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Arthur Korus

# Currency Overvaluation and R&D Spending

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EUROPÄISCHES INSTITUT FÜR INTERNATIONALE WIRTSCHAFTSBEZIEHUNGEN (EIIW)/
EUROPEAN INSTITUTE FOR INTERNATIONAL ECONOMIC RELATIONS
Bergische Universität Wuppertal, Campus Freudenberg, Rainer-Gruenter-Straße 21,
D-42119 Wuppertal, Germany
Tel.: (0)202 – 439 13 71
Fax: (0)202 – 439 13 77
E-mail: welfens@eiiw.uni-wuppertal.de
www.eiiw.eu

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**Summary**: This paper investigates the impact of an overvalued currency on R&D spending in manufacturing sectors. In particular, we explore whether a real overvaluation against the US Dollar affects R&D investments in manufacturing sectors of OECD countries. So far the literature has elaborated on either the impact of exchange rate swings on R&D investment or the effect of exchange rate volatility on R&D spending. Thus, to the author's best knowledge, this study is the first which investigates the relationship between real overvaluation and R&D spending. In this paper, we test empirically whether real overvaluation against the US dollar has a direct effect as well as an indirect effect via export activity on R&D investment by using OECD panel data of the manufacturing sectors of 16 OECD countries. We find that real overvaluation against the US dollar both directly and indirectly affects R&D intensities in manufacturing sectors. Furthermore, we have evidence that real overvaluation against the US Dollar caused by monetary policy and financial factors negatively affects R&D intensities in manufacturing sectors.

**Zusammenfassung:** Die vorliegende Studie untersucht den Zusammenhang zwischen einer realen Überbewertung und Ausgaben für Forschung und Entwicklung (FuE) im verarbeitenden Gewerbe. Es wird insbesondere betrachtet, ob eine reale Überbewertung gegenüber dem US-Dollar einen Einfluss auf die FuE-Ausgaben des verarbeitenden Gewerbes in 16 OECD Staaten ausübt. Die einschlägige Literatur untersuchte bisher nur den Zusammenhang zwischen Wechselkursbewegungen bzw. Wechselvolatilität und FuE-Ausgaben. Somit ist dieses Studie, nach dem Wissen des Autors, die erste, die den Zusammenhang zwischen einer realen Überbewertung und den FuE-Ausgaben untersucht. In dieser Studie wird empirisch überprüft, ob eine reale Überbewertung gegenüber dem US-Dollar einen direkten sowie einen indirekten Einfluss auf die FuE-Ausgaben des verarbeitenden Gewerbes in den OECD-Staaten hat. Es wird gezeigt, dass eine reale Überbewertung sowohl direkt als auch indirekt die FuE-Ausgaben des verarbeitenden Gewerbes in 16 OECD-Staaten beeinflusst. Darüber hinaus ergibt sich, dass eine reale Überbewertung gegenüber dem US-Dollar, verursacht durch die jeweilige Geldpolitik und Finanzmarktfaktoren, zu geringeren FuE-Ausgaben des verarbeitenden Gewerbes führt.

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*Arthur Korus, European Institute for International Economic Relations at the University of Wuppertal, Rainer-Gruenter-Str. 21, 42119 Wuppertal, Germany, Tel.: +49 202 439 1380, e-mail: korus@wiwi.uni-wuppertal.de*

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# Currency Overvaluation and R&D Spending

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# 1. Introduction

This paper studies the effect of an overvalued currency on R&D spending in manufacturing sectors. In particular, we want to find out whether a real overvaluation against the US dollar affects R&D investments of OECD countries in manufacturing sectors. So far, the literature has focused on either the impact of exchange rate swings on R&D investment or on the effect of exchange rate volatility on R&D spending (Zietz and Fayissa (1994); Funk (2003); Barlevy (2003); Aghion et al. (2006); Becker and Hall (2009); Mahagaonkar et al. (2009); Tabrizy (2014)). Thus, to the best of our knowledge, this study is the first which investigates the relationship between real overvaluation and R&D spending. First, we uncover possible transmission channels through which an overvalued currency has got an influence on R&D investment in manufacturing sectors. Second, we test empirically whether an overvalued currency affects R&D spending in manufacturing sectors.

By studying the effect of a real overvaluation on R&D investment, we focus on the special case of a real exchange rate appreciation. So far, the literature has investigated the impact of a real exchange rate appreciation on R&D investment. However, this literature does not distinguish between a real exchange rate appreciation, which reflects the fact that the country has become more competitive and productive, and an appreciation due to speculation. The latter type of real appreciation leads to an overvalued currency because the currency becomes much stronger than economic fundamentals would suggest. In this study, we will investigate the impact of a real appreciation on R&D spending if this appreciation is not justified by economic fundamentals.

An overvalued currency can cause many serious problems for an economy (Shatz and Tarr (2000)). First, assuming that a significant portion of the costs of production is paid in the domestic currency, an overvalued exchange rate makes exports less competitive. Second, an overvalued currency leads to price competitiveness gains for foreign producers in the domestic market. Hence, import-competing industries lose relative competitiveness. We suspect that the loss in price competitiveness induced by an overvaluation leads to adjustments of R&D spending in manufacturing sectors. Thus, overvaluation has got an impact on R&D spending through its effect on exports and imports. Third, an overvaluation could lead to lower productivity growth because export sectors and import-competing sectors might suffer from an overvalued currency. Fourth, an overvaluation can induce capital flight on the side of domestic agents because they expect that the domestic currency will depreciate. This will lead to lower investment in the domestic country. Fifth, if an overvalued exchange rate had a negative effect on R&D spending, it would hurt long-term economic growth.

We suspect that real overvaluation has got an impact on R&D spending in manufacturing sectors through several transmission channels. We hypothesize that real overvaluation affects R&D investment through trade and foreign direct investment. Furthermore, we propose that overvaluation affects R&D spending both directly and indirectly. From a theoretical perspective, it is not clear whether a real overvaluation influences R&D spending in manufacturing sectors positively or negatively. On the one hand, an overvalued currency could lead to lower profit prospects for export oriented firms and thus a real overvaluation could have a negative impact on R&D spending in manufacturing sectors. On the other hand, a real overvaluation affects R&D spending positively if domestic firms try to escape from higher product market competition due to overvaluation by increasing their R&D activities. Thus, we want to find out empirically whether real overvaluation has got a negative or positive impact on R&D spending in manufacturing sectors.

Our empirical results indicate that R&D intensities in manufacturing sectors are affected by both a direct effect of overvaluation on R&D activities and an indirect effect of an overvalued currency via its positive effect on high-tech exports. We find that real overvaluation, against the US dollar at time t and t-1, negatively affects manufacturing R&D. Hence, we find that the direct effect of real overvaluation against the US dollar on R&D intensity in manufacturing sectors shows a negative sign.

The paper is organized as follows. First, we take a brief look at the literature on exchange rates and R&D spending. We also provide a brief review of the literature on equilibrium real exchange rates. In Section 3, we discuss several transmission channels, through which real overvaluation affects R&D investment. In Section 4, we estimate real equilibrium exchange rates. Section 5 presents our empirical methodology and estimation results, while Section 6 concludes the study.

## 2. Related Literature

The link between R&D spending and exchange rates has been discussed in several studies. On the one hand, the impact of exchange rate swings on R&D investment and, on the other hand, the effect of exchange rate volatility on R&D investment has been analysed in the literature. Thus, we follow two strands of the literature which link R&D investment and exchange rates. The empirical literature which investigates the change in direction of R&D spending due to exchange rate swings seems to be inconclusive. Meanwhile, empirical evidence indicates unanimously that a negative relationship exists between exchange rate volatility and R&D spending.

Zietz and Fayissa (1994) discuss the impact of exchange rate changes on investment in R&D. Zietz and Fayissa (1994) show empirically to what extent R&D spending is driven by import competition. They focus on US manufacturing firms and use ordinary least squares, a fixed effect and a random effect estimator to detect the responsiveness of firms to changes in the competitive environment. In their framework, higher competition is caused by exchange rate appreciations. They find that R&D intensive firms respond to an exchange rate appreciation. Here, firms are classified as R&D intensive if their average R&D intensity is higher than three percent. These companies tend to increase their investments in R&D due to a decrease of the exchange rate. R&D intensive firms increase spending on R&D because of higher import competition due to an appreciation. Firms with an average R&D intensity, i.e. of less than three percent, do not react to exchange rate appreciations. Thus, an exchange rate appreciation does not influence the R&D spending of firms with an already low R&D intensity.

Funk (2003) argues that the impact of an exchange rate appreciation on R&D spending depends on the firms export status. Funk (2003) also uses observations from a panel of US manufacturing firms. Using dynamic heterogeneous panel estimation techniques, Funk (2003) finds that an exchange rate appreciation negatively affects the R&D spending of domestic firms. In contrast to domestic firms, exporters tend to reduce their R&D expenditures due to an exchange rate appreciation. In addition, their findings suggest that exporters raise their R&D expenditures in times of exchange rate depreciation. Thus, an increase in competitive advantage caused by an increase of the exchange rate positively affects the R&D spending of exporting companies.

