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The Yen exchange rate and the hollowing out of the Japanese industry

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Ansgar Belke
Ulrich Volz

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Ruhr-Universität Bochum (RUB), Department of Economics
Universitätsstr. 150, 44801 Bochum, Germany

Technische Universität Dortmund, Department of Economic and Social Sciences
Vogelpothsweg 87, 44227 Dortmund, Germany

Universität Duisburg-Essen, Department of Economics
Universitätsstr. 12, 45117 Essen, Germany

Editors

Prof. Dr. Thomas K. Bauer
RUB, Department of Economics, Empirical Economics
Phone: +49 (0) 234/3 22 83 41, e-mail: thomas.bauer@rub.de

Prof. Dr. Wolfgang Leininger
Technische Universität Dortmund, Department of Economic and Social Sciences
Economics – Microeconomics
Phone: +49 (0) 231/7 55-3297, e-mail: W.Leininger@tu-dortmund.de

Prof. Dr. Volker Clausen
University of Duisburg-Essen, Department of Economics
International Economics
Phone: +49 (0) 201/1 83-3655, e-mail: vclausen@vwl.uni-due.de

Prof. Dr. Roland Döhrn, Prof. Dr. Manuel Frondel, Prof. Dr. Jochen Kluve
RWI, Phone: +49 (0) 201/81 49-213, e-mail: presse@rwi-essen.de

Editorial Office

Sabine Weiler
RWI, Phone: +49 (0) 201/81 49-213, e-mail: sabine.weiler@rwi-essen.de

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Ansgar Belke and Ulrich Volz[1]

The Yen Exchange Rate and the Hollowing Out of the Japanese Industry

Abstract

Since the demise of the Bretton Woods system, the yen has seen several episodes of strong appreciation, including in the late 1970s, after the 1985 Plaza Agreement, the early and late 1990s and after 2008. These appreciations have not only been associated with "expensive yen recessions" resulting from negative effects on exports; since the late 1980s, the strong yen has also raised concerns about a de-industrialisation of the Japanese economy. Against this backdrop, the paper investigates the effects of changes to the yen exchange rate on the hollowing out of the Japanese industrial sector. To this end, the paper uses both aggregate and industry-specific data to gauge the effects of yen fluctuations on the output and exports of different Japanese industries, exploiting new data for industry-specific real effective exchange rates. Our findings support the view that the periods of yen appreciation had more than just transitory effects on Japanese manufacturing. The results also provide indication of hysteresis effects on manufacturing. While there are certainly also other factors that have contributed to a hollowing out of Japanese industry, a strong yen played a role, too.

JEL Classification: : F31, O14

Keywords: Yen appreciation; exchange rates; Japanese manufacturing; hollowing out; hysteresis

July 2019

1 Ansgar Belke, UDE, CEPS Brussels, IZA Bonn & King's College London; Ulrich Volz, SOAS University of London. *- The paper was written while the second author held the Banque de France Chair at EHESS in Paris. Ulrich Volz would like to thank Banque de France for financial support for this research project and Fondation France Japon de l'EHESS for its wonderful hospitality and great support. The authors are grateful for comments received by two anonymous referees, Kenji Aramaki, George Chortareas, Volker Clausen, Laurent Ferrara, Andy Filardo, Maurizio Habib, Benedicto Lukanima, Toshiyuki Matsuura, Volker Nitsch, Tobias Stöhr, Franz Waldenberger, Martin Weale and Naoyuki Yoshino and other participants at the 2nd Japan Economy Network Conference held at the Asian Development Bank Institute in Tokyo on 14-15 September 2017, the Banque de France-EHESS Workshop on "The Role of the Exchange Rate for the Real Economy – Experiences from Japan and the Europe" at Banque de France in Paris on 27 October 2017, an Economics Research Seminar at King's College in London on 14 March 2018, the International Conference on Macroeconomics and International Finance in Rethymno from 24-26 May 2018, the World Finance Conference in Mauritius from 25-27 July 2018, and the Annual Conference 2018 of the German Economic Association in Freiburg im Breisgau from 2-5 September 2018. We would also like to acknowledge very helpful comments and suggestions by Sébastien Lechevalier, Eiji Ogawa, Toshitaka Sekine and Wataru Takahashi during the research on this paper. We are also grateful to Tatsufumi Yamagata at IDE-JETRO for kindly providing us with industry-specific export data. The usual disclaimer applies.* *– All correspondence to: Ulrich Volz, Department of Economics, SOAS University of London, Thornhaugh Street, London WC1H 0XG, UK, e-mail: uv1@soas.ac.uk*

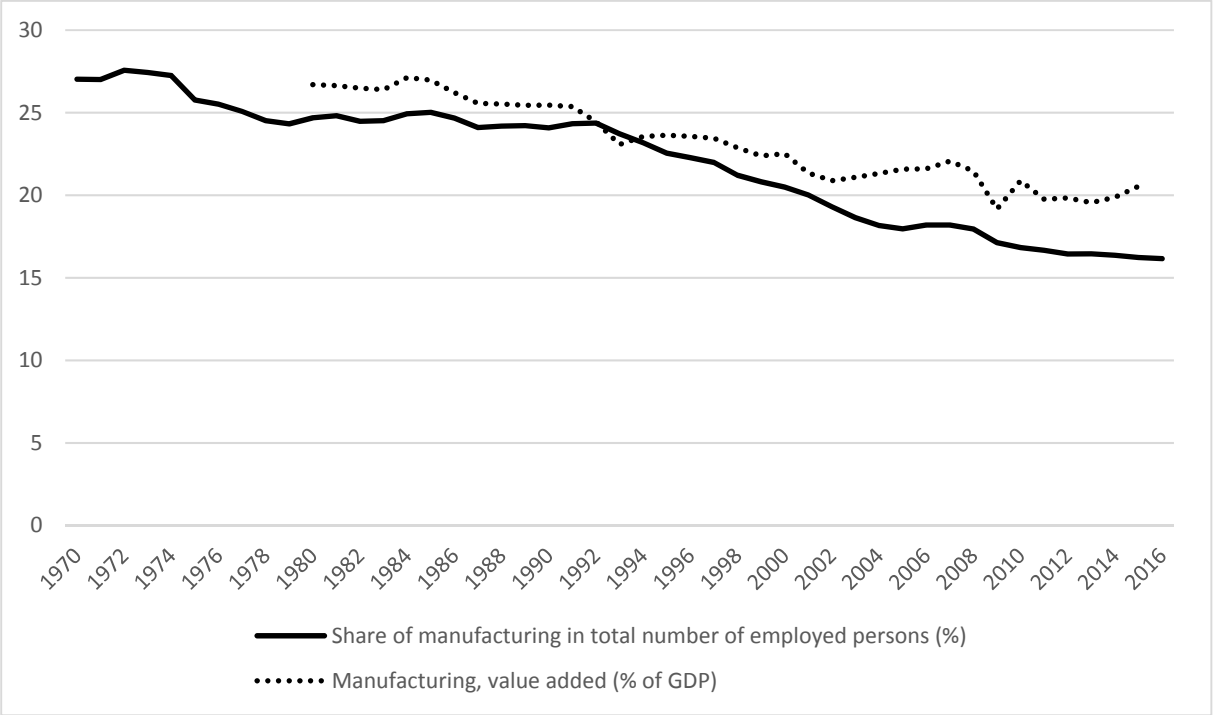
1. Introduction

A strong yen – *endaka* (円高) in Japanese – has repeatedly caused distress among Japanese policymakers and manufacturers. Since the demise of the Bretton Woods system in 1971, the yen has seen several episodes of strong appreciation, including in the late 1970s, after the 1985 Plaza Agreement, the early and late 1990s and after 2008 (Figure 1). These appreciations have not only been associated with "expensive yen recessions" – *endaka fukyo* (円高不況) in Japanese – resulting from negative effects on exports; since the late 1980s, the strong yen has also raised concern about a de-industrialisation of the Japanese economy. Indeed, the share of manufacturing in total output has declined from 26.7% in 1980 to 20.5% in 2015, while the share of manufacturing in total number of employed persons has declined from 27.0% to 16.2% between 1970 and 2016 (Figure 2). The decline in the share of manufacturing in total employment or GDP is not unique to Japan. It is indeed a phenomenon that can be seen across industrialised economies, with varying degrees. What makes Japan a particularly interesting case to analyse is that the yen's real effective exchange rate has shown much larger volatility than the currencies of other large advanced economies. Between 1980 and 2018, the standard deviation of Japan's annual real effective exchange rate was 17.0, compared to 12.3 for the U.S., 10.4 for the United Kingdom, and 5.3 for Germany. Exchange rate effects on manufacturing may therefore have been more pronounced than elsewhere.

Figure 1: Real effective exchange rate of the Japanese yen, 1964-2019 (2010=100)

Source: Compiled by authors with data from the BIS Effective Exchange Rate Indices (Monthly data: Narrow indices, updated 17 April 2019), www.bis.org/statistics/eer.htm.

Figure 2: Value added in manufacturing as share of GDP and share of manufacturing in total number of employed persons



Source: Compiled by authors with data from the Japan Labor Force Survey and the World Development Indicators.

While the strong yen and its potentially de-industrialising effect have received much attention in the political and economic policy discourse in Japan, there has been surprisingly little research on this in the academic literature. As pointed out by Hamada and Okada (2009: 200), most research on Japan's "lost decade" and hollowing out of the Japanese industry "have been broadly focused on its real and domestic aspects, such as total factor productivity (TFP), growth decline, non-performing loans, and governance." Hamada and Okada (2009: 200) argue that monetary and exchange rate policy have played an important role in this, and that "Japanese industries endured a heavy burden" due to a greatly overvalued real exchange rate.

Against this backdrop, the paper aims to investigate the effects of yen fluctuations on industrial production and the hollowing out of the Japanese industry. The major contribution of this study is an econometric analysis using new data for industry-specific real effective exchange rates (RIETI, 2018) to gauge the effects of yen fluctuations on the output and exports of different Japanese industries at monthly frequency. As recently shown by Fort et al. (2018) for the US economy, changes to manufacturing employment have differed considerably across sectors. The use of monthly, industry-specific data allows us to better capture potential effects of real effective exchange rate movements. We also use annual data since 1970 to investigate potential long-term effects of yen exchange rate changes on manufacturing employment. Following Rowthorn and Coutts (2004: 767), we define de-industrialisation – to which we also refer as "hollowing out" – as "a secular decline in the share of manufacturing in national employment".

