| RR | 0.427 | 0.900 | 1 | | |
| LS | 0.402 | 0.251 | 0.385 | 1 | |
| JS | 0.433 | 0.368 | 0.431 | 0.414 | 1 |

Note: The numbers are simple averages of the correlation coefficients between any two classifications for each country in the sample.

Table 3. Testing real undervaluation under different definitions of the FERR

| Dep. variable: ln*RER* | (1) | (2) IMF | (3) IRR | (4) RR | (5) LS | (6) JS | (7) IMF | (8) IRR | (9) RR | (10) LS | (11) JS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\ln A_{IS}$ | 0.052*** | 0.116*** | 0.087*** | 0.138*** | 0.138*** | 0.081*** | 0.156*** | 0.159*** | 0.154*** | 0.164*** | 0.110*** |
| | (0.018) | (0.031) | (0.032) | (0.030) | (0.035) | (0.026) | (0.034) | (0.034) | (0.032) | (0.039) | (0.030) |
| $\ln A_{IS} \times$ FERR | | −0.108** | −0.099** | −0.142*** | −0.115** | −0.009 | −0.184*** | −0.232*** | −0.237*** | −0.166*** | −0.101** |
| | | (0.042) | (0.045) | (0.046) | (0.045) | (0.041) | (0.046) | (0.048) | (0.048) | (0.049) | (0.044) |
| FERR | | 0.129*** | 0.045*** | 0.029** | 0.131*** | 0.112*** | 0.155*** | 0.050*** | 0.042*** | 0.134*** | 0.107*** |
| | | (0.011) | (0.011) | (0.013) | (0.012) | (0.011) | (0.011) | (0.013) | (0.015) | (0.013) | (0.012) |
| GGR_M2 | | | | | | | 0.000 | 0.000* | 0.000* | 0.001* | 0.000* |
| | | | | | | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Constant | −0.511*** | −0.556*** | −0.482*** | −0.465*** | −0.543*** | −0.532*** | −0.584*** | −0.509*** | −0.497*** | −0.571*** | −0.551*** |
| | (0.003) | (0.006) | (0.006) | (0.006) | (0.007) | (0.006) | (0.007) | (0.007) | (0.006) | (0.008) | (0.007) |
| Country FEs | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| No. countries | 156 | 153 | 148 | 148 | 150 | 151 | 152 | 148 | 148 | 149 | 151 |
| No. Obs. | 5,419 | 3,883 | 4,050 | 3,748 | 3,159 | 4,047 | 3,332 | 3,453 | 3,272 | 2,818 | 3,450 |
| Adjusted $R^2$ | 0.695 | 0.762 | 0.726 | 0.744 | 0.761 | 0.747 | 0.750 | 0.735 | 0.747 | 0.748 | 0.741 |

Note: Standard errors in parentheses. ***significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 4. Real undervaluation and growth

| | FE | | | | | Two-stage FE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dep. variable: | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| GR_GDPPC (%) | IMF | IRR | RR | LS | JS | IMF | IRR | RR | LS | JS |
| Lagged ln*GDPPC* | −4.372*** | −2.286*** | −3.341*** | −5.138*** | −4.088*** | −4.037*** | −3.044*** | −2.446*** | −3.522*** | −3.044*** |
| | (0.379) | (0.301) | (0.342) | (0.469) | (0.371) | (0.881) | (0.598) | (0.757) | (1.207) | (0.957) |
| $\ln A_{IS} \times$ FERR | −0.182 | 3.133*** | 2.535*** | 1.842*** | 1.221* | 0.704 | 2.089* | 2.757* | 2.422** | 1.335 |
| | (0.630) | (0.604) | (0.731) | (0.671) | (0.688) | (1.153) | (1.147) | (1.408) | (1.211) | (1.440) |
| FERR | 0.336 | 0.344 | 0.526* | 0.972*** | 0.902*** | 3.234 | −1.337 | −1.378 | −0.422 | 0.474 |
| | (0.280) | (0.239) | (0.294) | (0.283) | (0.254) | (2.165) | (1.163) | (1.760) | (1.440) | (1.219) |
| Constant | 8.690*** | 6.318*** | 7.622*** | 7.854*** | 7.193*** | | | | | |
| | (0.594) | (0.517) | (0.576) | (0.619) | (0.528) | | | | | |
| Country FEs | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FEs | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| No. countries | 153 | 148 | 148 | 150 | 151 | 148 | 141 | 142 | 140 | 146 |
| No. Obs. | 3,865 | 3,998 | 3,723 | 3,140 | 4,017 | 3,710 | 3,199 | 3,259 | 2,608 | 3,258 |
| Adjusted $R^2$ | 0.187 | 0.194 | 0.203 | 0.170 | 0.154 | 0.147 | 0.123 | 0.142 | 0.119 | 0.110 |