Building on the work of Zietz and Fayissa (1994) and Funk (2003), Tabrizy (2014) examines the effect of industry specific real exchange rate depreciations on manufacturing R&D spending. For this purpose, Trabizy (2014) introduces a partial equilibrium model of R&D investment. Their model predicts a negative relationship between an increase in price competitiveness and the R&D spending of a representative firm. Using a panel of manufacturing industries in Korea, a Panel Vector Autoregressive Model and the Corrected Least Square with Dummy Variables estimation technique, Trabizy (2014) finds that a lagged depreciation in the real exchange rate negatively affects industrial R&D expenditures. Thus, Trabizy (2014) finds empirical support for their theoretical predictions.

Mahagaonkar et al. (2009) study the impact of real exchange rate volatility on R&D intensity in manufacturing and services sectors. For this purpose they conduct a panel study of OECD countries. They argue that exchange rate fluctuations both directly and indirectly affect R&D intensity in manufacturing and services sectors. Exchange rate volatility influences R&D intensity indirectly because volatility negatively affects exports. Mahagaonkar et al. (2009) use the GARCH approach to measure real exchange rate volatility. They test whether this measure of exchange rate volatility affects R&D intensity in manufacturing and service sectors by using panel estimation techniques. Their findings suggest that R&D intensity in the manufacturing sector is adversely affected by real exchange rate volatility. They find empirical evidence for both a direct effect and an indirect effect of volatility on R&D intensity in manufacturing sectors. However, they do not find a statistically significant effect of real exchange rate volatility on R&D intensity in service sectors. Thus, their findings suggest that exchange rate volatility only affects R&D intensity in manufacturing sectors and not in service sectors. Our study is closely related to the work of Mahagaonkar et al. (2009) because we focus on the effect of real overvaluation on sectoral R&D intensity and we use almost the same panel data as Mahagaonkar et al. (2009) have used in their study. Moreover, our set of control variables is based on Mahagaonkar et al. (2009).

Our paper is also connected to the literature on the determinants of real exchange rates and equilibrium real exchange rate concepts. There exists a range of approaches for modelling the equilibrium exchange rate. One set of models assumes constant equilibrium real exchange rates. Purchasing Power Parity (PPP) belongs to this type of model. Within this framework, it is assumed that the equilibrium real exchange rate does not vary over time and relative prices evolve in order to equate the price of domestic and foreign goods. In a second set of approaches, the equilibrium real exchange rate is allowed to evolve with macroeconomic variables. One approach which allows for explicit deviations from PPP is the behavioural equilibrium exchange rate (BEER) approach developed by Clark and Mac Donald (1998). In order to derive equilibrium real exchange rates, Clark and Mac Donald

(1998) use co-integration methods and a set of fundamentals. They estimate a reduced-form relationship between the real exchange rate and a set of fundamental economic variables. Their set of determinants of the real exchange rate includes the terms of trade, the relative price of non-traded to traded goods, net foreign assets, the relative supply of domestic to foreign government bonds and the real interest rate differential. The estimation of the BEER is based on actual values of the fundamental determinants of the real exchange rate and on the co-integration methods. We use the BEER framework (1998) in estimating equilibrium real exchange rates[1].

# 3. Currency Overvaluation and R&D Spending – Theoretical Considerations

In this section we discuss the transmission channels through which an overvaluation affects R&D spending. From a theoretical point of view, there are several possible transmission channels through which an overvalued currency can affect R&D spending in the manufacturing sector. Hence, we focus on the possible effects of real overvaluation on non-price decisions such as investment in R&D in the manufacturing industry. We suspect that overvaluation affects R&D spending through two transmission channels: The first channel through which overvaluation affects R&D investment is the so-called trade channel, while the second channel is labelled as the foreign direct investment (FDI-) channel. Hence, we expect that an overvalued currency influences export volumes, export prices and thus export price competitiveness and foreign direct investments. We first discuss the impact of the trade channel on R&D spending in the manufacturing sector. Following that, we elaborate on the effect of the FDI-channel on R&D investment.

The literature has identified both internal finance and sales as the driving factors of R&D investment (Cohen (1995)). In particular, cash flow has been shown to be an important determinant of R&D spending. Profits are an important funding source of R&D investments and thus R&D spending should be positively correlated with cash flow. The recent empirical literature has generally shown that a higher cash flow leads to higher R&D spending (Becker (2013)). Thus, if an overvalued currency leads to lower cash flows of exporting firms, the R&D spending of these firms will decline. An overvalued currency makes domestic production more expensive compared to foreign production, thus lowering export price competitiveness (Campa and Goldberg (2001)). This could lead to lower profit prospects of export-oriented firms and, therefore, an overvaluation could have an adverse impact on the R&D spending of these firms. In such a case, c.p., that export-oriented firms are more adversely affected by an overvaluation than firms mainly selling their products to the domestic market, the magnitude of the effect of an overvaluation on total manufacturing R&D will depend on the export orientation of the domestic manufacturers. In particular, a persistently overvalued currency could have an impact on R&D spending in the manufacturing sector because a persistent overvaluation could result in a fundamental

[1] Other approaches within the second set of models are the fundamental equilibrium exchange rate (FEER) approach of Williamson (1994), the IMF CEGR approach of Faruqee et al. (1998), the NATREX approach of Stein (2001), the permanent equilibrium exchange rate (PEER) approach and the capital enhanced equilibrium exchange rate (CHEER).

shift in price competitiveness, which could lower the profit prospects of exporters in the manufacturing sector on a semi-permanent basis. Furthermore, firms could expect lower profit prospects due to an overvaluation. Lower expected profit prospects would likely negatively affect R&D spending in the manufacturing sector. To sum up, lower profit prospects triggered by an overvaluation would likely influence R&D investment behaviour, which would eventually drive the export competitiveness and underlying competitiveness of the overvalued country, respectively (Ree et al. (2015)).

The magnitude of the impact of an overvaluation on exporters' profit margins also depends on the price-setting behaviour of exporting firms. Thus, the exporter's mark-up[2] power determines the effect of an overvalued currency on its profits (Berman et al. (2012)). Exporters could respond to an overvaluation by adjusting their profit margins, export prices or both (Ree et al. (2015)). So, the effect of an overvaluation on profit margins depends on the pass-through of the stronger home currency to export prices. One possibility is that exporters do not change their export prices. So exporters do not adjust export prices due to an overvalued currency. In that case, the response of export volumes will be limited and the overvaluation will be absorbed by profit margins. Hence, existing profits and cash buffers will be used to absorb exchange rate losses. Lower profits will decrease the R&D spending of exporting firms. Summarizing, an overvaluation will have a limited or even no impact on export volumes and will reduce the R&D investment of exporting firms due to lower profit margins. Another possibility, is that exporters increase export prices and hold their price mark-up steady. The literature shows that the price pass-through is related to the degree of product differentiation (Ree et al. (2015)). Firms which export differentiated products are more likely to pass-through exchange rate gains or losses to export prices than firms which offer homogeneous goods. In that case, profit margins will not change or will even increase due to an overvaluation. So, the effect of overvaluation on R&D spending will be limited. Overall, the impact of an overvaluation on R&D spending is also determined by the pricing-to-market behaviour of exporters.

Campa and Goldberg (2001) show in their model that exchange rates affect import competition. An appreciation in the real exchange rate leads to higher import competition because foreign firms become more price competitive in the domestic market. According to the considerations of Campa and Goldberg (2001), we suspect that an overvalued currency leads to price competitiveness gains for foreign producers in the domestic market. Gains in price competitiveness raise imports of goods and services from abroad. Thus, an overvaluation increases product market competition. Increasing product market competition could trigger domestic firms who face an overvalued currency to invest more in R&D (Aghion et al. (2005)). Lu and Ng (2013) argue that firms who produce a bundle of products that are differentiated by product will shift production to higher-quality products due to increases in import competition. This adjustment of the output mix tends to increase the skill intensity of production and R&D spending. Thus, increasing product market competition will lead to higher R&D activities of firms if they try to escape from higher product market competition[3].

[2] A firm's mark-up power is determined amongst other things by the price elasticity of demand, the degree of price competition on its selling market, product differentiation and productivity.

[3] For example, Kaiser and Siegenthaler (2015) show empirical evidence that an appreciation of the Swiss franc increases both the R&D activities and skill intensity of Swiss exporters and that these firms upgrade the quality of their products.

The impact of an overvalued currency on profit margins and price competitiveness of exporters can be partially offset by cheaper imported inputs (Ree et al. (2015)). An emerging body of literature finds that the imported input channel plays a dominant role in dampening the effects on export prices (Amiti et al. (2014)). Amiti et al. (2014) show that a firm with a high import share and high market share have a low exchange rate pass-through. Thus, firms with a high import content and high market shares adjust export prices slightly due to an overvaluation and the hit on the absolute profit margins of exports will be offset by less expensive imported inputs. Whether an overvalued currency leads to cheaper imported inputs depends on the degree of imported input price pass-through to domestic producer prices (Ahn et al. (2016)).

