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by

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Martin Stuermer*

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Abstract

What drives the long-term demand for mineral commodities? This paper provides empirical evidence on the long-run demand for mineral commodities since 1840. I extend the partial adjustment model to account for country-specific structures and technological change. I find that a one percent increase in manufacturing output leads to a 1.5 percent increase in the demand for aluminum and a one percent increase in the demand for copper. The estimated manufacturing output elasticities of demand for lead, tin, and zinc are far below one. The estimated price elasticities of demand are highly inelastic for all mineral commodities in the long run. My results suggest that industrialization in China, for example, will cause the consumption of aluminum and copper to increase at a considerably higher rate than the one of lead, tin, and zinc. All variables adjust slowly to equilibrium, which helps to explain the extended fluctuation in these markets.

JEL classification: O13, Q31, N50

Keywords: Industrialization, elasticity of demand, nonstationary heterogenous panel, mineral commodities.

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1 Introduction

For business leaders and politicians facing rapid industrialization in China and elsewhere, understanding the nexus of industrialization - the process of moving production from primary to manufacturing sector (Black et al., 2009) - and the derived demand for mineral commodities is imperative. How does demand respond to changes in manufacturing output? What is the response to a change in price? What is the role of structural and technological change in shaping these relationships?

These questions have important implications both from a theoretical and a policy perspective. Demand shocks are a key driver of mineral commodity prices (Kilian, 2009; Stuermer, 2013a), which have pronounced macroeconomic implications for both developing and developed countries (see Bernanke, 2006; IMF, 2012b). The response of demand to a change in manufacturing output determines the contribution of demand shocks to the fluctuations of prices (Slade, 1991). The price inelasticity of demand is a key parameter in models of commodity price speculation, as a low price elasticity enables speculation on these markets (see Hamilton, 2009a; Kilian and Murphy, 2012). Finally, Acemoglu et al. (2012) claim in their theoretical analyses of resource wars that the price elasticity of demand is critical in shaping war incentives.

There is a rich body of empirical studies on the long-run and short-run elasticities of demand of mineral commodities with respect to economic activity and price (see Hamilton, 2009b; Pei and Tilton, 1999; Kilian and Murphy, 2012, for surveys of the current literature). This literature mainly focuses on energy and only provides empirical evidence for relatively short periods. For the most part, the literature does not capture the effects of long-term structural changes.

Examining the long-run manufacturing output elasticity of demand reveals how the intensity of use of a mineral commodity develops over the course of industrialization. The intensity of use is defined as the use of a certain material per unit of manufacturing output (Malenbaum, 1978; Tilton, 1990). If the estimated long-run manufacturing output elasticity of demand is higher than one, the use of the mineral commodity increases faster than manufacturing output. An estimated long-run manufacturing output elasticity of demand equal to one implies no change in the intensity of use over time. An estimate below one means a decreasing intensity of use over time.

There are four underlying factors that drive the derived demand of the manufacturing sector. First, technological change causes changes in the production cost of mineral commodities. This might drive its relative price up or down and hence promote substitution. For example, the invention of the electrolytic method lowered the price of aluminum and it substituted tinplate in the production of beverage cans (Chandler, 1990). Second, technological change leads to a more efficient use of mineral commodities, e.g., the invention of new aluminum alloys has made aluminum beverage cans far thinner than they used to be (Pei and Tilton, 1999). These two types of technological change alter "the material composition of goods" (Pei and Tilton, 1999, p. 90).

The next two factors affect the product composition of manufacturing output (Pei and Tilton, 1999, p. 90). Technological change might lead to the invention of new products (Pei and Tilton, 1999), e.g., the invention of airplanes has increased the demand for aluminum. Finally, consumer preferences change over the course of economic development altering the mix of products the manufacturing sector produces. For example, at a low per capita manufacturing output, the construction of infrastructure will lead to a product composition that is relatively steel intensive. At a higher per capita manufacturing output, consumers prefer high tech and consumption goods that are relatively aluminum intensive.

This paper is the first to provide empirical evidence on the long-run elasticities of demand with respect to manufacturing output and prices for several mineral commodities based on a long panel. To cover the main periods of industrialization, I employ a newly constructed data set for twelve major economies, which for some parts spans back to 1840. I focus on the demand for aluminum, copper, lead, tin, and zinc, because they have been used broadly throughout history and have been traded on integrated world markets for much of that time making data readily available.[1]

In contrast to the aforementioned literature, I use manufacturing output and not GDP as the explanatory variable. This has two advantages. First, the demand for mineral commodities is a derived demand. It is only used as an input for the manufacturing sector. Using manufacturing output allows me to control for technological change and changing consumer preferences that cause sectorial shifts in the economy, e.g., the shift to the service sector. Second, if a country produces the mineral commodity domestically, regressing GDP on the quantity used in the economy leads to the problem of reverse causality as mining is also

[1] Aluminum is only widely used since the end of the 19th century.

included in GDP.