The topic is not only of relevance to the Japanese economy, it also bears relevance for other advanced economies. Indeed, recent years have seen an intense discussion in several member countries of the Eurozone about purported negative effects of a too high euro exchange rate on manufacturing and

employment (e.g., Belke and Volz, 2015). For instance, Bénassy-Quéré et al. (2014: 7) estimate that for France "a 10% depreciation in the euro in relation to a partner country outside the eurozone increases the value of the average exporter's sales to this country by around 5-6%", with most of this effect realised in the same year as the depreciation. Likewise, the U.S. has recently seen a renewed discussion on de-industrialisation, with a prominent role of the dollar exchange rate in this discourse (e.g., Campbell, 2017; Levinson, 2017). A better understanding of any exchange rate effects on Japanese manufacturing should also provide insights for economic and monetary policy elsewhere.

The reminder of the paper is structured as follows. Section 2 provides a review of the literature on the effects of exchange rate changes on de-industrialisation. Section 3 comprises our empirical analysis. The empirical part is split into two sections: Firstly, we conduct an empirical analysis with annual, aggregate data from 1970 to 2016 that allows us to investigate potential long-term effects of yen exchange rate changes on manufacturing employment. Secondly, we use monthly, industry-specific data from January 2001 to June 2017 to gauge the dynamics of yen exchange rate changes on Japanese sectoral manufacturing employment. Section 4 summarises and concludes.

2. Literature review

It is well established that depreciated real exchange rates can help to stimulate industrial development and economic growth (Rodrik, 2008).[1] Although there seems to exist a "fear of appreciation" (Levy-Yeyati et al., 2013) relatively little research has been conducted on the effect of overvalued exchange rates on economies. The first systematic empirical cross-country analysis to investigate the effects of large exchange rate appreciation on current account balances and on real output was conducted by Kappler et al. (2013), who find that episodes of strong exchange rate appreciations are associated with deteriorating current account balances and a slow-down of real export growth, but no significant effects on output. Likewise, Bussière at al. (2015) examine to what extent large and rapid real exchange rate appreciations impact on economic growth. Using a sample of 53 emerging and advanced economies, they find that while large appreciations dampen export growth and boost import growth, output growth is higher on average.

The literature on de-industrialisation has focused less on exchange rate valuations than on changes in specialisation, consumption, technological progress and productivity, international trade and investment patterns (Rowthorn and Coutts, 2004). The major exemption is the U.S. economy, for which the effect of the dollar exchange rate on the U.S. industry has been studied widely. The findings in this literature are mixed, with some studies finding a large effect (Branson and Love, 1986, 1987, 1988a, 1988b; Revenga, 1992; Gourinchas, 1999; Kandil and Mirzaie, 2002, 2003; Klein et al., 2003; Campbell, 2017) and others a small or no impact (Glick and Hutchison, 1990; Goldberg, 1993; Campa and Goldberg, 1995 and 2001; Bahmani-Oskooee et al., 2000, 2007).[2]

[1] A recent study by Alfaro et al. (2018) confirms this for economies with high export participation.

[2] There are also a number of studies investigating exchange rate effects on European economies. For instance, using firm-level data, Moser et al. (2010) and Berman et al. (2012) find relatively small exchange rate effects on employment of German and French firms, respectively. Ekholm et al. (2012) analyse the impact of a real appreciation of the Norwegian krona on Norwegian net-exporting and import-competing firms in the early 2000s, finding negative effects on domestic employment across both groups of firms. Thorbecke and Kato (2017) examine the effect of changes to the Swiss franc exchange rate on the Swiss economy and find differences related to the sophistication of exports.

According to Rowthorn and Ramaswamy (1997a, 1997b) and Rowthorn and Coutts (2004, 2013), the most important internal/domestic factors contributing to de-industrialisation are productivity growth in the manufacturing sector and shifting patterns of domestic expenditure, i.e., with rising income consumption tends to shifts towards more services and away from manufactured goods (known as Engel's Law or Bell's Law). The most important external factors are identified as "North-South" trade and the outsourcing of labour-intensive manufacturing to low-wage countries. However, domestic factors, especially a higher productivity growth in manufacturing than in services, are widely seen as the dominant factor behind de-industrialisation (Rowthorn and Ramaswamy, 1997; Rowthorn and Coutts, 2004, 2013; Lawrence, 2017).[3]

Surprisingly few studies have looked into the potentially de-industrialising effect of *endaka*, even though Obstfeld (2010) pointed out that Japan's real economic growth rate has been strongly negatively correlated with the level of the yen's real effective exchange rate. Only few studies can be found that systematically try to verify the hypothesis that the strong yen has contributed to de-industrialisation and outsourcing of industry in Japan, including Dekle (1996), Dekle et al. (2010) and Yamashita (2013, 2015). Dekle (1996) and Dekle at al. (2010) find that yen appreciations of 1985 and 1995 significantly hurt the ability of Japan to compete with the U.S. by raising the relative production costs of Japanese industries. Yamashita (2013, 2015) finds that yen appreciation and outward FDI contributed to de-industrialisation and suggests that a weak yen may contribute to reshoring.[4]

A string of studies examines the role of Japanese outward direct investment in the hollowing out process. Japanese outward direct investment took off in the mid-1980s (Fukao et al., 2003). The number of Japanese multinationals increased by 290% between 1985 and 1992, while overseas production of Japanese firms increased from 3% in 1982 to 17% in 2002 (Ryan and Toubal, 2017). Analysing data on Japanese acquisitions in the United States from 1975-1992, Bloningen (1997) finds that real dollar depreciations increased the likelihood of Japanese acquisitions in U.S. industries. Likewise, the BOJ (2011) attributed the renewed shifting of production abroad since 2008 to the relative appreciation of the yen compared to the levels before the Lehman shock.

Empirically, the effect of outsourcing on domestic manufacturing employment is mixed. According to Baldwin (2006), offshoring labour-intensive production processes to adjacent lower-cost locations in Southeast and Northeast Asia since the mid-1980s did apparently allow Japanese companies to retain parts of manufacturing production domestically while maintaining international competitiveness. The BOJ (1989) finds that increased outward direct investment contributed to long-term structural adjustment in the export sector. This contributed to a temporary surge in the export of capital goods and parts to overseas production bases of Japanese companies. Yamashita and Fukao (2010) find no indication that expansion of overseas operations by Japanese manufacturing multinational enterprises reduced home employment over the period 1991-2002; indeed, their analysis suggests that it may have contributed to maintaining the level of home employment. A recent study by Ryan and Toubal (2017) uses Japanese firm-level data for the period 1982-2001 to compare employment between firms with and without foreign affiliates and the extent to which the development of foreign operations

[3] A further factor that appears to have played a role in the falling share of manufacturing is the outsourcing of various services that historically were conducted in-house and hence counted as manufacturing, whereas they are now counted as services. See Boulhol and Fontagné (2006). Evidence for this development in Japan is presented in Uemura and Tahara (2014).

[4] Bleaney (1997) looks at the pricing of Japanese manufacturing exports and finds a significant role of the yen real exchange rate.

affects firm-level domestic employment. It finds "some limited evidence" of the hollowing out of the Japanese economy by Japanese multinational firms shifting production abroad from 1991 onwards.

Using the same industry-specific exchange rates that will be employed in our empirical analysis later, Sato et al. (2013) analyse export price competitiveness and export performance of Japan, China and Korea and find that the strong yen after 2007 destroyed the Japanese electronics sector. Likewise, Thorbecke (2012) finds in a study focused on the Japanese electronics industry that the yen appreciation between 2007 and 2011 had a very damaging effect on electronics exports. However, neither study controls for employment effects. Kato (2018) examines the effects of exchange rate changes and productivity on manufacturing exports for the period 2002-2012 and finds exchange rates to be important factors to affect firm-level exports.

An important issue in this context is that exchange rate appreciations and depreciations may not have symmetrical effects. That is, a period of strong appreciation may lead to outsourcing and the loss of manufacturing capacities – and employment – in the home country, but a depreciation later on may not bring about a return (or "re-shoring") of manufacturing activities and employment, given that long-term investments have been made abroad, which will not be reversed. These hysteresis effects have been described in sunk cost models of trade hysteresis (Krugman, 1988; Baldwin and Krugman, 1989; Baldwin, 1990; Baldwin and Lyons, 1994) and empirically investigated mostly for the U.S. and a number of European economies.[5] Giovannetti and Samiei (1995) conduct an empirical analysis of the importance of hysteresis in international trade, using manufacturing exports for the United States, Germany, and Japan. They find "strong evidence" in favour of the presence of hysteresis only in the case of Japanese exports.

3. Empirical approach and findings

For our econometric analysis, we use both aggregate and industry-specific data to gauge the effects of changes of the real effective yen exchange rate. Taking account of the availability of different data series, we firstly conduct an empirical analysis with annual data from 1970 to 2016 that allows us to investigate potential long-term effects of yen exchange rate changes on manufacturing employment. Secondly, we use monthly data from 2001:M01 to 2017:M06 to check the dynamics of yen exchange rate changes on Japanese sectoral manufacturing employment, exploiting a new monthly dataset on Japanese sectoral exchange rates which are only available from 2001 onwards. For this purpose, we use a mixed time series-panel framework.

3.1 Analysis with annual data, 1970-2016

3.1.1 Data and empirical model

Building on Rowthorn and Ramaswamy (1997a) and Rowthorn and Coutts (2004, 2013), we estimate the following model for Japan and annual data ranging from 1970 to 2016:[6]

[5] See Belke et al. (2013), Belke and Kronen (2019), Campa (2004) and Campbell (2017).

[6] The same framework is applied by Boulhol and Fontagné (2006), who analyse the change in the share of manufacturing in employment between 1970 and 2002 for 16 OECD countries. But none of these studies controls for exchange rate effects.

(1) $EMPMAN = \beta_0 + \beta_1 EMPMAN_{t-1} + \beta_2 CAP + \beta_3 EXPMAN + \beta_4 OFDI + \beta_5 TFP + \beta_6 EXPCHIN + \beta_7 EXR + \varepsilon,$

with *EMPMAN* = Share of manufacturing in the total number of employed persons (%), *CAP* = Gross domestic fixed capital formation (% of GDP), *EXPMAN* = Manufacturing exports, *OFDI* = Outward direct investment, *TFP* = Total factor productivity at constant national prices, *EXPCHIN* = Chinese exports, and *EXR* = Real effective exchange rate. Appendix 1 provides more details on the variables and sources.

The selection of explanatory variables in (1) is motivated by the standard variables used in previous studies on de-industrialisation. To these we add *EXR* as the variable of our particular interest to investigate the hypothesis that movements of the yen's real effective exchange rate have contributed to a de-industrialisation of the Japanese economy.