The above mentioned effects of an overvalued currency on R&D spending referred to the trade channel. In the following, we discuss the investment channel - through which an overvaluation has also got an impact on the R&D investment of firms. According to Bradford Jensen et al. (2015) firms are likely to undertake vertical FDI in the context of a sustained foreign currency undervaluation. An undervalued foreign currency should have an impact on the international investment activities of firms, because a depreciated currency lowers the costs of production inputs abroad relative to production costs at home and thus, according to the comparative advantage motive for vertical (resource-seeking) FDI (Helpman (1984)), firms should set up vertical affiliates in that country. Setting up vertical affiliates can be associated with the offshoring of R&D activities and thus overvaluation negatively influences the R&D spending of firms. An overvaluation should only affect vertical FDI and not horizontal (market-seeking) FDI, because, on the one hand, firms that produce in an undervalued currency do not benefit from undervaluation as costs and revenues are undervalued (Bradford Jensen et al. (2015)) and, on the other hand, firms that produce in an undervalued country for export to the MNCs home market benefit from undervalued costs (revenues are not undervalued). An overvalued currency potentially reduces FDI from abroad because production costs in the host-country increase relative to the factor costs in the source country. Less FDI from abroad can be associated with less adaptive and innovative R&D spending of foreign affiliates. Hence, an overvaluation has got a negative impact on R&D investment of foreign multinationals in an overvalued country. Overall, our considerations suggest that the investment channel negatively influences R&D spending in the overvalued country.

To sum up, the sign of the impact of an overvaluation on R&D investment is ambiguous. On the one hand, we have shown that an overvalued currency lowers profit prospects and thus R&D spending but this effect can be partially offset by cheaper intermediate inputs. On the other hand, overvaluation can lead to higher price competitiveness and hence to increasing R&D spending. Thus, from a theoretical point of view, the effect of the trade channel on R&D spending is unclear. However, we have argued that the investment channel negatively influences R&D investment. In the following, we show empirically whether an overvaluation negatively or positively affects R&D spending in the manufacturing industry. In order to find out whether a real overvaluation affects R&D spending in the manufacturing sector, we have to compute equilibrium real exchange rates.

# 4. Computing Real Overvaluation vis-à-vis the United States

Making judgements about exchange rates being over- or undervalued requires deriving "equilibrium" values of exchange rates. That should be based on a well-specified model. In practice, this turns out to represent a challenge given the number of determinants of the real exchange rate. The literature on the determinants of real exchange rates is very extensive (Froot and Rogoff (1995); Rogoff (1996)). Moreover, the literature on this subject is vast and little consensus prevails as regards what is the best approach. Driver and Westaway (2004) review many different equilibrium exchange rate concepts (model- vs. estimation based approaches).

We use the behavioural equilibrium exchange rate (BEER) approach[4] to detect real overvaluations of 17 OECD countries vis-à-vis the US dollar. The BEER approach relies on reduced-form estimation, hence, panel regression methods are used to estimate a long-run co-integrating relationship between real exchange rates and a set of fundamentals. Our reduced-form estimation and choice of fundamentals relates to the work of Clark and MacDonald (1998) and Adler and Grisse (2014).

## The Methodology

While most of the literature focuses on the estimation of effective equilibrium exchange rates, we study bilateral real exchange rates. So, we are able to estimate nominal equilibrium exchange rates in three steps. First, real bilateral exchange rates are regressed on a set of potential fundamentals. We deal with mostly non-stationary and co-integrated data. Thus, we can estimate the long-run relationship between bilateral real exchange rates and potential determinants by using the DOLS-technique (Stock and Watson (1993)) including a set of country-specific constant terms:

(5) $$R_{i,t} = \alpha_i + \beta Z_{i,t} + \sum_{s=-p}^{p} \gamma_s \Delta Z_{i,t+s} + \varepsilon_{i,t}$$ ,

where $R_{i,t}$ denotes the CPI (Consumer Price Index)-based bilateral real exchange rate versus country i. The bilateral real exchange rate is defined in terms of domestic goods per foreign goods[5]. Thus, a decrease of the real exchange rate is associated with a real appreciation of the domestic currency. The variable $\alpha_i$ is a country-specific constant. The inclusion of country fixed effects is necessary because bilateral real exchange rates are index numbers and there could be country-specific effects, which are not captured by other explanatory variables (Lee et al. (2006)). $Z_{i,t}$ is a vector of explanatory variables[6], with each variable defined as the value in the foreign relative to the domestic country. We have to note that our estimated equilibrium rates will depend on both the set of fundamentals

[4] The BEER approach is based on the work of Clark and MacDonald (1998).

[5] Thus, we follow most of the scientific literature by defining the real exchange rate in price notation. See Appendix 1 C for a detailed definition of the real exchange rate.

[6] Explanatory variables that are expressed in percentage of GDP are computed as the difference between the foreign and domestic variable. For other variables, we work with the ratio.

included and the sample size. So there is considerable uncertainty about the true model. The parameter vector $\beta$ captures the long-run (co-integrating) relationship between the bilateral real exchange rate and fundamentals. The variable $\gamma_s$ describes a vector of parameters and $\varepsilon_{i,t}$ is the error term. The residual shows deviations from the equilibrium exchange rate, thus we can determine overvaluations based on the sign of the residual. Due to the short sample in the time dimension we have to assume that parameters are identical across the currencies in the panel. Second, the predicted values from the long-run (co-integrating) relationship between the real exchange rate and its determinants are interpreted as equilibrium real exchange rates, denoted by:

(6) $$R^{*}_{i,t} = \hat{\alpha}_i + \hat{\beta} Z_{i,t}$$

In a third step, the nominal equilibrium exchange rate is computed by multiplying the equilibrium real exchange rate with the price differential:

(7) $$E^{*}_{i,t} = R^{*}_{i,t} \frac{P_t^H}{P_t^F}$$

## Fundamental Determinants of the Real Exchange Rate

In this section we present several fundamental determinants of the real exchange rate. As previously mentioned, economic theory suggests a number of potential determinants of the real exchange rate. Hence, our choice of variables is somewhat arbitrary. We include government consumption, the terms of trade variable, GDP per capita and the real interest rate variable, as these fundamentals turned out to be the most important variables in explaining the behaviour of the real exchange rates of the 16 OECD countries[7]. Our independent variables can be divided into demand-side and financial factors[8]. Factors that affect demand for traded relative to non-traded goods will have an impact on the real exchange rate because it is assumed that the supply of non-traded goods is less elastic than the supply of traded goods. Any shock that induces a higher relative demand for non-tradable goods leads to an increase in the prices of non-traded goods relative to traded goods. Thus, an increase in the demand for non-traded goods is associated with a real appreciation of the real exchange rate. The following demand-side factors are included in our main regressions:

- PPP-adjusted real GDP per capita: Higher income is associated with a higher demand for domestic non-traded goods relative to traded goods (Lee et al. (2008)). If the supply of non-traded goods is less elastic than the supply of traded goods, a higher demand for domestic non-traded goods will lead to an increase in prices of non-traded goods relative to traded goods. Thus, an increase of domestic relative to foreign income leads to an appreciation of the real exchange rate. Bergstrand (1991) finds that higher wealth can lead to a preference shift in favour of non-traded goods. This shift induces price increases of domestic non-traded goods

[7] We estimate equilibrium real exchange rates for Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Denmark, UK, Sweden, Norway, Switzerland, Canada and Japan.
[8] See Appendix 1 C for variable definitions and data sources.

relative to traded goods and thus an appreciation of the real exchange rate. This variable also captures the Balassa-Samuelson effect. Balassa (1965) and Samuelson (1964) state that countries with higher productivity growth in the traded than in the non-traded goods sector experience a real appreciation of their currency. Balassa (1965) and Samuelson (1964) consider a small open economy that produces traded and non-traded goods. Balassa (1965) and Samuelson (1964) assume that prices of traded goods are fixed on world markets and thus given. Higher productivity growth in the traded goods sector leads to higher wages in this sector. Assuming that productivity growth in the non-traded sector is lower than in the traded goods sector and that labour is mobile across the two sectors internally but not internationally, higher productivity growth in the traded-goods sector induces higher wages in the non-traded sector. Higher wages in the non-traded goods sector are associated with price increases of non-traded goods. Hence, higher productivity growth in the traded than in the non-traded goods sector is associated with a decrease of the real exchange rate.