Note: Standard errors in parentheses. ***significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 5. Undervaluation and industrial employment, exports, and investment

| Dependent variable | Share of ind. employment (%) | | Export/GDP (%) | | Investment/GDP (%) | |
|---|---|---|---|---|---|---|
| | FE | FE + IVs | FE | FE + IVs | FE | FE + IVs |
| Lagged ln*GDPPC* | 5.696*** | 8.167*** | 10.993*** | 12.439*** | 2.027*** | 0.009 |
| | (0.543) | (1.051) | (0.578) | (1.086) | (0.753) | (1.548) |
| $\ln A_{IS}\times$FERR | 3.971*** | 5.587 | 9.931*** | 15.103*** | 4.476*** | 4.127* |
| | (1.101) | (3.486) | (1.143) | (1.883) | (1.030) | (2.415) |
| FERR | −1.040*** | −5.120** | 0.361 | −4.312* | −1.073** | −15.787* |
| | (0.277) | (2.512) | (0.455) | (2.251) | (0.528) | (9.137) |
| | | | | | | |
| Country FEs | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FEs | Yes | Yes | Yes | Yes | Yes | Yes |
| No. countries | 130 | 106 | 148 | 141 | 106 | 93 |
| No. Obs. | 1,665 | 1,473 | 3,977 | 3,189 | 1,882 | 1,623 |
| Adjusted $R^2$ | 0.863 | 0.775 | 0.890 | 0.873 | 0.542 | 0.459 |

Note: Standard errors in parentheses. ***significant at 1% level; **significant at 5% level; *: significant at 10% level.

Table 6. Determinants of growth

| Dep. variable: GR_GDPPC (%) | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Lagged ln*GDPPC* | −12.094*** | −1.980*** | −4.092*** | −4.543*** | −6.278*** |
| | (1.028) | (0.330) | (0.564) | (0.566) | (1.181) |
| Gov exp. (% GDP) | −0.348*** | −0.148*** | −0.285*** | −0.265*** | −0.176*** |
| | (0.053) | (0.020) | (0.036) | (0.036) | (0.067) |
| Pop. of 15–64 (%) | 0.755*** | 0.223*** | 0.313*** | 0.319*** | 0.564*** |
| | (0.124) | (0.035) | (0.058) | (0.057) | (0.137) |
| Ind. employment (%) | −0.076 | | 0.012 | 0.017 | 0.001 |
| | (0.048) | | (0.030) | (0.029) | (0.053) |
| Export (% GDP) | 0.062*** | | | 0.051*** | 0.051** |
| | (0.019) | | | (0.009) | (0.020) |
| Investment (% GDP) | 0.132*** | | | | 0.085*** |
| | (0.033) | | | | (0.032) |
| $\ln A_{IS} \times$ FERR | | 1.851*** | 2.595** | 1.990* | 0.731 |
| | | (0.583) | (1.133) | (1.129) | (1.641) |
| FERR | | 0.553** | 0.228 | 0.309 | 0.005 |
| | | (0.227) | (0.273) | (0.271) | (0.581) |
| Country FEs | Yes | Yes | Yes | Yes | Yes |
| Year FEs | Yes | Yes | Yes | Yes | Yes |
| No. Countries | 98 | 143 | 126 | 126 | 83 |
| No. Obs. | 997 | 3,858 | 1,646 | 1,639 | 677 |
| Adjusted $R^2$ | 0.454 | 0.207 | 0.464 | 0.474 | 0.470 |