Increases in fixed capital formation could theoretically have both positive and negative effects on manufacturing employment. On the one hand, an increased investment in the domestic manufacturing sector could have positive employment effects. On the other hand, however, capital investment could advance the automation of manufacturing production, with neutral or even negative effects on manufacturing employment. In contrast, an increase in manufacturing exports should clearly have a positive effect on domestic manufacturing employment. As discussed above, the effect of outward direct investment can be ambiguous: on the one hand a shifting of production abroad may have negative employment effects, but at the same time there could be positive outcomes because it may increase the competitiveness of domestic operations which would remain important parts of regional or global value chains (Baldwin, 2006; Yamashita and Fukao, 2010).

As mentioned above, productivity increases have been identified in the de-industrialisation literature as a major factor behind the fall in manufacturing employment, so we would expect a negative coefficient. We use TFP as our measure of productivity. We considered using alternative measures of productivity, such as multifactor productivity, but were not able to obtain data ranging back to the 1970s.

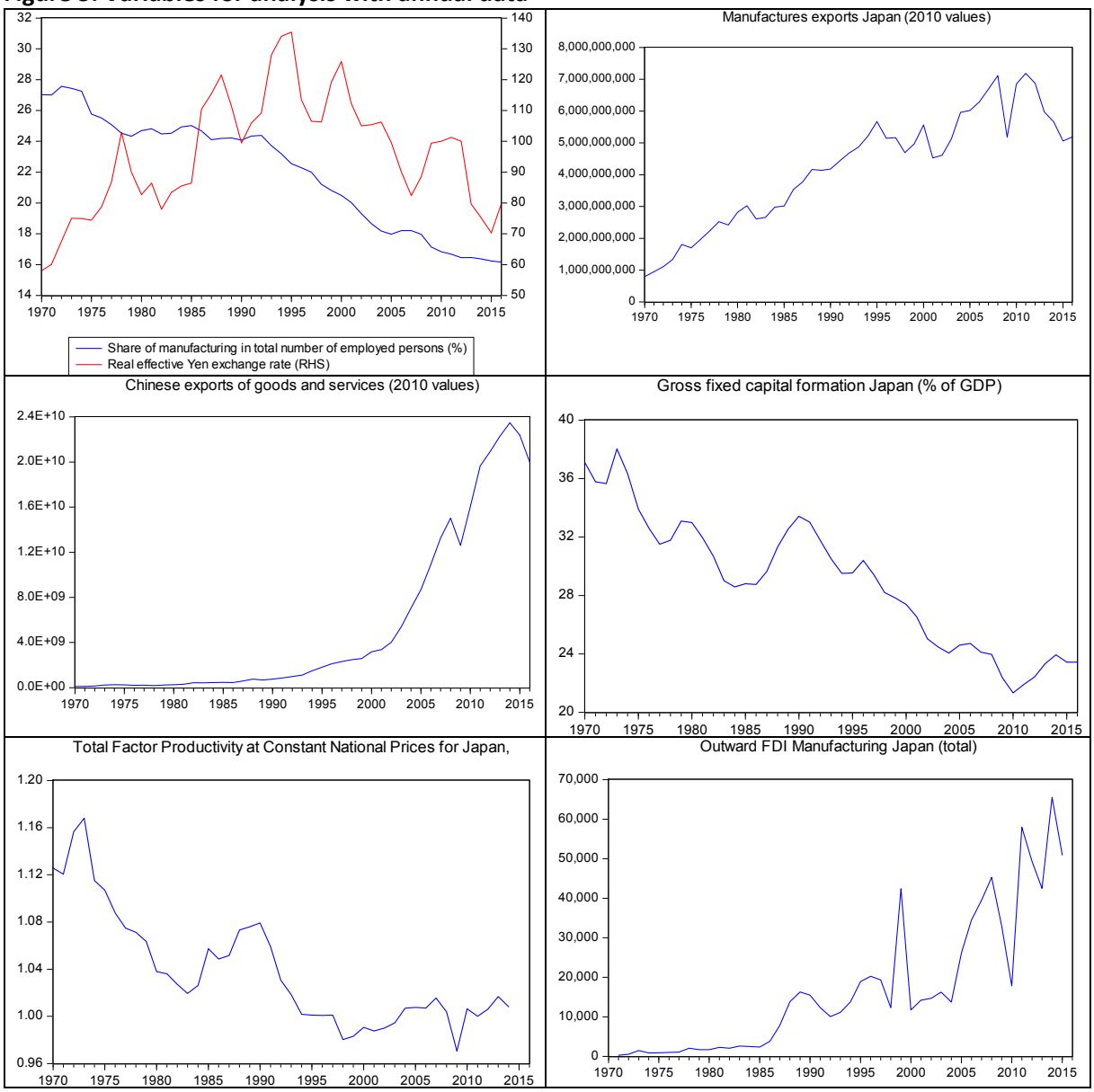
The effects of Chinese export growth are, again, ambiguous.[7] While Chinese export growth is a reflection of China's rapid growth process, which has also opened up great opportunities for Japanese companies, Chinese exporters have increasingly become competitors of Japanese manufacturing firms. Last but not least, we would expect the coefficient estimate for the real effective exchange rate – our main variable of interest – to be negative if the hollowing out hypothesis were to hold.

Figure 3 graphically displays the time series of the variables used in our estimations based on annual data. It conveys a first impression of the stationarity properties of the time series used. At first glance, all time series appear to contain, probably stochastic, trends. We will explicitly check for stochastic trends before we start our estimation exercise in order to make sure that the stochastic properties of the included variables meet the standard assumptions of our regression analysis. Moreover, some first indications of correlations can be derived as well. Whether this means "causation" in an econometric sense will be checked later on in this section.

[7] Unfortunately, no data was available for Chinese manufacturing exports for this period. This is why we selected total exports from China.

The top left panel of Figure 3 shows the two main variables of interest, the share of manufacturing in total number of employed persons and the real effective exchange rate. Between 1970 and the mid-1990s, the real effective exchange rate showed a clear long-term appreciation trend, but with two periods – 1978-1982 and 1988-1990 – of depreciation. After a peak in 1995, the real effective exchange rate then shows a declining trend, albeit with periods of strong appreciation in 1998-2000, 2007-2011 and 2015-2016. Over the entire sample period, the share of manufacturing in total number of employed persons shows a long-term declining trend, although the share of manufacturing remains stable over the periods 1987-1992, 2005-2007 and 2012-2016.

Figure 3: Variables for analysis with annual data



Source: Compiled by authors.

3.1.2 Unit root tests

We proceed with unit root tests of the variables to be employed in our empirical model. The results of our single time series unit root tests are displayed in Table 1. All variables turn out to be integrated of order one (I(1)), except Chinese exports EXPCHIN which appears borderline I(2).

Table 1: Results of unit root tests (ADF test statistics and probabilities)

Variable	Level	First difference	Integration order of variable
CAP	-1.33 (0.6087)	-4.96 (0.0002)	I(1)
EMPMAN	-0.56 (0.8680)	-4.69 (0.0004)	I(1)
EXPCHIN	2.52 (1.0000)	-0.59 (0.9735)	I(1)/I(2)
EXPMAN	-1.92 (0.3195)	-8.10 (0.0000)	I(1)
EXR	-2.75 (0.0088)	-5.20 (0.0001)	I(1)
OFDI	0.45 (0.9827)	-8.23 (0.0000)	I(1)
TFP	-1.83 (0.3629)	-6.17 (0.0000)	I(1)

Source: Compiled by authors.
Note: Table displays empirical realisations of the Augmented Dickey-Fuller test with a constant (MacKinnon (1996) one-sided p-values).

For the real effective yen exchange rate (EXR), with exception of the ADF-test, all complementary unit root tests including the Dickey-Fuller GLS (ERS) test, the Phillips-Perron test, the Kwiatowski-Phillips-Schmidt-Shin test and the Ng-Perron unit root test point into the direction of an I(1) process. Hence, we proceed with the yen exchange rate considering it as an I(1) variable. The results are available on request.

As a robustness check, we also conducted Dickey-Fuller GLS tests, Phillips-Perron tests, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) and Ng-Perron unit root tests not only for the yen exchange rate but also for all other variables. The results overall stayed the same. Among others, they support treating EXPCHIN finally as an I(1) variable in our regressions.

Given the unit root tests conducted in this section and their rather unambiguous results, we feel legitimised to employ the levels of the variables in the framework of a cointegration approach (option 1) and/or use the first differences of all variables as stationary variables in our Autoregressive Distributed Lag (ARDL) estimations (option 2).

Regarding our regression analysis two issues come to mind. Firstly, there is a relatively broad consensus in the literature that one may well find impacts of exchange rate changes on employment even if there is less evidence of an impact on trade (Belke and Gros, 2001). Secondly, a thorough regression analysis is necessary to consider leads and lags of the variables when it comes to establish any one-way “causation”. This is dramatically shown by the main results of the export hysteresis literature which shows that a positive coefficient of the exchange rate in export, employment, investment or industrial output equations may just hide a more complex dynamic of the relationship

which may include stepwise negative effects of an appreciation of the home currency (Krugman and Baldwin, 1987; Belke et al., 2013).[8]

We now turn to the first option, the estimation of a cointegrating equation in order to assess the impact of the yen exchange rate (EXR) on the share of manufacturing in total number of employed persons in Japan (EMPMAN), taking the other variables contained in eq. (1) into account simultaneously in the long-run relationship.

3.1.3 A cointegration approach: in search of long-run "causation" of "hollowing out"

As our cointegration framework we choose Dynamic Ordinary Least Squares (DOLS). This is because DOLS allows us to test for *causality* running from the independent to the dependent variables. The DOLS estimation technique *controls for endogeneity* of explanatory variables (Stock and Watson, 1993; Wooldridge, 2009). Endogeneity in the form of feedback effects or reverse causality between the dependent and independent variables would lead to a misspecification of our estimated models. More specifically, the DOLS procedure controls for endogeneity of all explanatory variables by inserting *leads and lags* of the changes of all exogenous variables. Hence, DOLS is *a powerful estimation technique*, where standard errors are corrected for heteroscedasticity and cross-section correlation (Saikkonen, 1991; Stock and Watson, 1993). By inserting the leads and lags of the exogenous variables in first differences, the explanatory variables in levels become *(super-) exogenous* and the regression results *unbiased* (Wooldridge, 2009).

Table 2 displays the results of a DOLS estimation of our fully specified empirical model (eq. (1)). The share of manufacturing in total number of employed persons (EMPMAN) represents the dependent variable. The estimated coefficient of the yen exchange rate (marked in bold) is negative as expected from theory and highly significant. Seen on the whole, also the other estimated coefficients are significant and their signs corresponding with our priors. TFP shows a negative coefficient, suggesting that higher productivity has resulted in a lower share of manufacturing employment, but this effect is not statistically significant. Gross domestic fixed capital formation shows a positive sign and is highly significant. As expected, manufacturing exports have a positive and significant effect on manufacturing employment, whereas outward direct investment has a negative and significant effect. Chinese exports show a positive sign, suggesting that the positive effects of Chinese economic development on Japanese manufacturing dominated the negative competition effect. Finally, the empirical realisations of the goodness-of-fit criteria, among them the very high R-Squared, indicate the appropriateness of our selected empirical model.