- **Terms of trade**: On the one hand, improvements in the terms of trade can induce an appreciation of the real exchange rate (Christiansen et al. (2009)). Increasing export revenues lead to higher wealth. Higher wealth is associated with higher demand for domestic non-traded goods. Higher demand for non-traded goods leads to price increases of non-tradables. Thus, improvements in the terms of trade can be associated with a decreasing real exchange rate. On the other hand, improvements in the terms of trade can lead to a real depreciation (Christiansen et al. (2009)). Improvements in the terms of trade could induce an increase of imports of goods and services because domestic products have become more expensive relative to foreign products. This could lead to a deterioration of the trade balance. A deteriorating trade balance is associated with a depreciation of the real exchange rate. Thus, economic theory suggests that the effect of an improvement in the terms of trade on the real exchange rate is ambiguous. We use terms of trade of goods and services as a measure of terms of trade. Instead of terms of trade in goods and services one could also use a commodity-based measure (Lee et al. (2008)). The second measure is likely to be more relevant for developing countries than for advanced economies. Since we are dealing with developed countries we use only the terms of trade in goods and services as a measure of terms of trade.
- **Government consumption:** Higher government consumption induces an appreciation of the real exchange rate because it is assumed that government spending is biased towards non-traded goods (Ostry (1994)). Thus, higher government consumption leads to higher demand for non-traded goods relative to traded goods. Hence, increasing government consumption induces price increases of non-traded goods. This leads to a decrease of the real exchange rate.

Furthermore, we include a real interest rate variable to capture the effects of monetary policy and financial markets on real exchange rates. Higher real interest rates should lead to a decrease of the real exchange rate because higher domestic real interest rates should attract domestic and foreign capital from abroad (Clark and MacDonald (1998)). Thus, higher domestic real interest rates should be associated with an appreciation of the real exchange rate.

## DOLS Regression Results

We compute 16 panel data sets, which we use to run DOLS regressions. All panel data sets consist of 22 OECD countries[9], namely the countries of the Euro area, United Kingdom, Denmark, Norway, Sweden, Canada, USA, Australia, New Zealand and Switzerland. We include the euro area economies separately[10] so that we have enough observations. We use annual data from 1980 to 2013[11]. All bilateral real exchange rates are computed by using CPI data from the OECD. We estimate two different BEER models and thus we compute two equilibrium real exchange rates for each country. One model includes terms of trade, government consumption and GDP per capita. The second BEER model includes terms of trade, government consumption, GDP per capita and the real interest rate differential variable.

In our first BEER model, we use three economic fundamentals to explain the equilibrium real exchange rate: terms of trade, government consumption and GDP per capita. These fundamentals affect the real exchange rate in the medium-term. Thus, we estimate the following equation:

$$R_{i,t} = \alpha_i + \beta_1 TOT_{i,t-1} + \beta_2 GOV_{i,t} + \beta_3 GDP_{i,t} + \varepsilon_{i,t} \quad , \tag{8}$$

where $R_{i,t}$ denotes the bilateral real exchange rate at time t versus country i. $TOT_{i,t-1}$ is the terms of trade variable at time t-1.[12] Government consumption at time t is captured by $GOV_{i,t}$. $GDP_{i,t}$ represents the GDP per capita variable at time t and $\varepsilon_{i,t}$ is the error term. Note, that the number of observations varies across country specifications because some variables, included in computing long-term equilibrium exchange rates, are not available for all years. Table 1 reports the estimation of the results of real exchange rates based on equation (8). In our first BEER model terms of trade and government consumption are highly significant. The coefficients of terms of trade in goods and services show the expected sign. Thus, improvements in the terms of trade in goods and services are related with an appreciation of the real exchange rate. The coefficients of the government consumption variable also have the expected sign. GDP per capita is not always statistically significant. In the case of Norway, UK and Sweden, the GDP per capita variable is not statistically significant. Thus, we have to exclude GDP per capita for the calculation of the equilibrium real exchange rate of Norway, UK and Sweden. Though, GDP per capita is statistically significant in all other regressions. The GDP per capita coefficients have almost the expected positive sign, which means that a rise of GDP per capita is associated with an appreciation of the real exchange rate. In the case of Greece and Italy, the signs of the GDP per capita coefficients are at odds with the prediction of economic theory because these coefficients have a negative sign.

[9] We limit ourselves to these 22 countries to ensure complete data availability for the explanatory variables.
[10] This is necessary to get precise estimations.
[11] We focus on data from 1980 on to avoid the time period of strong real exchange rate adjustments following the break-up of Bretton Woods.
[12] We lag the terms of trade variable by one year because we want to mitigate endogeneity problems with respect to the real exchange rate.

**Table 1: DOLS regression results according to equation (8), 1980-2013**

| | Terms of trade | Government consumption | GDP per capita | Observations | Adjusted R² |
|---|---|---|---|---|---|
| BE | 0.4355*** | 0.0321*** | 0.3814*** | 630 | 0.9501 |
| | (0.0747) | (0.0048) | (0.0702) | | |
| CA | 0.8092*** | 0.0588*** | 0.9179*** | 600 | 0.911301 |
| | (0.0971) | (0.0111) | (0.2083) | | |
| DK | 2.4333*** | 0.1593*** | 0.7168* | 630 | 0.9688 |
| | (0.3578) | (0.0356) | (0.4164) | | |
| FI | 0.5806*** | 0.0325*** | 0.2663*** | 630 | 0.9412 |
| | (0.0727) | (0.0052) | (0.0662) | | |
| FR | 0.4897*** | 0.0326*** | 0.3444*** | 630 | 0.9400 |
| | (0.0752) | (0.0066) | (0.0654) | | |
| DE | 0.3969*** | 0.0382*** | 0.2713*** | 570 | 0.9455 |
| | (0.0692) | (0.0048) | (0.0700) | | |
| GR | 2.7059*** | 0.1370*** | -2.8039*** | 630 | 0.4804 |
| | (0.5969) | (0.0427) | (0.4114) | | |
| IE | 0.7494*** | 0.0243*** | 0.2875*** | 630 | 0.9349 |
| | (0.1254) | (0.0055) | (0.0378) | | |
| IT | 0.7885*** | 0.0210*** | -0.1962*** | 630 | 0.9076 |
| | (0.1197) | (0.0068) | (0.0644) | | |
| JP | 0.5242*** | 0.0284*** | 0.2703** | 630 | 0.9328 |
| | (0.0723) | (0.0054) | (0.1093) | | |
| NL | 0.6615*** | 0.02866*** | 0.2052*** | 630 | 0.9317 |
| | (0.0778) | (0.0081) | (0.0889) | | |
| NO | 1.1042*** | 0.1618*** | | 630 | 0.9042 |
| | (0.2132) | (0.0583) | | | |
| PT | 1.3340*** | 0.0892*** | 0.2272* | 630 | 0.8332 |
| | (0.1884) | (0.0091) | (0.1232) | | |
| ES | 0.5902*** | 0.0412*** | 0.1613** | 630 | 0.9270 |
| | (0.0500) | (0.0075) | (0.0625) | | |
| SE | 3.3686*** | 0.4265*** | | 630 | 0.8720 |
| | (0.7354) | (0.0675) | | | |

| | | | | |
|---|---|---|---|---|
| GB | 0.2175*** (0.0578) | 0.0135*** (0.0047) | 630 | 0.8703 |

*Notes*: The dependent variables are CPI-based real bilateral exchange rates. A positive coefficient means that increases in the explanatory variable in the foreign country relative to the domestic country are associated with a depreciation of the domestic currency. Coefficient covariance computed using sandwich method. Long-run variances (Bartlett kernel, Newey-West fixed bandwidth) used for coefficient covariances. Standard errors in parentheses. ***, ** and * display significance at the 1%, 5% and 10% level, respectively.

Second, we estimate equilibrium real exchange rates of the above mentioned 16 OECD countries based on terms of trade, government consumption, GDP per capita and real interest rates. For this, we add the real interest rate differential into specification (1). The real interest rate differential influences the bilateral real exchange rate in the short-run. Hence, we also estimate the following BEER model:

(9) $$R_{i,t} = \alpha_i + \beta_1 TOT_{i,t-1} + \beta_2 GOV_{i,t} + \beta_3 GDP_{i,t} + \beta_4 RID_{i,t} + \varepsilon_{i,t}$$ ,

where $RID_{i,t}$ captures the real interest rate differential at time t. Table 2 displays the results of the estimations of the real exchange rate based on our second BEER model. In Table 2, the coefficients of terms of trade in goods and services are highly statistically significant in all regressions and show the expected sign. Thus, an increase of the terms of trade in goods and services leads to an appreciation of the real exchange rate. Government consumption is mostly statistically significant with the exception of Norway. Thus, we exclude government consumption in computing the equilibrium real exchange rate of Norway. The government consumption coefficients show the predicted sign. Hence, a rise in government consumption is associated with a decreasing real exchange rate. The GDP coefficient is not statistically significant in the case of Denmark, Finland, Greece, Portugal, Spain and Sweden. So we omit GDP per capita in these cases. Moreover, the coefficients of GDP per capita are highly statistically significant and show almost the expected sign. The real interest rate coefficients are mostly statistically significant and mostly display the predicted sign. In the case of Denmark and Spain, however, the real interest rate coefficients are statistically significant but do not show the expected sign.