Note: Standard errors in parentheses. ***significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 7. Undervaluation and growth: Industrial versus developing countries

| | Undervaluation | | Growth | |
|---|---|---|---|---|
| | Industrial | Developing | Industrial | Developing |
| Lagged ln*GDPPC* | | | −9.188*** | −10.424*** |
| | | | (1.093) | (0.999) |
| $\ln A_{IS}$ | 0.303*** | 0.092** | | |
| | (0.054) | (0.045) | | |
| $\ln A_{IS} \times$ FERR | −0.394*** | −0.218*** | 0.795 | 2.815** |
| | (0.075) | (0.068) | (1.020) | (1.094) |
| FERR | −0.017 | 0.001 | −0.501 | 1.369** |
| | (0.023) | (0.028) | (0.405) | (0.584) |
| GGR_M2 | −0.001 | 0.000 | | |
| | (0.002) | (0.001) | | |
| Constant | −0.220*** | −0.811*** | 27.046*** | 2.914*** |
| | (0.011) | (0.012) | (2.780) | (0.662) |
| Country FEs | Yes | Yes | Yes | Yes |
| Year FEs | | | Yes | Yes |
| No. countries | 80 | 101 | 81 | 103 |
| No. Obs. | 947 | 1,197 | 1,103 | 1,264 |
| Adjusted $R^2$ | 0.825 | 0.699 | 0.359 | 0.347 |

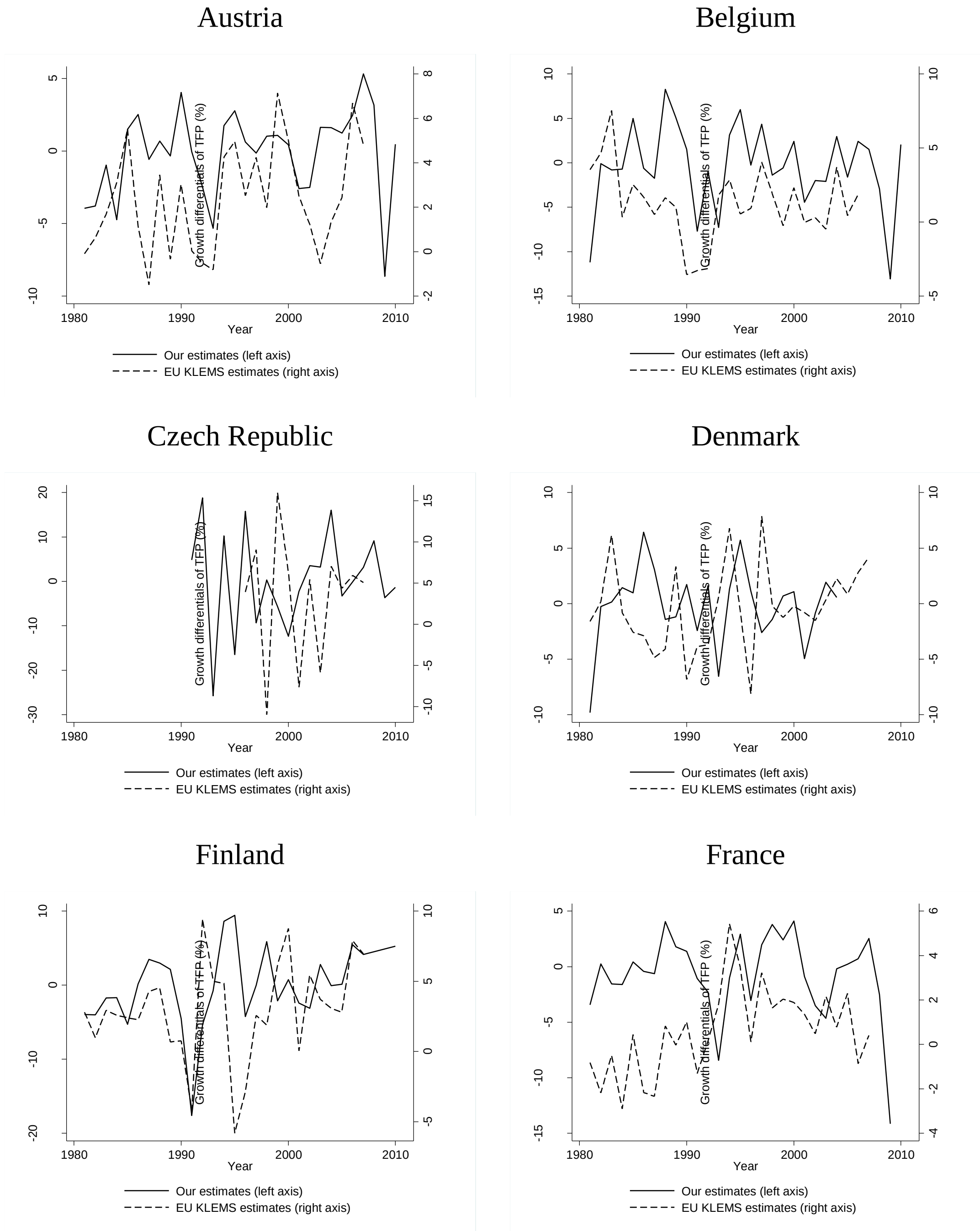
Note: Standard errors in parentheses. ***significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 8. Undervaluation and the shares of industrial employment, exports, and investment in industrial countries