[8] The hysteresis argument is mainly related to the irreversibility of investment-type decisions, due to high fixed costs which cannot be recovered ex post (sunk costs). Industrial manufacturing production, the focus of the second part of this paper, is a very good example because it is dependent on investment-type decisions related to, among others, fixed investment, hiring and firing decisions and establishing distribution networks.

Table 2: Dynamic least squares estimation for fully specified model

Dependent Variable: EMPMAN
Method: Dynamic Least Squares (DOLS)
Sample (adjusted): 1973-2013
Included observations: 41 after adjustments
Cointegrating equation deterministics: C
Fixed leads and lags specification (lead=1, lag=1)
Long-run variance estimate (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TFP	-10.49578	6.642659	-1.580057	0.1337
CAP	1.108099	0.135792	8.160269	0.0000
EXPCHIN	2.20E-10	8.54E-11	2.572967	0.0204
EXPMAN	1.42E-09	3.67E-10	3.879566	0.0013
OFDI	-0.000192	3.60E-05	-5.325351	0.0001
EXR	**-0.051424**	**0.016242**	**-3.166034**	**0.0060**
C	2.783452	5.976907	0.465701	0.6477
R-squared	0.992483	Mean dependent var		22.11307
Adjusted R-squared	0.981208	S.D. dependent var		3.295862
S.E. of regression	0.451804	Sum squared resid		3.266036
Long-run variance	0.175494			

Source: Compiled by authors.

Our robustness checks reveal that the total goodness-of-fit does not become significantly lower if EXPCHIN is eliminated from our empirical model. This does not come as a surprise since both variables represent indicators of the world business cycle, i.e., the so-called “global factor”. For exactly this reason, we leave out EXPCHIN in our next DOLS-specification. The corresponding regression results are displayed in Table 3. Again, the estimation results clearly are in accordance with our priors.

Table 3: Dynamic least squares estimation for model excluding Chinese exports

Dependent Variable: EMPMAN
Method: Dynamic Least Squares (DOLS)
Sample (adjusted): 1973-2013
Included observations: 41 after adjustments
Cointegrating equation deterministics: C
Fixed leads and lags specification (lead=1, lag=1)
Long-run variance estimate (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

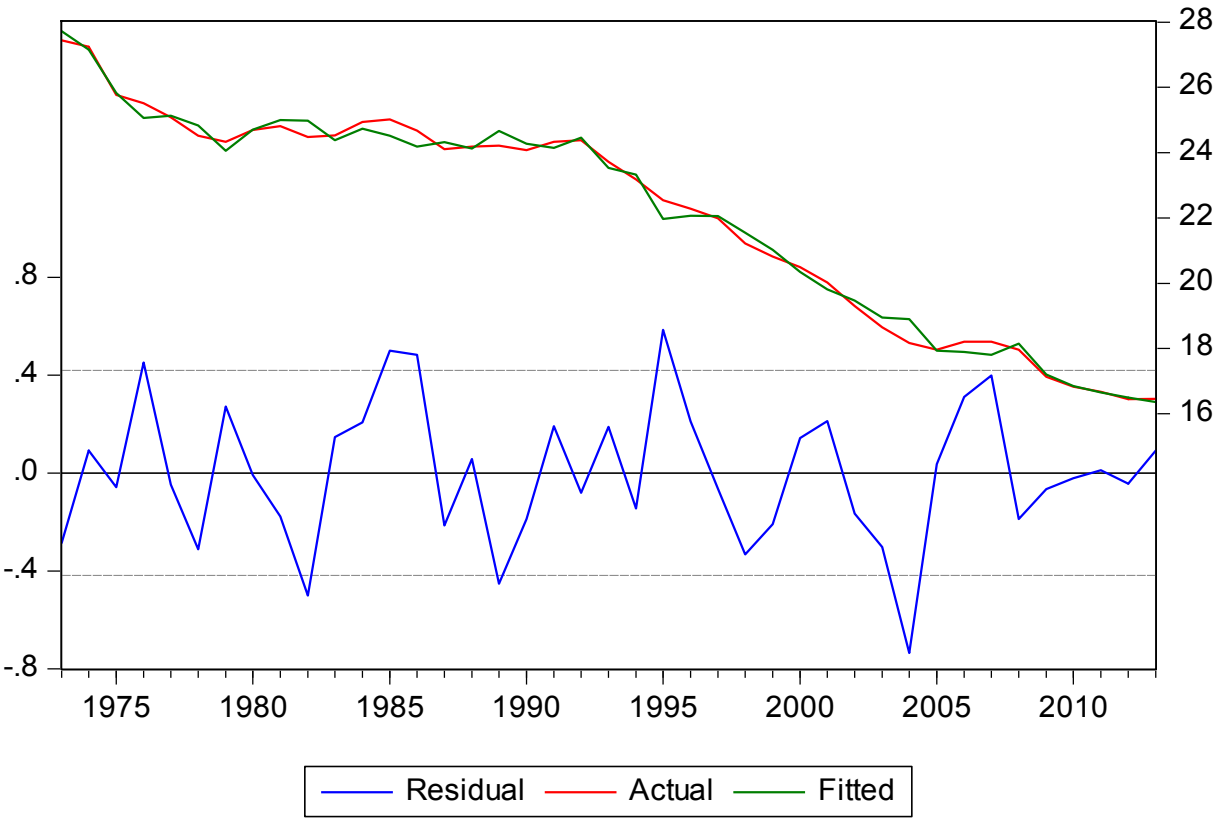
Variable	Coefficient	Std. Error	t-Statistic	Prob.
TFP	-4.949611	8.354137	-0.592474	0.5602
CAP	0.930860	0.140335	6.633109	0.0000
EXPMAN	1.10E-09	4.76E-10	2.309287	0.0317
OFDI	-0.000122	3.54E-05	-3.440251	0.0026
EXR	**-0.055554**	**0.020831**	**-2.666873**	**0.0148**
C	3.580114	8.186393	0.437325	0.6666
R-squared	0.988524	Mean dependent var		22.11307
Adjusted R-squared	0.977048	S.D. dependent var		3.295862
S.E. of regression	0.499324	Sum squared resid		4.986488
Long-run variance	0.337452			

Source: Compiled by authors.

As robustness checks we also conducted DOLS regressions with White correction of the coefficient covariance matrix (White, 1980). There is no substantial change of the estimation results, with respect to the magnitude and the sign of the estimated coefficients. If at all, the significance of, for instance, the yen exchange rate, even slightly increases once again in the specification excluding Chinese exports. Moreover, we also enacted DOLS regression with Newey-West correction of the coefficient covariance matrix (Newey and West, 1987). Again, the estimation results do not change much with respect to both the magnitude and the sign of the estimated coefficients. All these results are available on request.

Application of the DOLS procedure requires the time series to be non-stationary *and* to be cointegrated over time. We are able to show that both conditions are satisfied in our case. Evidence of non-stationarity has been delivered already by the results of our unit root tests in Section 3.1.2. And empirical support of cointegration among the variables contained in our empirical models is conveyed by cointegration tests (Table 4 for the fully specified model and Table 5 for the model without Chinese exports). Figures 4 and 5 display the residuals (which form the basis for the Engle-Granger cointegration tests described in Tables 4 and 5) and the actual and fitted values according to the DOLS regression models described in Tables 2 and 3, respectively.

Figure 4: Residuals, actual and fitted values (fully specified DOLS model)



Source: Compiled by authors.

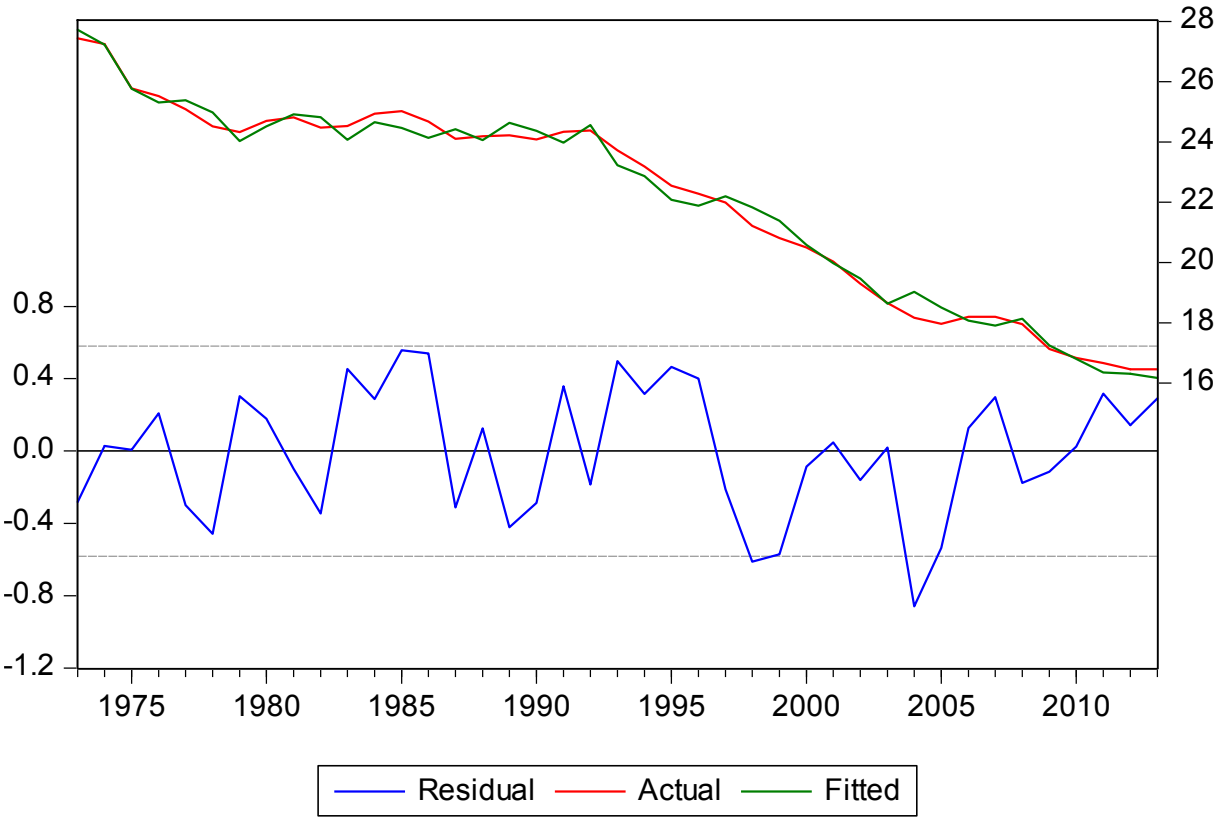
Table 4: Test for cointegration (for fully specified DOLS model)

Cointegration Test – Engle-Granger
Equation: EQ01
Specification: EMPMAN TFP CAP EXPCHIN EXPMAN OFDI EXR C
Cointegrating equation deterministics: C
Null hypothesis: Series are not cointegrated
Dependent Variable: D(RESID)
Method: Least Squares
Sample (adjusted): 1972-2014
Included observations: 43 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID(-1)	-0.282619	0.107162	-2.637302	0.0117
R-squared	0.141977	Mean dependent var		0.005944
Adjusted R-squared	0.141977	S.D. dependent var		0.559905
S.E. of regression	0.518638	Akaike info criterion		1.547760
Sum squared resid	11.29738	Schwarz criterion		1.588718
Log likelihood	-32.27683	Hannan-Quinn criter.		1.562864
Durbin-Watson stat	1.855124			

Source: Compiled by authors.