**Table 2: DOLS regression results, 1980-2013 (Overvaluation based on equation (9))**

| | Terms of trade | Government consumption | GDP per capita | Real rate | Obsevations | Adjusted R² |
|---|---|---|---|---|---|---|
| BE | 0.3463*** (0.0658) | 0.0227*** (0.0046) | 0.3892*** (0.0548) | 0.0080* (0.0041) | 613 | 0.9711 |
| CA | 0.7460*** (0.0779) | 0.0284*** (0.0074) | 0.9538*** (0.1595) | 0.0434*** (0.0073) | 581 | 0.9525 |
| DK | 2.4544*** (0.3218) | 0.0847*** (0.0318) | | -0.0452*** (0.0168) | 630 | 0.9688 |
| FI | 0.2264*** (0.0474) | 0.0134*** (0.0036) | | 0.0074** (0.0029) | 478 | 0.9789 |

| | | | | | | |
|---|---|---|---|---|---|---|
| FR | 0.3832*** | 0.0215*** | 0.3429*** | 0.0207*** | 613 | 0.9675 |
| | (0.0669) | (0.0050) | (0.0495) | (0.0044) | | |
| DE | 0.3329*** | 0.0278*** | 0.3502*** | 0.0134*** | 553 | 0.9677 |
| | (0.0629) | (0.0039) | (0.0608) | (0.0042) | | |
| GR | 1.5323*** | 0.0840*** | | 0.0554*** | 418 | 0.9197 |
| | (0.3746) | (0.0194) | | (0.0059) | | |
| IE | 0.6231*** | 0.0110** | 0.2373*** | 0.0127*** | 613 | 0.9600 |
| | (0.1090) | (0.0048) | (0.0304) | (0.0026) | | |
| IT | 0.7078*** | 0.0156** | -0.1831*** | 0.0213*** | 613 | 0.9206 |
| | (0.1224) | (0.0071) | (0.0696) | (0.0071) | | |
| JP | 0.4730*** | 0.0285*** | 0.4078*** | 0.0080*** | 630 | 0.9385 |
| | (0.0739) | (0.0057) | (0.1255) | (0.0025) | | |
| NL | 0.4372*** | 0.0170*** | 0.3242*** | 0.0223*** | 613 | 0.9734 |
| | (0.0528) | (0.0044) | (0.0552) | (0.0027) | | |
| NO | 1.0830*** | | 2.1058*** | 0.1680*** | 630 | 0.9465 |
| | (0.1388) | | (0.6971) | (0.0166) | | |
| PT | 0.8024*** | 0.0739*** | | 0.0485*** | 613 | 0.8641 |
| | (0.2019) | (0.0090) | | (0.0069) | | |
| ES | 0.6221*** | 0.0512*** | | -0.0096** | 532 | 0.9496 |
| | (0.0749) | (0.0078) | | (0.0048) | | |
| SE | 4.2507*** | 0.2916*** | | 0.2054*** | 623 | 0.8947 |
| | (0.7331) | (0.0547) | | (0.0325) | | |
| GB | 0.2262*** | 0.0083** | 0.2049*** | 0.0217*** | 623 | 0.9192 |
| | (0.0529) | (0.0041) | (0.0597) | (0.0037) | | |

*Notes:* The dependent variables are CPI-based real bilateral exchange rates. A positive coefficient means that increases in the explanatory variable in the foreign relative to the domestic country are associated with a depreciation of the domestic currency. Coefficient covariance computed using sandwich method. Long-run variances (Bartlett kernel, Newey-West fixed bandwidth) used for coefficient covariances. Standard errors in parentheses. ***, ** and * display significance at the 1%, 5% and 10% level, respectively

# 5. Real Overvaluation against the US Dollar and R&D Intensity – Empirical Analyses

As mentioned previously, the aim of our study is to find out whether a real overvaluation against the US dollar has got an impact on innovation. Thus we assume, that the causality runs from overvaluation to innovative activities. It could also be possible that innovative activities affect real exchange rates. Hansen and Roeger (2000) show in their model that the removing of barriers which prevent innovative activities leads to technological advancement and/or to a higher supply of domestic products. Further, they argue that in this case the real exchange rate will appreciate if the innovation takes place in the tradable sector. Furthermore, a real depreciation is likely when the innovative activities are concentrated in the non-tradable sector. However, this kind of appreciation (depreciation) is not associated with an overvaluation (devaluation) because innovative activities affect the equilibrium real exchange rate. Hence, when we observe an appreciation of the real exchange rate due to higher R&D activities, this appreciation is in line with fundamentals because the real exchange rate converts to a new level of the equilibrium real exchange rate.

## The Methodology

We use R&D intensity in the manufacturing sector as a dependent variable in our estimation. Note, that we focus only on R&D intensity in the manufacturing sector. Here, R&D intensity is computed by dividing R&D expenditure by production[13]. Using R&D intensity instead of R&D expenditure has got the advantage that it corrects for scale factors (Mahagaonkar et al. (2009)) and industry regularities[14]. In order to test whether an overvaluation affects R&D intensity we use panel estimation methods. The Hausman test shows that we have to use the fixed effect model. Thus, our starting point is the following equation:

(10) $$R\&D_{i,t} = \alpha_i + \gamma Over_{i,t} + \beta' X_{i,t} + \beta + \varepsilon_{i,t}$$

where i denotes the country and t the year. $R\&D_{i,t}$ is our dependent variable and displays the sectoral R&D intensity using production. The variable $\alpha_i$ is the time-invariant fixed effect. $Over_{i,t}$ is our explanatory variable of interest and captures real overvaluation against the US dollar at time t. This variable is defined as a dummy variable and is equal to one if a currency is overvalued against the US dollar in real terms and zero otherwise. The dummy is based on the sign of the residual from the above mentioned DOLS regressions. Whenever the residual in equation (5) shows a negative sign, the dummy in equation (8) is equal to one. Thus, the dummy variable in equation (8) is the connection between equation (5) and (8). Note, that we use two BEER models to capture real overvaluation. Our first BEER model includes terms of trade, government consumption and GDP per capita as determinants of the real exchange rate. The second BEER model includes terms of trade,

[13] Hence, our measure of R&D intensity is based on the production method.

[14] Extensive research (Cohen and Klepper (1992); Lee (2000)) show that R&D intensity follows a log-normal distribution and reports similarities within firms and industries.

government consumption, GDP per capita and the real interest rate differential. In our first baseline specifications, we make use of our measure for overvaluation based on the first BEER model. Hence, the dummy variable in equation (8) is equal to one if a currency is overvalued against the US dollar in real terms with respect to its equilibrium based on equation (8) and zero otherwise. In further main specifications, the dummy variable in equation (10) is equal to one if a currency is overvalued in real terms against the US Dollar with respect to its equilibrium rate based on equation (9). The variable $X_{i,t}$ includes several control variables. The variable $\beta$ is a constant and $\varepsilon_{i,t}$ is the error term.

The choice of control variables follows the vast R&D literature and is close to Becker (2009) and Mahagaonkar et al. (2009). We use the following control variables[15]:

- Industry size: This variable is crucial in knowledge flows both across and within industries and captures employment effects on innovation. Acs and Audretsch (1987) show that large firms spend more on R&D than small firms because large firms tend to be more capital intensive than small firms. Small firms tend to have a large share of skilled workers. Asker and Baccara (2008) prove that with increasing industry size, R&D spending becomes more concentrated. Here, the industry size variable is defined as the ratio of industry employment to total employment in the economy.

- Export performance: A higher export intensity seems to be associated with a higher R&D intensity because exporting firms learn from exporting by gaining access to technical expertise from foreign buyers. Furthermore, competition on international markets increases the probability of exporters to innovate. Exporters have to improve their products and processes to remain competitive. However, a high export intensity of an industry could point to some degree of monopoly power. Higher monopoly power is associated with a lower R&D intensity (Aghion et al. (2005)). Thus a higher export intensity could lead to a decrease of sectoral R&D intensity. Export performance is captured by the export-import ratio.

- Intermediate inputs: An appreciation of the real exchange rate decreases the cost of imported intermediate inputs. Decreasing costs of imported intermediate inputs could spur investments of export oriented firms. Landon and Smith (2007) show that in times of appreciation, costs of imported intermediate inputs decrease more than costs of domestic inputs. However, they state that the impact of decreasing costs, due to an appreciation, of intermediate inputs on investment depends highly on the substitutability between imported and domestic intermediate goods. Moreover, Campa and Goldberg (1999) show that the effect of imported inputs on investment also depends on the firms monopoly power.

- High-tech exports: This variable captures the inherent R&D intensity of the industry structure. Some industries are characterised by a high degree of R&D intensity. Typically, high-tech industries are associated with high R&D intensities. Thus, countries specialised in high-tech industries should exhibit a high R&D intensity per se. In the short-run, the industry structure is given and thus some variation of R&D intensity in a country.

- Public support to R&D spending: The impact of direct fiscal support, like R&D subsidies, on sectoral R&D intensity depends on the effectiveness of direct fiscal

[15] See Appendix 2 B for detailed variable definitions and data sources.