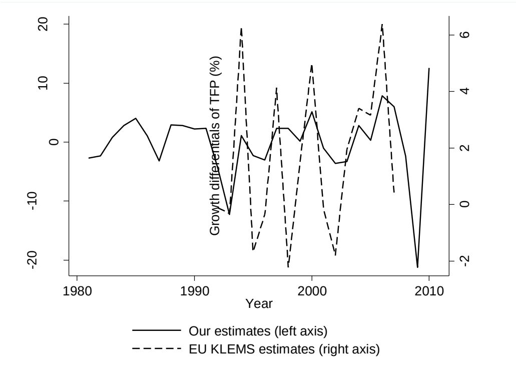
| | Industrial employment | | Exports | | Investment | |
|---|---|---|---|---|---|---|
| | Industrial | Developing | Industrial | Developing | Industrial | Developing |
| Lagged ln*GDPPC* | −0.077 | 7.738*** | 6.093** | 7.449*** | −4.587 | 1.378 |
| | (0.813) | (1.176) | (2.989) | (1.664) | (2.809) | (1.558) |
| $\ln A_{IS} \times$ FERR | 3.933*** | −0.322 | 20.142*** | 7.638*** | −7.128*** | 8.363*** |
| | (0.950) | (2.384) | (2.783) | (1.744) | (2.460) | (1.370) |
| FERR | 0.560** | −2.234*** | 2.554** | −1.101 | −5.785*** | −0.403 |
| | (0.267) | (0.660) | (1.114) | (0.934) | (1.379) | (0.758) |
| Country FEs | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FEs | Yes | Yes | Yes | Yes | Yes | Yes |
| No. countries | 74 | 81 | 81 | 103 | 38 | 95 |
| No. Obs. | 886 | 510 | 1,095 | 1,262 | 302 | 1,093 |
| Adjusted $R^2$ | 0.919 | 0.843 | 0.937 | 0.849 | 0.632 | 0.610 |

Note: Standard errors in parentheses. ***significant at 1% level; **significant at 5% level; *significant at 10% level.