Figure 5: Residuals, actual and fitted values (DOLS model excluding Chinese exports)



Source: Compiled by authors.

Table 5: Test for cointegration (for DOLS model without Chinese exports)

Cointegration Test – Engle-Granger

Equation: EQ01
Specification: EMPMAN TFP CAP EXPMAN OFDI EXR C

Cointegrating equation deterministics: C
Null hypothesis: Series are not cointegrated
Engle-Granger Test Equation:
Dependent Variable: D(RESID)
Method: Least Squares
Sample (adjusted): 1972-2014
Included observations: 43 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID(-1)	-0.367846	0.119751	-3.071757	0.0037
R-squared	0.183441	Mean dependent var		-0.001782
Adjusted R-squared	0.183441	S.D. dependent var		0.677695
S.E. of regression	0.612390	Akaike info criterion		1.880087
Sum squared resid	15.75091	Schwarz criterion		1.921045
Log likelihood	-39.42186	Hannan-Quinn criter.		1.895191
Durbin-Watson stat	1.861195			

Source: Compiled by authors.

It turns out that the residuals in Figures 4 and 5 are well-behaved, i.e., stationary, and that the Engle-Granger tests do in fact reject the null hypothesis of no cointegration. Seen on the whole, thus, we feel legitimised to argue that the yen real effective exchange rate has had a long-run negative impact on the share of manufacturing in total number of employed persons in Japan since the 1970s.

We now turn to the second option mentioned above, that is to conduct ARDL estimations based on the first differences of the non-stationary variables.

3.1.4 Autoregressive Distributed Lag (ARDL) estimations: in search of the dynamics underlying "hollowing out"

In this section, we employ ARDL estimations in order to estimate the intertemporal dynamics of the equation explaining the change in manufacturing employment (D(EMPMAN)). ARDLs are standard least squares regressions that include lags of both the dependent variable and explanatory variables as regressors (Greene, 2008). Their application requires the data to be stationary. This leads us to employ (only) the first differences of the variables of our empirical model. This comes at the cost that we are not able to exploit level information (as it is the case in our cointegration exercise). The ARDL model selection process employed by us uses the same sample for each estimation and selects the final model by maximising the empirical realisation of information criteria (in our case, of the Akaike criterion). The empirical results of the ARDL exercise are displayed in Table 6.

Table 6: ARDL estimation of fully specified model

Dependent Variable: D(EMPMAN)
Method: ARDL
Sample (adjusted): 1973-2014
Included observations: 42 after adjustments
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): D(TFP) D(CAP) D(EXPMAN) D(EXPCHIN) D(OFDI) D(EXR)
Fixed regressors: C
Number of models evaluated: 1458
Selected Model: ARDL(1, 2, 0, 1, 1, 0, 0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
D(EMPMAN(-1))	0.391195	0.141019	2.774061	0.0094
D(TFP)	-3.808531	4.248908	-0.896355	0.3772
D(TFP(-1))	2.768530	3.802030	0.728171	0.4722
D(TFP(-2))	-6.491839	3.288327	-1.974207	0.0576
D(CAP)	0.109411	0.071213	1.536395	0.1349
D(EXPMAN)	4.35E-10	1.70E-10	2.564722	0.0156
D(EXPMAN(-1))	-2.45E-10	1.18E-10	-2.081662	0.0460
D(EXPCHIN)	-1.47E-10	1.01E-10	-1.456282	0.1557
D(EXPCHIN(-1))	1.50E-10	8.89E-11	1.683592	0.1026
D(OFDI)	2.83E-07	5.12E-06	0.055276	0.9563
D(EXR)	**-0.016393**	**0.006865**	**-2.387858**	**0.0234**
C	-0.175573	0.068215	-2.573808	0.0152

R-squared	0.486519	Mean dependent var	-0.266650
Adjusted R-squared	0.298243	S.D. dependent var	0.362367
S.E. of regression	0.303559	Akaike info criterion	0.688472
Sum squared resid	2.764433	Schwarz criterion	1.184949
Log likelihood	-2.457906	Hannan-Quinn criter.	0.870450
F-statistic	2.584071	Durbin-Watson stat	1.718422
Prob(F-statistic)	0.019257		

Source: Compiled by authors.

The expression ARDL(1, 2, 0, 1, 1, 0, 0) in Table 6 indicates the model selected by our search algorithm according to the Akaike information criterion. The first entry in brackets denotes the lags of the endogenous lagged variable. The second entry corresponds with the lag number of the change of total factor productivity, the third entry indicates the lag number of the change in gross domestic fixed capital formation (CAP). The fourth one stands for the lag number of the change in manufacturing exports (EXPMAN). The fifth entry denotes the lag number of the change in Chinese exports (EXPCHIN). The sixth entry is related to the lag number of the outward direct investment variable (OFDI). And the seventh entry refers to the lag number of lags of the yen exchange rate (EXR). The result column containing the yen exchange rate effect denotes the significant estimated coefficient for the exchange rate (-0.016393) and its significance level (0.02) in the selected ARDL model. Values in brackets in Table 6 denote the respective significance level (probabilities). Once again, we find a positive and significant effect of the yen exchange rate on the share of manufacturing employment.

Summing up, our annual data analysis based on DOLS and ARDL estimations provides robust results which indicate that increases in the real effective yen exchange rate, i.e., appreciations, did have significant negative effects on the share of manufacturing in total employment in Japan. This is despite the fact that the yen also experiences longer periods of real effective depreciation and is thus indicative of hysteresis effects (Krugman and Baldwin, 1987, Belke et al., 2013). Our DOLS estimations also find a negative and significant effect of outward FDI.

3.2 Analysis with monthly data, 1991-2017

Having investigated the long-term impact of real effective exchange movements on aggregate manufacturing employment with annual data spanning almost five decades, we now turn to an analysis using higher frequency and, importantly, sector specific data. If exchange rate changes are to have a long-term impact on manufacturing, there ought to be some short-term impacts too. Using sector-specific data at higher frequency allows us to uncover such potential effects. Ideally, we would be using sector-specific employment to mirror the annual data analysis. However, since we were not able to obtain matching monthly sector-specific employment data, we chose to use sector-specific industrial production data as dependent variable as a second-best option, given that industrial production and industrial employment are highly correlated.

3.2.1 Data and empirical model

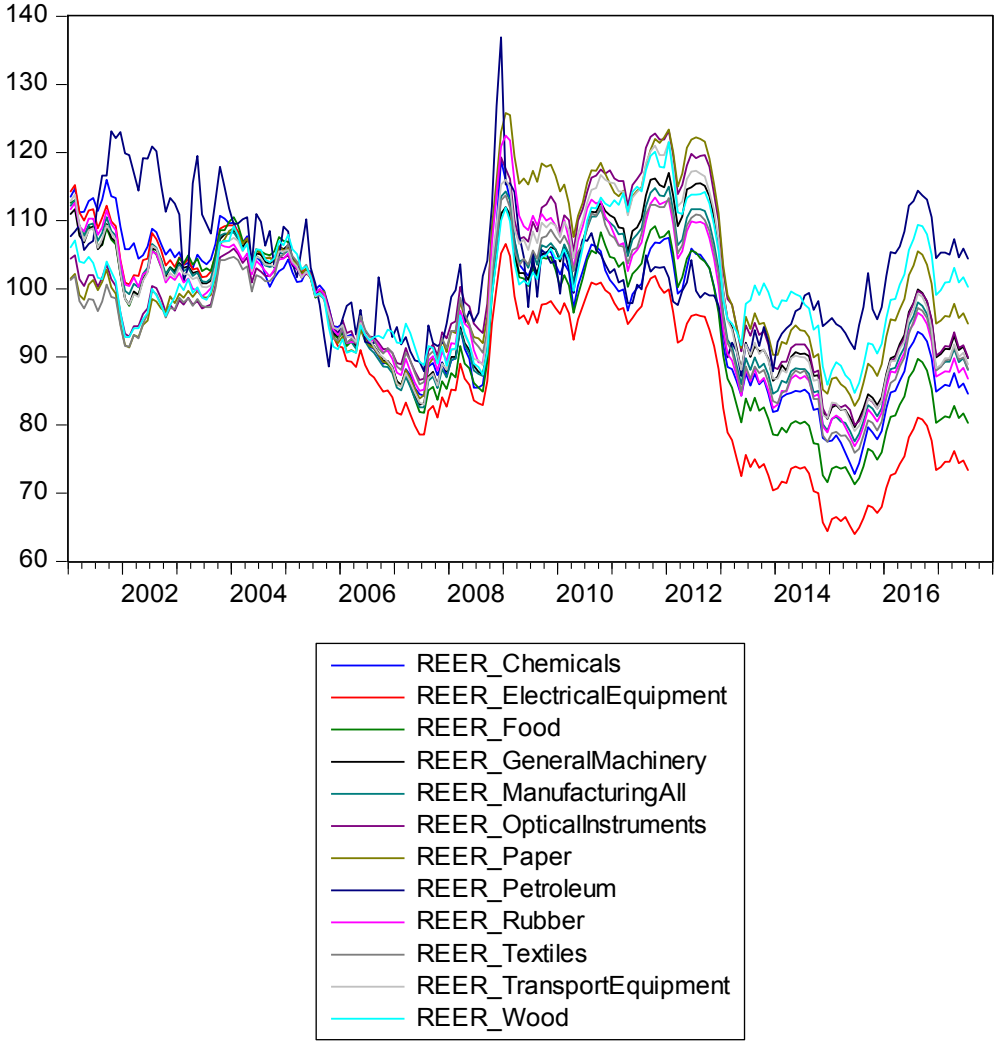
In order to exploit our new dataset on sector-specific yen exchange rates (Figure 6), which are calculated by using industry-specific producer price indices (RIETI, 2018), we now estimate the real yen effective exchange rate effects on Japanese industrial production, using monthly data from 1991 to 2017:

$$(2) \quad INP_X = \beta_0 + \beta_1 INP_X_{t-1} + \beta_2 EX_X + \beta_3 REER_X + \beta_4 INDINPUTPRICE + \beta_5 TFP + \beta_6 INPUSA + \varepsilon,$$

where *INP_X* = Industrial production by industry *X*, *EX_X* = Exports by industry *X*, *REER_X* = Industry-specific real effective exchange rate of industry *X* for 11 different industrial sectors and manufacturing as a whole, *INDINPUTPRICE* = Industrial input price, and *INPUSA* = Industrial production United States.[9] Appendix 2 provides further details on the variables and sources used.