R&D support in stimulating private R&D spending (Dimos and Pugh (2016)). Hence, the question is whether R&D subsidies increase net R&D spending. Net R&D spending only includes the part of R&D investment which is financed by the private sector. It could be argued that on the one hand R&D subsidies could induce an increase of net R&D investment (complementarity) and on the other hand that these measures could crowd out private R&D spending (substitutability). The empirical and theoretical literature is inconclusive whether R&D subsidies boost net R&D investment or not (Dimos and Pugh (2016)).

## Empirical Results

In this section we test empirically whether real overvaluation against the US dollar influences R&D intensity in manufacturing sectors. We restrict our empirical analysis to the time-period from 1988 to 2008 because usable data for all countries included is only available for this time period. At first, 22 countries, i.e. the same countries as used in our DOLS regressions, were included in our dataset. Due to many missing observations, variables and data on business R&D, we arrive at a sample of 16 OECD countries. First, we test whether real overvaluation has got a direct impact on R&D activities in manufacturing sectors. Second, we test for an indirect effect of real overvaluation against the US dollar on R&D intensities in manufacturing sectors.

Initially, we test whether deviations of bilateral real exchange rates from its equilibrium values based on equation (8) affect our dependent variable. As mentioned before, our dependent variable is R&D intensity in manufacturing sectors. We use the fixed-effect model and 16 countries are included in our estimations. Table 3 displays the results of the estimations of R&D intensity in manufacturing sectors, whereby real overvaluation against the US dollar is computed according to equation (8).

**Table 3: Fixed Effects Panel Estimation on the Total Manufacturing Sector 1988-2008 (Real Overvaluation against the US Dollar based on equation (8))**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Industry Size | -0.0585*** | -0.0575*** | -0.0571*** | -0.0605*** | -0.0542*** |
| | (0.0087) | (0.0086) | (0.0093) | (0.0097) | (0.0082) |
| High-Tech Exports | 0.0191*** | 0.0202*** | 0.0186*** | | 0.0257*** |
| | (0.0059) | (0.0055) | (0.0062) | | (0.0030) |
| Export-Import ratio | | | | -0.0036 | |
| | | | | (0.0032) | |
| Intermediate inputs | -0.0231*** | -0.0175*** | -0.0178*** | -0.0280*** | -0.0233*** |
| | (0.0079) | (0.0069) | (0.0079) | (0.0076) | (0.0065) |
| BERD financed by Government | 0.0094* | 0.0119*** | 0.0128*** | -0.0031 | |
| | (0.0053) | (0.0049) | (0.0049) | (0.0065) | |
| Overvaluation | 0.0003 | | | -0.0220 | -0.0073 |
| | (0.0352) | | | (0.0357) | (0.0350) |
| Overvaluation t-1 | | -0.0524 | | | |
| | | (0.0378) | | | |
| Overvaluation t-2 | | | -0.0420 | | |
| | | | (0.0334) | | |
| Constant | 3.8927*** | 3.4929*** | 3.5208*** | 5.0959*** | 3.8228*** |
| | (0.6674) | (0.5998) | (0.7315) | (0.7294) | (0.5276) |

| | | | | | |
|---|---|---|---|---|---|
| Observations | 259 | 249 | 236 | 269 | 302 |
| Number of countries | 16 | 16 | 16 | 16 | 16 |
| R-squared | 0.9403 | 0.9446 | 0.9534 | 0.9382 | 0.9353 |
| Adjusted R-squared | 0.9353 | 0.9397 | 0.9491 | 0.9332 | 0.9310 |

Notes: The dependent variable is R&D intensity using production. Clustered standard errors in parentheses. ***, ** and * display significance at the 1%, 5% and 10% level, respectively.

In our first specification (column (1) of Table 3) we include industry size, high-tech exports, intermediate input, the percentage of business enterprise expenditure on R&D and real overvaluation against the US dollar based on our first BEER model. The coefficients of industry size, high-tech exports and intermediate input are highly statistically significant. The proportion of BERD financed by government positively affects the R&D intensity in the manufacturing sector and is statistically significant at the 10% level. Interestingly, our explanatory variable of interest, namely our overvaluation dummy variable, shows a positive sign but is not significant. Thus, it seems that an overvaluation against the US dollar based on equation (8) does not affect R&D intensities in the manufacturing sectors of 16 OECD countries.

In a next step, we lag our overvaluation dummy variable by one year (column (2) of Table 3). This is motivated by Scherer and Huh (1992). They find that the adjustment of R&D spending triggered by higher import competition takes place slowly. As mentioned previously, real overvaluation could lead to higher import competition. This, in turn, could trigger adjustments of R&D investments. Thus, one might expect that firms respond to real overvaluation by adjusting their R&D expenditures slowly. Here, we use the same set of control variables as in our first specification (column (1) of Table 3). The result shows that real overvaluation is associated with a decrease of R&D intensity in manufacturing sectors. But the coefficient of the one-year lagged overvaluation dummy is not statistically significant. All other coefficients are statistically significant at the 1 percent level. In column (3) of Table 3 we lag our overvaluation dummy by two years. The coefficient is negative but not statistically significant. All other control variables remain statistically significant.

Next, we replace high-tech exports by the export-import ratio[16] (column (4) of Table 3). Industry size, intermediate inputs, percentage of BERD financed by government and the overvaluation dummy are included as additional explanatory variables. As in the case of specification 1, the coefficient of the overvaluation dummy variable is not statistically significant. Here, only industry size and intermediate inputs are statistically significant. Our policy variable has become insignificant.

In column (5) of Table 3 we exclude the policy variable. We include industry size, high tech exports and intermediate inputs as control variables. Our explanatory variable of interest is our overvaluation dummy at time t. In doing so, our number of observations increases. So we get more precise estimations. The result shows that the coefficient of our

[16] High-tech exports and the export-import ratio are highly correlated with each other, thus we do not put both variables together into our regressions.

dummy remains statistically insignificant. The coefficients of industry size, high-tech exports and intermediate inputs are statistically significant at the 1% level.

We conclude that a deviation of the real exchange rate from its equilibrium rate based on our first BEER model does not affect R&D intensities in manufacturing sectors. Thus, a real overvaluation against the US dollar based on our first measurement for real overvaluation does not influence R&D intensities in manufacturing sectors. Hence, it seems that a real overvaluation based on fundamentals which affect real exchange rates only in the medium-run has got no explanatory power. In a next step, we check empirically whether deviations of bilateral real exchange rates from their equilibrium levels based on our second BEER model have got a direct impact on R&D intensities in manufacturing sectors.

Table 4 reports the results of the estimations of R&D intensity in manufacturing sectors, whereby our explanatory variable of interest is the overvaluation dummy variable based on equation (9). In column (1) of Table 4 we include industry size, high-tech exports, intermediate inputs and the proportion of BERD financed by government as control variables. A striking result is that the coefficient of the overvaluation dummy is negative and statistically significant at the ten percent level. Thus, a real overvaluation against the US dollar based on our second BEER model seems to be negatively associated with R&D intensities in manufacturing sectors. Moreover, deviations of real exchange rates from its equilibrium values affect R&D intensities in manufacturing sectors. The industry size variable and the coefficient of intermediate inputs are highly statistically significant. The coefficient of high-tech exports is statistically significant at the ten percent level. Our policy variable shows a positive sign but is insignificant.

In column (2) of Table 3 we include the one-year lagged overvaluation dummy variable based on equation (9), industry size, high-tech exports, intermediate inputs and our policy variable as explanatory variables. The coefficient of the one-year lagged dummy variable displays a negative sign and is significant at the five percent level. Thus, a real overvaluation in the previous period negatively affects R&D intensities in manufacturing sectors at time t. We have at least two possible explanations as to why real overvaluation at time t-1 affects R&D intensities in manufacturing sectors. On the one hand, we argue that R&D investments in manufacturing sectors respond to higher import competition caused by real overvaluation against the US dollar slowly. On the other hand, it is also possible that real overvaluation is not reflected immediately in the profit margins of exporting firms due to contractual obligations. Furthermore, all control variables are statistically significant.

Next, we include the two-year lagged overvaluation dummy based on our second BEER model into our empirical model (column (3) of Table 3). Here, industry size, high-tech exports, intermediate inputs and BERD financed by government are included as control variables. The coefficients of our control variables are statistically significant. The two-year lagged dummy variable shows the expected sign but is insignificant. It can be interpreted, that real overvaluation against the US dollar at time t-2 does not affect R&D intensities in manufacturing sectors. This result also indicates that the impact of a real overvaluation based on equation (9) on R&D intensity fades away after two years.

Next, the high-tech variable is replaced by the export-import ratio (column (4) of Table 4). The other control variables are industry size, intermediate inputs and BERD financed by government. Our explanatory variable of interest is the overvaluation dummy based on equation (9) at time t. The result indicates that the dummy variable is statistically significant. In contrast to model 1, the coefficient of our dummy variable becomes statistically significant at the one percent level. The sign of the coefficient of the dummy variable remains negative. The export-import ratio variable is statistically highly significant and shows a negative sign. The industry size variable and the coefficient of intermediate inputs are also statistically significant. The policy variable becomes not statistically significant.