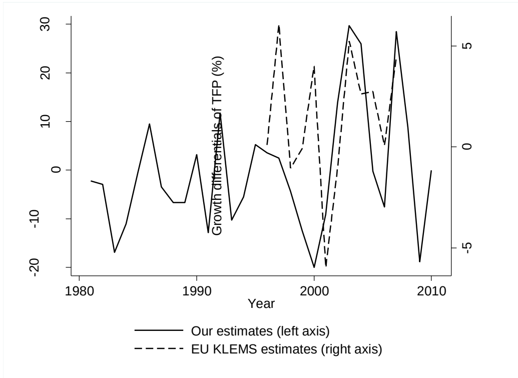
Figure 1. Sectoral growth differentials of TFP: A comparison with EU KLEMS



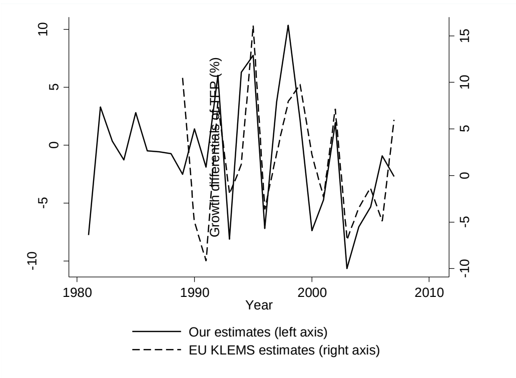
## Germany



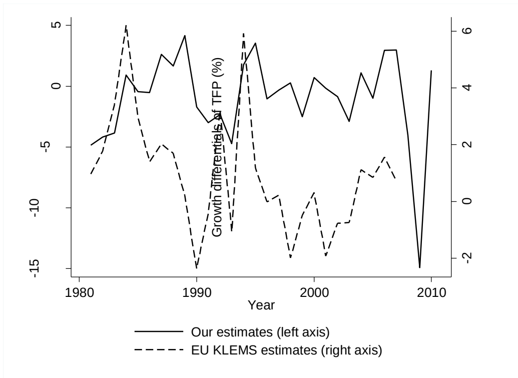

## Hungary



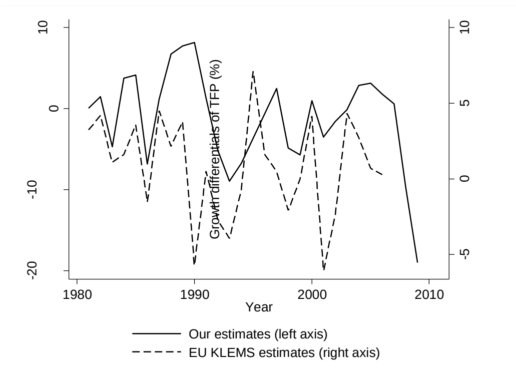

## Ireland



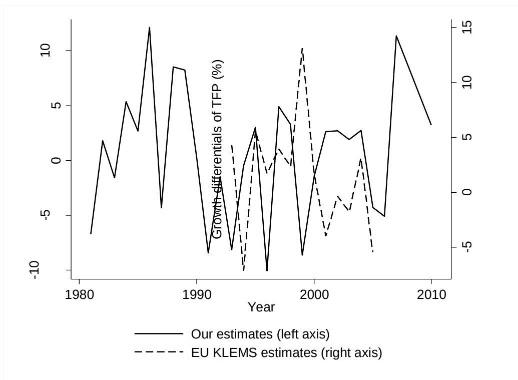

## Italy



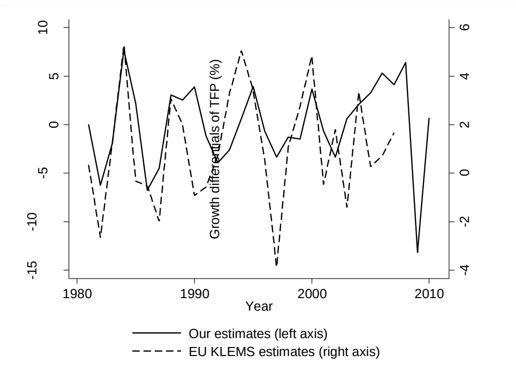

## Japan



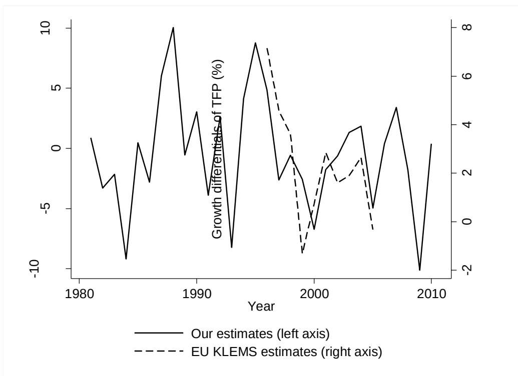