[9] The time series of industrial production have been seasonally adjusted, using the Census X-13 procedure.

Figure 6: Real effective exchange rates for different industrial sectors

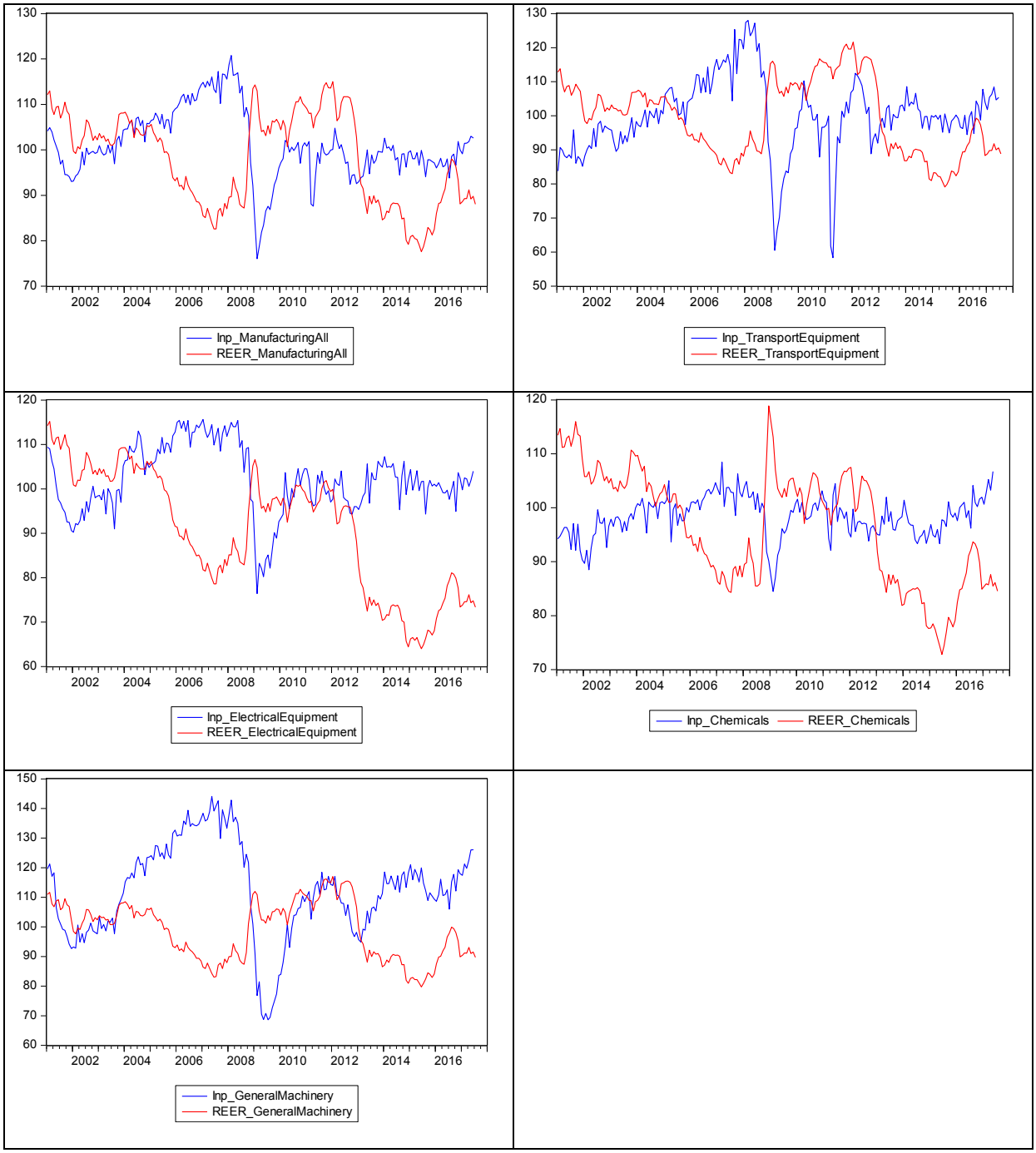


Source: Compiled by authors with data from RIETI (2018).
Note: "ManufacturingAll" refers to the average REER of the various industrial sectors.

Our data set covers the following 11 industrial sectors: chemicals (CHEMICALS), electrical equipment (ELECTRICALEQUIPMENT), food (FOOD), general machinery (GENERALMACHINERY), optical instruments (OPTICALINSTRUMENTS), paper (PAPER), petroleum related products (PETROLEUM), rubber related products (RUBBER), textiles (TEXTILES), transport equipment (TRANSPORTEQUIPMENT), wood related products (WOOD) and manufacturing as a whole (MANUFACTURINGALL). Details of these sectors are provided in Appendix 3.

While all other variables are industry-specific, INDINPUTPRICE and INPUSA are non-industry-specific variables. In this sense, we follow a mixed panel-time series modelling approach after having estimated sector-specific ARDL models. Figure 7 shows industrial production (INP) and industry-specific real effective exchange rates (REER) for selected industries. The two series tend to move in opposite direction, indicating that real effective exchange rates may indeed have a negative impact on industrial production.

Figure 7: Industrial production and industry-specific real effective exchange rates for selected industries



Source: Compiled by authors with data from RIETI (2018) and METI (2017).

3.2.2 Unit root tests

We now proceed with unit root tests of the variables listed below eq. (2) to be employed in our ARDL estimations and in our empirical mixed time series-panel models of Japanese industrial production which both necessitate the variables to be stationary.

The wide array of unit root tests we conducted, including the ordinary Augmented-Dickey-Fuller test, the Dickey-Fuller GLS (ERS) test, the Phillips-Perron test, the Kwiatowski-Phillips-Schmidt-Shin test and the Ng-Perron unit root test, suggest an I(1) process for each of the variables. Hence, we proceed with

the individual variables considering them as I(1) variables which have to be differenced once in order to become stationary. The results are available on request.

We first conduct sector-specific Autoregressive Distributed Lag (ARDL) estimations based on first differences of the (non-pooled) variables.

3.2.3 Sector-specific autoregressive distributed lag-estimations for Japanese industrial production

The pattern of the results of our ARDL estimations of eq. (2) based on first differences of the (non-pooled) sector-specific and two further non-sector specific variables is displayed in Table 7. We rely on the same mechanics of ARDL model selection which have already been explained in Section 3.1.4. This time, entries in the "selected model" column indicate the model selected according the Akaike information criterion. The first entry in brackets denotes the lags of the *endogenous lagged variable*, the second entry corresponds with the lag number of the change of the *sector-specific exchange rate*, the third entry indicates the lag number of the change in *US industrial production* and the fourth stands for the lag number of the change in Japanese *industrial input prices*. Deviating from the specification of eq. (2) we leave out sector-specific exports for reasons explained above. Column 2 in Table 7 containing the yen exchange rate effect denotes the significant estimated coefficients for the *yen exchange rate* in the selected ARDL model. The *total* exchange rate effect (next column) is indicated in the third column of Table 7 by the *sum* of the period-specific significant entries. Values in brackets denote the respective significance level (probabilities). To illustrate, Table 8 contains a detailed ARDL estimation example for manufacturing sector as a whole. Its results are summarised in the first row of Table 7. Here, the impact coefficient of the exchange rate on the industrial production in the Japanese manufacturing sector is -0.61 with a high significance of below 0.01.

Table 7: Impact of the real effective yen exchange rate on Japanese industrial production – A survey of estimated sector-specific ARDL models (excluding exports)

Japanese industry sector	Selected ARDL model	Yen exchange rate effects	Yen exchange rate effect (total)
Manufacturing all	ARDL(4, 3, 2, 0)	Lag 3: -0.61 (0.0032)	-0.61
Chemicals	ARDL(2, 3, 1, 0)	Lag 3: -0.41 (0.0036)	-0.41
Electrical equipment	ARDL(3, 3, 1, 2)	Lag 3: -1.04 (0.0101)	-1.04
Transport equipment	ARDL(3, 3, 2, 0)	Lag 3: -0.83 (0.0148)	-0.83
Rubber	ARDL(3, 3, 1, 0)	Lag 1: 0.44 (0.0981) Lag 3: -0.95 (0.0004)	-0.51
Optical instruments	ARDL(2, 3, 0, 0)	Lag 0: 0.90 (0.0294) Lag 3: 1.43 (0.0004)	-0.53
Paper	ARDL(4, 3, 1, 0)	Lag 3: -0.38 (0.0008)	-0.38
Food	ARDL(3, 0, 0, 0)	—	—
Textiles	ARDL(4, 3, 4, 0)	1: 0.27 (0.0785) 3: -0.25 (0.0830)	0.01

Source: Compiled by authors.