In model 5, we exclude our R&D subsidy variable from our regression. We use industry size, high-tech exports and intermediate inputs as control variables. Furthermore, the overvaluation variable based on our second BEER model is included. In comparison to our specification in column (1), our number of observations increases. The dummy variable remains statistically significant at the ten percent level and shows a negative sign. Moreover, all other control variables are highly statistically significant.

**Table 4: Fixed Effects Panel Estimation on the Total Manufacturing Sector 1988-2008 (Real Overvaluation against the US Dollar based on equation (9))**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Industry Size | -0.0603*** | -0.0610*** | -0.0600*** | -0.0577*** | -0.0568*** |
| | (0.0086) | (0.0084) | (0.0086) | (0.0088) | (0.0081) |
| High-Tech Exports | 0.0124* | 0.0142*** | 0.0148*** | | 0.0190*** |
| | (0.0070) | (0.0063) | (0.0070) | | (0.0047) |
| Export-Import ratio | | | | -0.0063*** | |
| | | | | (0.0018) | |
| Intermediate inputs | -0.0248*** | -0.0217*** | -0.0199*** | -0.0293*** | -0.0253*** |
| | (0.0075) | (0.0083) | (0.0073) | (0.0072) | (0.0067) |
| BERD financed by Government | 0.0078 | 0.0101* | 0.0125*** | -0.0064 | |
| | (0.0057) | (0.0057) | (0.0052) | (0.0059) | |
| Overvaluation | -0.0612* | | | -0.0761*** | -0.0664* |
| | (0.0352) | | | (0.0287) | (0.0346) |
| Overvaluation t-1 | | -0.0817*** | | | |
| | | (0.0357) | | | |
| Overvaluation t-2 | | | -0.0421 | | |
| | | | (0.0344) | | |
| Constant | 4.2056*** | 3.9806*** | 3.8024*** | 5.4934*** | 4.1604*** |
| | (0.7003) | (0.7513) | (0.6671) | (0.6244) | (0.5882) |
| Observations | 257 | 246 | 232 | 267 | 298 |
| Number of countries | 16 | 16 | 16 | 16 | 16 |
| R-squared | 0.9432 | 0.9469 | 0.9533 | 0.9449 | 0.9379 |
| Adjusted R-squared | 0.9384 | 0.9421 | 0.9488 | 0.9404 | 0.9336 |

Notes: The dependent variable is R&D intensity using production. Clustered standard errors in parentheses. ***, ** and * display significance at the 1%, 5% and 10% level, respectively.

Thus, evidence shows that real overvaluation against the US dollar has got a direct impact on R&D intensities in the manufacturing sectors of 16 OECD countries. We have used two different BEER models in order to determine real overvaluation against the US Dollar. It seems that deviations of real exchange rates from their equilibrium rate based on our first BEER model do not influence the R&D intensities of manufacturing firms. Note that this measurement does not contain the real interest rate differential. By adding the real interest rate differential into our estimations of the real exchange rate, we compute our second equilibrium real exchange rate. We have shown empirically that real overvaluations based on our second BEER model affects R&D intensities in manufacturing sectors directly. Note that the measurement of the equilibrium real exchange rate based on our second BEER model captures monetary policy and financial factors. Hence, we suspect that real overvaluations caused by monetary policy and financial factors dampens R&D investments of manufacturers. If the main driver of misalignment is the real interest rate differential, R&D intensities of manufacturing sectors will shrink.

The real interest rate differential and thus overvaluation based on equation (9) matters for R&D intensities in manufacturing sectors for at least two reasons. A widening of the real interest rate differential is associated with a stronger currency because domestic financial assets become attractive relative to foreign assets. An appreciation caused by higher domestic interest rates can be associated with a real overvaluation of the domestic currency if the magnitude of the decrease of the real exchange rate is not justified by the higher real interest rate differential. In such a case, an appreciation is not in line with fundamentals and thus the domestic currency will be overvalued. An overvalued currency is associated with lower profit margins and higher competition. Hence, exaggerations of financial markets which lead to an overvalued currency negatively affect R&D intensities of manufacturing sectors. The second reason is that a higher interest rate differential could reflect tighter financial conditions for domestic firms because government bond yields influence corporate bond yields and bank lending rates. Thus, higher government bond yields are associated with tighter financial conditions for domestic firms. Domestic firms which rely heavily on external funds to finance R&D expenditures are negatively affected by tighter financial conditions. These firms decrease investments in R&D due to higher corporate bond yields and lending rates.

So far, we have estimated the direct effect of real overvaluation against the US dollar on R&D intensities in manufacturing sectors. However, it could be argued that export performance is endogenous to innovative activity and depends on exchange rate swings. On the one hand, it can be argued that exports increase innovative activity because exporters have to keep up their innovative goods by increasing their R&D investments. On the other hand, higher exports influence innovative activity because fiercer competition on international markets forces exporting firms to increase expenditures in R&D. Thus, we face an endogeneity problem. Moreover, an overvaluation affects R&D intensities in manufacturing sectors and export activity. Thus, we test for an indirect effect of real overvaluation against the US dollar on R&D intensities in the manufacturing sectors.

**Table 5: Instrumental Variable Fixed Effect Panel Estimation 1988-2008 (specification 1: Export-Import Ratio)**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Industry Size | -0.0880 | -0.1132* | -0.0947*** | -0.0979*** |
| | (0.0649) | (0.0659) | (0.0311) | (0.0256) |
| Export-Import ratio | 0.0228 | 0.0522 | 0.0293 | 0.0348 |
| | (0.0633) | (0.0724) | (0.0274) | (0.0270) |
| Intermediate Input Share in Production | -0.0347*** | -0.0368 | -0.0356*** | -0.0324*** |
| | (0.0112) | (0.0265) | (0.0124) | (0.0153) |
| BERD financed by Government | 0.0324 | 0.0734 | 0.0415 | 0.0509 |
| | (0.0870) | (0.1000) | (0.0398) | (0.0396) |
| Constant | 2.8830 | -0.0422 | 2.2778 | 1.4450 |
| | (5.9571) | (6.6428) | (2.9961) | 3.1120 |
| Observations | 269 | 258 | 267 | 255 |
| Number of countries | 16 | 16 | 16 | 16 |
| R-squared | 0.8754 | 0.6779 | 0.8391 | 0.8147 |
| Adjusted R-squared | 0.8659 | 0.6521 | 0.8267 | 0.7997 |

Notes: The dependent variable is R&D intensity using production. Clustered standard errors in parentheses. ***, ** and * display significance at the 1%, 5% and 10% level, respectively.

Dealing with potential endogeneity problems requires an instrumental variable approach. Table 5 and Table 6 display results from the instrumental variable fixed effects regressions in the manufacturing sectors. In Table 5 we test whether real overvaluation influences R&D intensities of manufacturing sectors via the export-import channel. In column (1) of Table 5 we show the result of the first specification, where the export-import ratio is explained by overvaluation at time t based on equation (8). In contrast to our regression results (Table 3 and Table 4), the coefficient of the export-import ratio is positive. Moreover, the result indicates that the coefficient of the export-import variable is not statistically significant. Thus, manufacturing sectors do not seem to be indirectly affected by an overvaluation. In model 2, we use overvaluation at time t-1 based on equation (8) as an instrumental variable. The export-import variable displays a positive but insignificantly effect on innovative activity of manufacturers. In model in Table 5 the export-import ratio is explained by overvaluation at time t based on equation (8). The result shows that the export-import ratio remains statistically not significant. In our last specification (column (4) of Table 5) we use overvaluation at time t-1 based on the second BEER model as an instrument. The result displays no statistically significant relationship between the export-import variable and the dependent variable. So, all empirical models in Table 5 indicate that the export-import ratio has no statistically significantly impact on R&D intensities in manufacturing sectors. Hence, we conclude that real overvaluation against the US dollar does not affect manufacturing R&D via the export-import channel.

**Table 6: Instrumental Variable Fixed Effect Panel Estimation 1988-2008 (specification 2: High-Tech Exports)**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Industry Size | -0.0586*** | -0.0408*** | -0.0271 | -0.0290 |
| | (0.0160) | (0.0139) | (0.0325) | (0.0216) |
| High-Tech Exports | 0.0189 | 0.0715* | 0.0989 | 0.1043* |
| | (0.0260) | (0.0420) | (0.0842) | (0.0607) |
| Intermediate Input Share in Production | -0.0231* | -0.0058 | 0.0014 | 0.0062 |
| | (0.0129) | (0.0159) | (0.0312) | (0.0263) |
| BERD financed by Government | 0.0094 | 0.0285* | 0.0401 | 0.0406 |
| | (0.0123) | (0.0159) | (0.0338) | (0.0269) |
| Constant | 3.9015*** | 1.3552 | 0.0578 | -0.3292 |
| | (1.6570) | (1.9377) | (4.2546) | (3.1750) |
| Observations | 259 | 249 | 257 | 246 |
| Number of countries | 16 | 16 | 16 | 16 |
| R-squared | 0.9403 | 0.9235 | 0.8879 | 0.8870 |
| Adjusted R-squared | 0.9355 | 0.9171 | 0.8789 | 0.8775 |

Notes: The dependent variable is R&D intensity using production. Clustered standard errors in parentheses. ***, ** and * display significance at the 1%, 5% and 10% level, respectively.