## Luxembourg



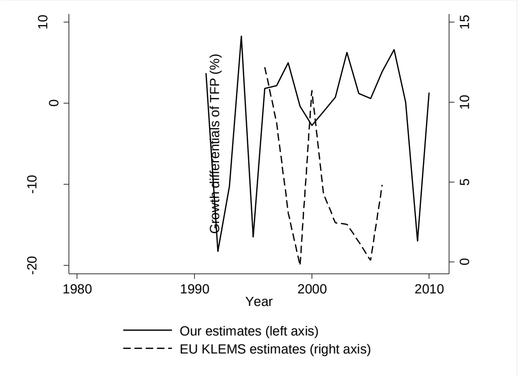

## Netherlands



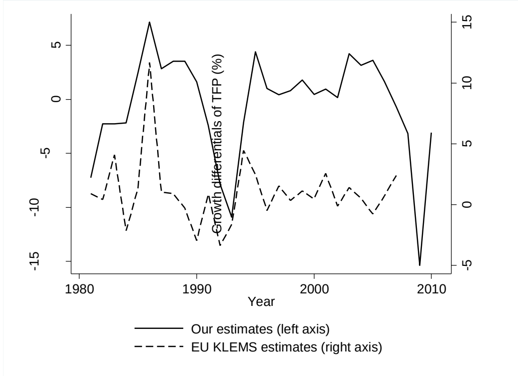

## Portugal



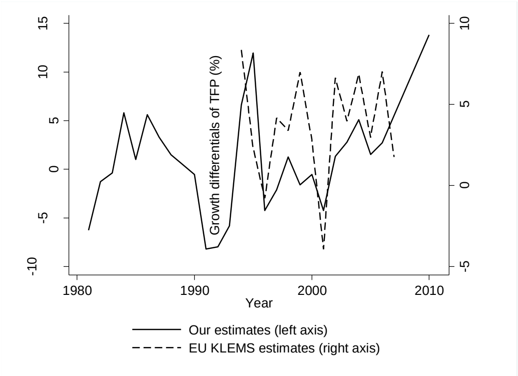
## Slovenia



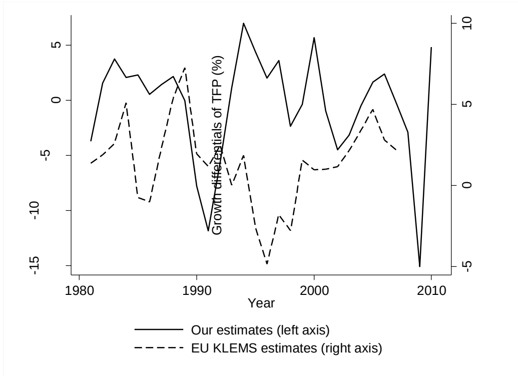

## Spain




## Sweden




## United Kingdom




## United States

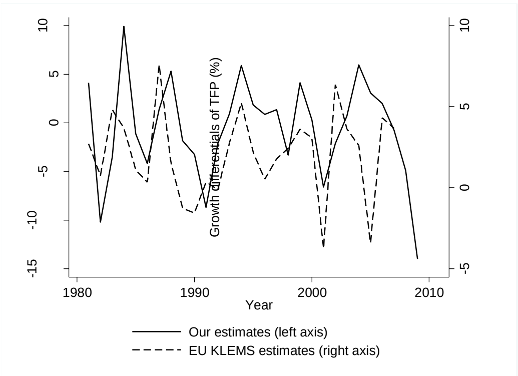


Figure 2. Exchange rate regimes, quasi-relative-relative TFPs, and growth in China