Table 8: Impact of the real effective yen exchange rate on Japanese manufacturing industrial production – an estimated ARDL model

Dependent Variable: D(INP_MANUFACTURINGALL)
Method: ARDL
Sample (adjusted): 2001M06-2017M06
Included observations: 193 after adjustments
Maximum dependent lags: 4 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (4 lags, automatic): D(REER_MANUFACTURINGALL) D(INPUSA) D(INDINPUTPRICE)
Fixed regressors: C
Number of models evaluated: 500
Selected Model: ARDL(4, 3, 2, 0)

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
D(INP_MANUFACTURINGALL(-1))	-0.697699	0.072846	-9.577785	0.0000
D(INP_MANUFACTURINGALL(-2))	-0.867266	0.086039	-10.07993	0.0000
D(INP_MANUFACTURINGALL(-3))	-0.283453	0.087358	-3.244752	0.0014
D(INP_MANUFACTURINGALL(-4))	-0.165924	0.071672	-2.315035	0.0217
D(REER_MANUFACTURINGALL)	0.189543	0.219093	0.865127	0.3881
D(REER_MANUFACTURINGALL(-1))	0.213997	0.216040	0.990543	0.3232
D(REER_MANUFACTURINGALL(-2))	0.040311	0.213098	0.189164	0.8502
D(REER_MANUFACTURINGALL(-3))	**-0.614792**	**0.205586**	**-2.990434**	**0.0032**
D(INPUSA)	0.892882	0.661064	1.350675	0.1785
D(INPUSA(-1))	2.602084	0.653861	3.979568	0.0001
D(INPUSA(-2))	0.966521	0.681389	1.418456	0.1578
D(INDINPUTPRICE)	-0.013329	0.085517	-0.155863	0.8763
C	-0.227603	0.422910	-0.538183	0.5911

R-squared	0.549736	Mean dependent var	0.050777
Adjusted R-squared	0.519718	S.D. dependent var	8.436238
S.E. of regression	5.846512	Akaike info criterion	6.434549
Sum squared resid	6152.707	Schwarz criterion	6.654316
Log likelihood	-607.9340	Hannan-Quinn criter.	6.523548
F-statistic	18.31378	Durbin-Watson stat	2.104685
Prob(F-statistic)	0.000000		

Source: Compiled by authors.

The ordinary Pearson correlations conducted for the example of the Japanese manufacturing sector displayed in Table 9 demonstrate that *exports* of the Japanese manufacturing sector *dominate* any impact on the industrial *production of the same sector.* Our additional robustness checks show that we can *generalise* this statement for all sectors considered here: branch-specific exports dominate any impact on the respective sector's industrial production.

Table 9: Ordinary Pearson correlations –the Japanese manufacturing sector

	D(INP_MANUFACTURINGALL)	D(EX_MANUFACTURINGALL)	D(REER_MANUFACTURINGALL)	D(INDINPUTPRICE)	D(INPUSA)
D(INP_MANUFACTURINGALL)	1.000000	0.826584	-0.008935	-0.058282	-0.011778
D(EX_MANUFACTURINGALL)	0.826584	1.000000	-0.103245	0.023029	0.092910
D(REER_MANUFACTURINGALL)	-0.008935	-0.103245	1.000000	-0.308087	-0.120676
D(INDINPUTPRICE)	-0.058282	0.023029	-0.308087	1.000000	0.241691
D(INPUSA)	-0.011778	0.092910	-0.120676	0.241691	1.000000

Source: Compiled by authors.

As a robustness check, we estimated sector-specific ARDL models, this time including Japanese exports. The results are surveyed in Table 10. The pattern of the results does change in the sense that only for chemicals, electrical equipment, rubber, paper and food there is still a significant impact of the sector-specific yen exchange rate with the "correct" sign.

Table 10: Impact of the real effective yen exchange rate on Japanese industrial production – a survey of estimated sector-specific ARDL models (including exports)

Japanese industry sector	Selected ARDL model	Yen exchange rate effects	Yen exchange rate effect (total)
Manufacturing all	ARDL(4, 3, 4, 1, 0)	Lag 0: 0.49 (0.0001) Lag 1: 0.30 (0.0198) Lag 2: 0.26 (0.0377) Lag 4: -0.27 (0.0183)	0.78
Chemicals	ARDL(2, 0, 3, 0, 1)	Lag 3: -0.40 (0.0020)	-0.40
Electrical equipment	ARDL(3, 4, 4, 2, 4)	Lag 3: -0.74 (0.0180) Lag 4: -0.57 (0.0604)	-1.31
Transport equipment	ARDL(3, 2, 0, 0, 1)	Lag 0: 0.67 (0.0004)	0.67
Rubber	ARDL(4, 1, 3, 0, 1)	Lag 1: 0.53 (0.0268) Lag 3: -0.84 (0.0004)	-0.31
Optical instruments	ARDL(4, 6, 3, 0, 2)	Lag 0: 1.30 (0.0008) Lag 1: 0.80 (0.0382) Lag 3: -0.83 (0.0276)	1.27
Paper	ARDL(4, 4, 3, 3, 2)	Lag 3: -0.26 (0.0101)	-0.26
Food	ARDL(3, 4, 3, 0, 0)	Lag 3: -0.67	-0.67
Textiles	ARDL(4, 4, 0, 3, 3)	—	—

Source: Compiled by authors.

3.2.4 Panel estimations

As a first step, we test for unit roots in the pooled sector-specific time series. In order to make sure that we employ stationary variables in our panel estimations we conducted the following panel unit root tests for the pools of sector-specific variables: Levin, Lin and Chu (2002), Breitung (2000), Im,

Pesaran and Shin (2003), Fisher-type tests using ADF and PP tests (Maddala and Wu 1999; Choi 2001), and Hadri (2000). All variables turned out to be I(1). The results are available on request.

As a second step, we conduct *Pooled Least Squares* estimations of a *mixed time series-cross section* model based on stationary time series with White cross-section standard errors (to allow for general contemporaneous correlation between the branch-specific residuals) and White covariance (White, 1980, MacKinnon and White, 1985). Non-zero covariances are allowed across cross-sections (degree-of-freedom corrected). The estimator we employ in this study is thus robust to cross-equation (contemporaneous) correlation between the branch-specific residuals and heteroskedasticity. The estimation results for our final model are displayed in Table 11.

Table 11: Sectoral industrial production in Japan – determinants according to a Pooled Least Squares panel model

Dependent Variable: D(INP?)				
Method: Pooled Least Squares				
Sample (adjusted): 2001M05-2017M05				
Included observations: 193 after adjustments				
Cross-sections included: 6				
Total pool (balanced) observations: 1158				
White cross-section standard errors & covariance (d.f. corrected)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-0.358571	0.337580	-1.062181	0.2884
D(INP?(-1))	-0.219148	0.047894	-4.575686	0.0000
D(EX?)	1.15E-08	1.30E-09	8.860615	0.0000
Sector-specific exchange rate coefficients:				
_CHEMICALS--D(REER_CHEMICALS(-3))	-0.360894	0.123608	-2.919660	0.0036
_OPTICALINSTRUMENTS--D(REER_OPTICALINSTRUMENTS(-3))	-1.337488	0.315744	-4.235989	0.0000
_PAPER--D(REER_PAPER(-3))	-0.297193	0.138053	-2.152741	0.0315
_RUBBER--D(REER_RUBBER(-3))	-0.883009	0.247108	-3.573367	0.0004
_WOOD--D(REER_WOOD(-3))	-0.480935	0.178896	-2.688341	0.0073
_TEXTILES--D(REER_TEXTILES(-3))	-0.356062	0.127916	-2.783562	0.0055
Fixed Effects (Cross)	Not listed			
Effects Specification:				
Cross-section fixed (dummy variables)				
R-squared	0.214667	Mean dependent var		-0.221503
Adjusted R-squared	0.205743	S.D. dependent var		7.903358
S.E. of regression	7.043560	Akaike info criterion		6.754121
Sum squared resid	56755.83	Schwarz criterion		6.815228
Log likelihood	-3896.636	Hannan-Quinn criter.		6.777180
F-statistic	24.05440	Durbin-Watson stat		2.173264
Prob(F-statistic)	0.000000			

Source: Compiled by authors.

As a third step, we conduct *Pooled Estimated Generalised Least Squares* (EGLS, cross-section weights), once again with White cross-section standard errors and White covariance. The results are summarised in Table 12. The results of our fixed effects redundancy test (at the beginning of Table 12) support our specific choice of fixed effects empirically.

Table 12: Sectoral industrial production in Japan – determinants according to a Pooled EGLS panel model (with cross-section weights)

Redundant Fixed Effects Tests			
Test cross-section fixed effects			
Effects Test	Statistic	d.f.	Prob.
Cross-section F	0.567082	(6,1335)	0.7568
Dependent Variable: D(INP?)			
Method: Pooled EGLS (Cross-section weights)			
Sample (adjusted): 2001M05-2017M05			
Included observations: 193 after adjustments			
Cross-sections included: 7			
Total pool (balanced) observations: 1351			
Linear estimation after one-step weighting matrix			
White cross-section standard errors & covariance (d.f. corrected)			

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.343342	0.261892	-1.311005	0.1901
D(INP?(-1))	-0.295981	0.035982	-8.225786	0.0000
D(EX?)	9.47E-09	6.45E-10	14.67241	0.0000
Sector-specific exchange rate coefficients:				
_CHEMICALS--D(REER_CHEMICALS(-3))	-0.373475	0.116986	-3.192474	0.0014
_ELECTRICALEQUIPMENT--D(REER_ELECTRICALEQUIPMENT(-3))	-0.526605	0.390197	-1.349589	0.1774
_OPTICALINSTRUMENTS--D(REER_OPTICALINSTRUMENTS(-3))	-1.424987	0.324191	-4.395513	0.0000
_PAPER--D(REER_PAPER(-3))	-0.295707	0.137656	-2.148153	0.0319
_RUBBER--D(REER_RUBBER(-3))	-0.956390	0.250240	-3.821885	0.0001
_TEXTILES--D(REER_TEXTILES(-3))	-0.374923	0.134393	-2.789746	0.0053
_WOOD--D(REER_WOOD(-3))	-0.493905	0.180759	-2.732399	0.0064
Fixed Effects (Cross)	Not listed			

Effects Specification			
Cross-section fixed (dummy variables)			
Weighted Statistics			
R-squared	0.278419	Mean dependent var	-0.271561
Adjusted R-squared	0.270312	S.D. dependent var	9.014895
S.E. of regression	7.699971	Sum squared resid	79151.55
F-statistic	34.34033	Durbin-Watson stat	2.186795
Prob(F-statistic)	0.000000		
Unweighted Statistics			
R-squared	0.345881	Mean dependent var	-0.196151
Sum squared resid	79450.20	Durbin-Watson stat	2.222602

Source: Compiled by authors.

And as a fourth and final step, we present estimation results based on Pooled Estimated Generalised Least Squares (EGLS) regressions conducted by the cross-section *Seemingly Unrelated Regression* (SUR)

method (Table 13).[10] Also in this case, we rely on White cross-section standard errors and White covariance. Again, the tabulated results of the fixed effects redundancy test (in the upper part of Table 13) empirically corroborate our specific choice of fixed effects. In all three estimation variants applied here we allow not only for *fixed effects in the constant* but *also for cross-section specific slope coefficients*. The selection of the final model was conducted according to the same criteria applied throughout the paper and described in detail beforehand.