Next, we test whether an overvalued currency affects manufacturing R&D via the high-technology export channel. Table 6 shows the corresponding instrumental variable fixed effects regressions in models 1 to 4. In model 1 (column (1) of Table 6), the high-technology export share in manufacturing exports is explained by overvaluation against the US dollar at time t based on the first BEER model. The result shows that the coefficient of the high-technology export variable is positive but statistically not significant. In model 2, we use overvaluation at time t-1 based on equation (8) as an instrumental variable. The high-tech export variable shows a positive sign and is statistically significant at the 10 percent level. Thus, we have evidence that overvaluation at time t-1 based on the first BEER model affects R&D intensities in manufacturing sectors via the high-technology export channel. In model 3, real overvaluation at time t based on equation (9) is used as an instrumental variable. Here, the high-technology export variable does not statistically significantly affect innovative activity in the manufacturing sector. In model 4, we use real overvaluation at time t-1 found on equation (9) as an instrumental variable. The high-technology export coefficient displays a positive sign and is statistically significant at the 10 percent level. Thus, it seems that real overvaluation at time t-1 against the US dollar based on the second BEER model also affects R&D intensities in manufacturing sectors via the high-technology export channel. To sum up, evidence supports our above-mentioned hypothesis that R&D intensities in manufacturing sectors are affected by real overvaluation via its negative effect on the export activity of manufacturers. More specifically, our results suggest that real overvaluation against the US dollar at time t-1, based on both BEER models, affects manufacturing R&D via the high-technology export channel and not via the export-import channel.

Hence, we find evidence that real overvaluation against the US dollar exerts both a direct and an indirect effect on R&D intensities in manufacturing sectors. Our empirical results suggest that real overvaluation against the US dollar at time t and t-1 based on the second BEER model (equation (9)) affect manufacturing R&D directly. Moreover, real overvaluation at time t-1 based on equation (9) shows a statistically significant indirect effect on R&D in manufacturing sectors. Lagged overvaluation and overvaluation at time t based on the first BEER model do not affect R&D intensities directly. However, our empirical results suggest that overvaluation at time t-1 found in equation (8) has an indirect effect on innovative activities of manufacturers. We think that the results from the instrumental variable fixed effects regressions are more convincing than from the fixed effects estimations because the instrumental variable approach accounts for potential endogeneity problems.

# 6. Conclusion

This paper studies the effect of an overvalued currency on R&D spending in manufacturing sectors. More specifically, we investigate whether a real overvaluation against the US dollar affects the R&D intensities in manufacturing sectors of OECD countries. So far, the literature has concentrated on the effect of exchange rate swings on R&D investments and on the impact of exchange rate volatility on R&D spending. The effect of an overvalued currency on R&D investment has been ignored in the literature. Thus, to our knowledge, our study is the first which addresses this gap.

We construct real overvaluation against the US dollar based on the BEER model of Clark and MacDonald (1998). In particular, we estimate two different BEER models by using the DOLS-methodology. The first BEER model includes terms of trade, government consumption and GDP per capita. In the second BEER model, terms of trade, government consumption, GDP per capita and the real interest rate differential are included. Based on these two BEER models, we compute two equilibrium real exchange rates for each country included in this study.

We test whether real overvaluation against the US dollar, based on the DOLS regressions, affects R&D intensities in the manufacturing sectors of 16 OECD countries. We test two specifications, one with a direct effect of real overvaluation against the US dollar on R&D intensities and one with an indirect effect. We have evidence, that real overvaluation against the US dollar both directly and indirectly affects R&D intensities in the manufacturing sectors of 16 OECD countries.

At first, we test for a direct effect of real overvaluation on R&D activities in manufacturing sectors. Our results suggest that real overvaluation against the US dollar at time t and t-1, based on the BEER model in which the real interest rate differential variable is included, negatively affects R&D intensities in manufacturing sectors. Thus, real overvaluation against the US dollar will have an adverse impact on long-term growth via its negative effect on R&D intensities in manufacturing sectors if real overvaluation is driven by financial and monetary factors. Next, we instrument exports with real overvaluation against the US dollar at time t and t-1 based on both BEER models. We find that both measures of real overvaluation against the US dollar influence R&D intensities in manufacturing sectors via the high-tech export channel. Thus, our regressions also reveal an indirect effect of real overvaluation on R&D activity.

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# Appendix 1

### A Country list

The estimations in Section 4.2 use annual data from 1980 to 2013 for the following 22 countries: Australia (AU), Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), Finland (FI), France (FR), Germany (DE), Greece (GR), Italy (IT), Ireland (IE), Japan (JP), Luxembourg (LU), Netherlands (NL), New Zealand (NZ), Norway (NO), Portugal (PT), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom(GB), United States (US). We limit ourselves to these 22 countries to ensure complete data availability for the explanatory variables.

### B The Bilateral Real Exchange Rate

The (bilateral) real exchange rate Q gives the price of a well-defined foreign goods basket in terms of a domestic goods basket. It is computed by using information on the nominal ex-change rate as well as on prices in the two countries:

(11) $$R_{i,t} = \frac{E_{i,t} P_t^F}{P_t^H},$$

where $R_{i,t}$ denotes the real exchange rate at time t, $P_t^F$ describes the price of a foreign goods basket at time t and $P_t^H$ is the price of a domestic goods basket at time t. The nominal exchange rate $E_{i,t}$ reflects the price of a foreign currency in terms of the domestic currency. Accordingly, an increase in $E_{i,t}$ reflects a nominal depreciation of the domestic currency. A decrease in $E_{i,t}$ reflects a nominal appreciation of the domestic currency. A decrease in $R_{i,t}$ is a real appreciation of the domestic currency. Thus, nominal and real exchange rates are expressed in price notation. Exchange rates can also be expressed in quantity notation. For instance, the nominal exchange rate in quantity notation reflects the price of the domestic currency in terms of a foreign currency. In quantity notation, an increase of the nominal exchange rate depicts an appreciation of the domestic currency. Both approaches, the price notation as well as the quantity notation are correct. To define the real exchange rate we need to specify the domestic and foreign price level. Usually, the prices P used to compute real exchange rates are national consumer price indices (CPI). Alternatives are national producer price indices (PPI), unit labour costs (ULC) and the GDP deflator. One can also use the price of a homogenous good or of a clearly defined basket of homogenous goods in the domestic and foreign country to compute the bilateral real exchange rate. Here, we use the consumer price indices to calculate bilateral real exchange rates. Data on consumer price indices were taken from OECD.stat. Data on bilateral nominal exchange rates come from various central banks and Thomson Reuters Financial Datastream.

C Variable definitions and data sources

For our estimations in Section 4.2, we use the following variables and data sources:

- Government consumption: General Government Final Consumption expenditure in percent of GDP. Data on government consumption were taken from the World Banks Database, World Development Indicators (WDI).
- GDP per capita: PPP constant 2010 international dollars. Data on output per capita were taken from OECD.stat.
- Real interest rate differential: Long- (short-)term interest rate minus GDP deflator. Data on long- and short-term government bond yields were taken from IMF International Finance Statistics (IFS). Data on GDP deflator are from the World Banks Database, World Development Indicators (WDI).
- Terms of trade in goods and services: Ratio of export prices to import prices. Data on terms of trade were provided by the OECD. Index, 2010=100.

# Appendix 2

### A Country list

The estimations in Section 5.2 use annual data from 1988 to 2008 for the following 16 countries: Belgium (BE), Canada (CA), Denmark (DK), Finland (FI), France (FR), Germany (DE), Greece (GR), Italy (IT), Ireland (IE), Japan (JP), Netherlands (NL), Norway (NO), Portugal (PT), Spain (ES), Sweden (SE), United Kingdom (GB). Due to many missing observations, variables and data on business R&D, we arrive at a sample of 16 OECD countries.

### B Variable definitions and data sources

For our estimations in Section 5.2, we use the following variables and data sources:

- R&D investment: R&D expenditures as a percentage of production. Data were taken from the OECD Structural Analysis Statistics (STAN) Database.
- Industry size: Ratio of industry employment and total employment. Data come from the OECD STAN Database.
- Export-import ratio: Exports as a percentage of imports. Data were taken from the OECD STAN Database.
- Intermediate inputs: The difference between production (gross) and value added of goods and services as a percentage of production. Data on intermediate inputs and production were taken from the OECD STAN Database.
- High-tech exports: High-technology exports as a percentage of manufactured exports. Data on high-technology exports as a percentage of manufactured exports were taken from the World Banks Database, WDI.
- Business enterprise expenditure on R&D financed by government: Percentage of BERD financed by government. Data were taken from the OECD Main Science and Technology Indicators (MSTI) database.

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