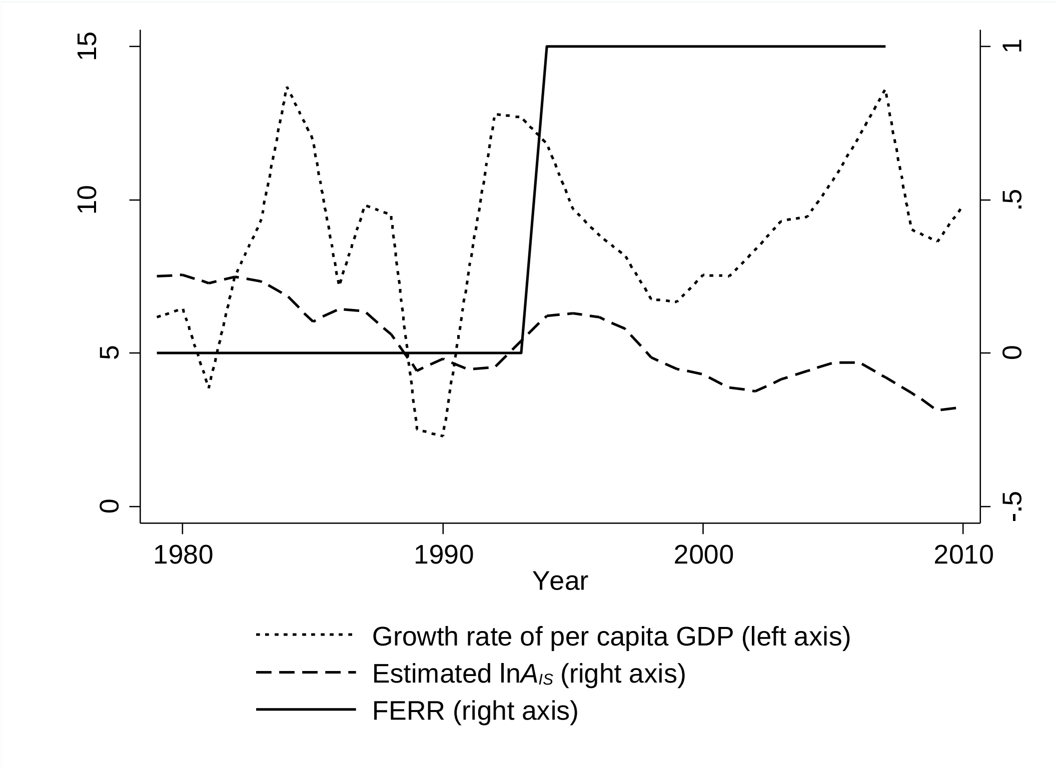
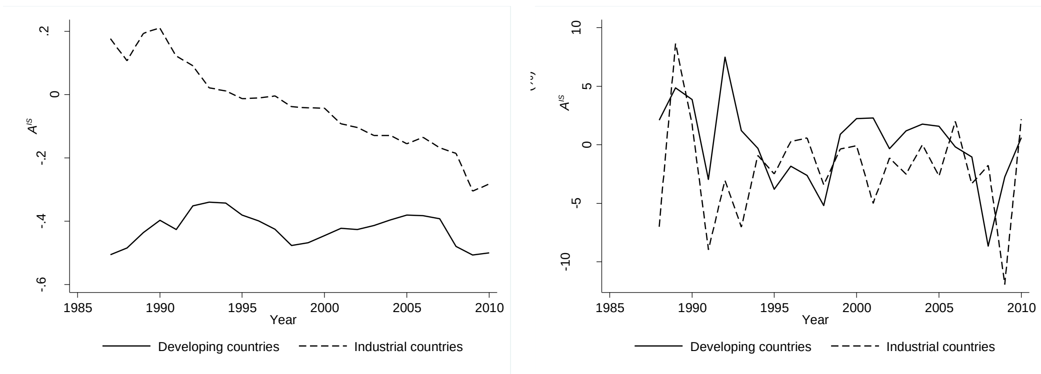



Figure 3. Quasi-relative-relative TFPs in industrial and developing countries

Means

Growth of means




Note: The constant estimated from Equation (10) is added to the estimate of ln$A_{IS}$ for each country. The growth rates are calculated for the means of ln$A_{IS}$ in industrial and developing countries, respectively.