Table 13: Sectoral industrial production in Japan – Determinants according to a Pooled EGLS panel model (cross-section SUR)

Redundant Fixed Effects Tests				
Test cross-section fixed effects				
Effects Test		Statistic	d.f.	Prob.
Cross-section F		1.404752	(8,1717)	0.1895
Dependent Variable: D(INP?)				
Method: Pooled EGLS (Cross-section SUR)				
Sample (adjusted): 2001M05 2017M05				
Included observations: 193 after adjustments				
Cross-sections included: 9				
Total pool (balanced) observations: 1737				
Linear estimation after one-step weighting matrix				
White cross-section standard errors & covariance (d.f. corrected)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.284434	0.201984	-1.408203	0.1593
D(INP?(-1))	-0.314740	0.021822	-14.42294	0.0000
D(EX?)	5.42E-09	1.92E-10	28.27803	0.0000
Sector-specific exchange rate coefficients:				
_CHEMICALS--D(REER_CHEMICALS(-3))	-0.299775	0.092382	-3.244931	0.0012
_ELECTRICALEQUIPMENT--				
D(REER_ELECTRICALEQUIPMENT(-3))	-0.493090	0.355530	-1.386914	0.1656
_GENERALMACHINERY--				
D(REER_GENERALMACHINERY(-3))	-0.340410	0.309889	-1.098489	0.2721
_OPTICALINSTRUMENTS--				
D(REER_OPTICALINSTRUMENTS(-3))	-1.304587	0.313259	-4.164558	0.0000
_PAPER--D(REER_PAPER(-3))	-0.209617	0.133158	-1.574201	0.1156
_RUBBER--D(REER_RUBBER(-3))	-0.754217	0.210364	-3.585299	0.0003
_TEXTILES--D(REER_TEXTILES(-3))	-0.281019	0.119584	-2.349969	0.0189
_TRANSPORTEQUIPMENT--				
D(REER_TRANSPORTEQUIPMENT(-3))	-0.387704	0.183868	-2.108603	0.0351
_WOOD--D(REER_WOOD(-3))	-0.376419	0.147706	-2.548435	0.0109
Fixed Effects (Cross)	Not listed			
	Effects Specification			
Cross-section fixed (dummy variables)				
	Weighted Statistics			
R-squared	0.361957	Mean dependent var		-0.029174
Adjusted R-squared	0.354897	S.D. dependent var		1.216267
S.E. of regression	0.976993	Sum squared resid		1638.903
F-statistic	51.26540	Durbin-Watson stat		2.169783
Prob(F-statistic)	0.000000			
	Unweighted Statistics			
R-squared	0.437827	Mean dependent var		-0.142372
Sum squared resid	114827.5	Durbin-Watson stat		2.336021

Source: Compiled by authors.

[10] Cross-section SUR allows for contemporaneous correlation between cross-sections (clustering by period). It is sometimes referred to as the Parks estimator.

Overall, the estimation results displayed in Tables 11 to 13 again appear well-behaved with an eye on our main hypothesis. Significant negative sector-specific impacts of the yen effective real exchange rate can be established for at least six and a maximum of all nine sectors, the exact number of sectors depending on the chosen estimation procedure. This corroborates the empirical findings of Sato et al. (2013) and Thorbecke (2012) for Japanese exports.

According to our Pooled Least Squares estimations (Table 11) significantly negative effects of the (sector-specific) yen exchange rate on Japanese industrial production emerge for the chemicals, the optical instruments, the paper, the rubber, the wood and the textiles sectors.

Our estimations based on Pooled EGLS (cross-section weights, Table 12) reveal that the (sector-specific) yen exchange rate negatively impacts sectoral industrial production in the chemicals, the optical instruments, the paper, the rubber, the textiles and the wood sectors.

The expected negative sectoral exchange rate effect emerges from our Pooled EGLS (Cross-section SUR) estimates for the chemicals, the optical instruments, the rubber, the textiles, the transport equipment and the wood sectors (Table 13). We would like to stress that the evidence of negative yen exchange rate impacts on Japanese sectoral industrial production is thus confirmed by the most sophisticated estimation method applied by us in this paper: the feasible GLS specification correcting for both cross-section heteroskedasticity and contemporaneous correlation (cross-section SUR).

Thus, for five industrial sectors (chemicals, optical instruments, rubber, wood and textiles) all three models find negative and significant coefficient estimates for the yen exchange rate, while such effects are found for a further sector (paper) in two out of the three estimated estimation methods (Pooled Least Squares and Pooled EGLS/Cross-section SUR). Furthermore, Pooled EGLS finds significant negative effect also for the transport equipment sector. In all cases, the sectoral yen exchange rate enters the final model consistently with a *lag of three months* (time-to-build effect). What is more, the selected empirical models are rather *parsimonious* in terms of the number of variables included. The (changes in the) Japanese industrial input price (INDINPUTPRICE) and US industrial production (INPUSA) are not part of the finally selected model. However, the lagged endogenous variable (change in Japanese industrial production) turns out to be highly significant throughout. Hence, in accordance with, for instance, Belke and Gros (2001), we feel legitimised to argue that our final empirical models can be interpreted as (at least partly) *reduced forms* against which we are able to separate the additional marginal impacts of the yen exchange rate and Japanese exports on industrial production.[11] Finally, critics may argue that the empirical realisations of the R-squared are not overly high. However, this type of evidence is quite typical of regressions of changes on changes. Moreover, the R-squared in our estimations appears to be located in the upper possible range.

Summing up, in our monthly data analysis with sector-specific data, both ARDL estimations and estimations of a mixed time series-cross section model suggest small but highly significant effects of the real yen effective exchange rate (REER) on industrial production for a broad range of industrial sectors.[12]

[11] This interpretation is valid for all finally selected model specifications in this paper which do not include the full set of variables proposed by theory, i.e., by our equations (1) and (2).

[12] In Section 3.2 we spared cointegration analysis because the time span 2000 to 2017 is much shorter than the one available in Section 3.1., i.e. 1970 to 2016. Note that using quarterly data (Section 3.2) instead of annual

5. Conclusions

In this paper we have investigated the role of the yen exchange rate in the de-industrialisation that has taken place in Japan over recent decades. There are certainly multiple factors that have played a role in this process, and we do not seek to evoke the impression that the exchange rate has been the single most important factor. Yet our results suggest that a strong yen had more than just transitory effects on Japanese manufacturing employment and output.

In our annual data analysis, the DOLS and ARDL estimations provide robust results which indicate that appreciations of the real effective yen exchange rate did have significant negative effects on the share of manufacturing in total employment in Japan. This is despite the fact that the yen also experienced longer periods of real effective depreciation, which is indicative of hysteresis effects on manufacturing. Our findings are consistent with recent research on the hollowing out of the U.S. economy, where findings by Campbell (2017) also point at the presence of hysteresis effects. But we should also highlight that the magnitude of the exchange rate effects in our annual data analysis are much smaller than of those variables that have the biggest effect on manufacturing employment, namely TFP and fixed capital formation.

We also find significant negative effects of the real effective yen exchange rate on industrial output when using monthly and industry-specific data. Our ARDL estimations find significant negative effects for chemicals, electrical equipment, transport equipment, rubber, optical instruments and paper. Our panel analysis with sector-specific monthly data suggests that movements of the sector-specific real effective yen exchange rate had significant impact on up to seven industrial sectors (chemicals, optical instruments, rubber, wood, textiles, paper and transport equipment). Still, we should also mention that our ARDL and panel estimations did not uncover significant exchange rate effects for several industrial sectors, including general machinery, one of the most important industrial sectors for Japan.

From a policy perspective, our findings suggest that central banks should try to avoid rapid, large-scale appreciations of the type Japan has seen a number of times over recent decades as negative effects on the manufacturing sector cannot be easily reversed at a later stage. This would suggest that an exchange rate policy that seeks to moderate exchange movements – often referred to as "leaning against the wind" – may be more adequate than entirely freely floating rates, even for large, advanced economies. In fact, Japan followed such an exchange rate policy at times (e.g., Quirk, 1977; Takagi, 1991). However, given Japan has persistently recoded a large bilateral trade surplus vis-à-vis the US, it was repeatedly under heavy pressure from the US administration to let the yen appreciate against the US dollar – most notably in the run-up to the Plaza agreement. Foreign exchange interventions therefore became politicised and difficult to follow through. It is interesting to note that China for long resisted pressure from the US to let the renminbi appreciate – which arguably contributed to the malaise of Japan's manufacturing sector. Since ending its dollar peg, China has been cautious to allow only gradual appreciation of its currency.

Given the importance of the manufacturing sector for growth, development and employment, policy makers ought to consider potential adverse effects of rapid, large-scale exchange rate appreciations. As pointed out by Frankel (1999), no single exchange rate regime is right for all countries or at all times. There can be therefore no general recommendations regarding the most appropriate exchange rate

ones (Section 3.1) does not help, because integration and cointegration are sample (period) properties which are not necessarily dependent on the number of observations.

regime. But our findings suggest that the exchange rate is too important to be ignored by policy makers.

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Appendix

Appendix 1: Variables and sources for analysis with annual data, 1970-2016

Variable	Source
EMPMAN = Share of manufacturing in total number of employed persons (%)	Japan Labor Force Survey, Statistics Bureau
CAP = Gross domestic fixed capital formation (% of GDP)	World Bank World Development Indicators
EXPMAN = Manufacturing exports	World Bank World Development Indicators
OFDI = Outward direct investment	Japanese Trade and Investment Statistics, JETRO
TFP = Total factor productivity at constant national prices	Penn World Table 9.0
EXPCHIN = Chinese exports	World Bank World Development Indicators
EXR = Real effective exchange rate	Bank of Japan

Appendix 2: Variables and sources for analysis with monthly data, 1991-2017

Variable	Source
INP_X = Industrial production by industry X	METI Survey of Production
EX_X = Exports by industry X	Global Trade Atlas
REER_X = Industry-specific real effective exchange rate of industry X for 11 different industrial sectors and manufacturing as a whole	Sato et al. (2013); RIETI (2017)
INDINPUTPRICE = Industrial input price	IMF Primary Commodity Prices
INPUSA = Industrial production United States	World Bank Global Economic Monitor

Appendix 3: Industry classifications

ISIC.R3	Industry name	Description
15-16	Food	Food, beverage and tobacco
17-19	Textile	Textiles, textile products, leather and footwear
20	Wood	Wood products (excl. furniture)
21-22	Paper	Paper, paper products, printing, and publishing
23	Petroleum	Coke, refined petroleum products, and nuclear fuel
24	Chemicals	Chemicals and chemical products
25	Rubber	Rubber and plastics products
29	General machinery	Machinery and equipment
30-32	Electrical equipment	Electrical machinery and apparatus
33	Optical instruments	Optical and precision instruments
34-35	Transport equipment	Transport equipment

Source: Sato et al. (2015).