My estimation strategy relies on an extension of the partial adjustment model, as it is the standard approach in empirical energy demand analysis. This is done in order to ensure the comparability of results with previous studies. I regress derived demand on manufacturing output, the relative price of the respective mineral commodity, and lagged values of demand. I follow Pesaran et al. (1998, 1999) in accounting for differences in the economic structures across countries by relaxing the assumption of equal short-run coefficients.

I attempt to control for the effects of the three types of technological change and the consumer preferences in a stepwise manner. Technological change that drives substitution is captured by the price of the respective mineral commodity. I introduce a common linear time trend and finally time fixed effects following Pesaran et al. (1998) to account for technological changes that lead to new products and resource efficiency. This allows me to take advantage of the panel structure of the data, as it makes it possible to control for ommitted common technological trends and spillover effects (Pesaran et al., 1998). This leaves those effects that are time indepedent and country specific, and hence reflect changes in consumer preferences, to be captured by per capita manufacturing output. I regard the comparison between the three specifications also as a misspecification test for the importance of ommitted common trends and shocks in technological change (Pesaran et al., 1998).

Several findings emerge. First, the estimated long-run manufacturing output elasticities of demand vary significantly between the five examined mineral commodities. A one percent increase in manufacturing output leads to an approximately 1.5 percent increase in the demand for aluminum. This means that its demand increases at a higher rate than manufacturing output over time. The estimated manufacturing output elasticity of copper demand is close to one, which implies a stable intensity of use over time. The estimates are far below one for lead, tin, and zinc demands. This causes the intensity of use of these mineral commodities to decline over time.

The estimated long-run price elasticities of demand are rather low for the examined mineral commodities. Again, there are pronounced differences across the examined mineral commodities. While it is about -0.7 and -0.8 in the case of aluminum demand, it is about -0.4 for copper demand, and below or equal to about -0.2 for lead, tin, and zinc demands. This shows that, with the exception of aluminum and copper, the aforementioned mineral commodities are rather essential to manufacturing output as the processing industry changes its use slowly in response to price.

My estimation results show that the relationship between per capita manufacturing output, relative prices, and the per capita demand for mineral commodities is driven by technological change and consumer preferences that are country specific. Effects that are common to all countries over time play only a role in decreasing aluminum and lead demand over time. The model for tin seems to be misspecified.

I find strong evidence for the existence of long-run relationships in all regressions. The estimated speed of demand adjustment is rather slow for all commodities, and it takes more than ten years in the cases of lead, tin, and zinc to revert back to equilibrium. This is reasonable, given that adjustments in manufacturing capital are rather slow and that inventories play an important role in these markets. Overall, my empirical results are plausible given narrative evidence on the use of these mineral commodities over time.

The estimated long-run manufacturing output elasticities of demand for all examined mineral commodities except tin are higher or equal to the income elasticity of oil demand (which is 0.55 according to Gately and Huntington (2002) for twenty-five OECD countries over 1971 to 1997). The ones for copper and aluminum are also higher than estimates of the income elasticity of aggregate energy demand (0.8 according to Adeyemi and Hunt (2007) for fifteen OECD countries from 1962 to 2003).

The estimated manufacturing output elasticities of demand suggest that industrialization in China will cause aluminum to increase relative to manufacturing output, while copper will grow in proportion to manufacturing output. The demand for lead, tin, and zinc decreases relative to manufacturing output in the long-term. My results help mining firms define their long-term investment strategies and hence, allow for smoother markets. Moreover, countries dependent on the mineral commodity exports may better judge the long-term perspective of the respective markets and adjust their macroeconomic and fiscal policies accordingly. Finally, my results suggest that demand is a larger contributor to the volatility of aluminum and copper prices than to that of lead, tin, zinc, and energy, since manufacturing output fluctuations lead to larger fluctuations in the cases of aluminum and copper demands (see Slade, 1991).

The estimates of the price elasticity are in contrast to the literature on oil and energy, where long-run price elasticity is estimated to be significant (-1.25 for energy demand according to Heal and Chichilnisky (1991) and -0.64 for oil demand in OECD countries according to Gately and Huntington (2002)). These results are important, because according to models of commodity price speculation, a low price elasticity of demand makes these markets prone to speculation (see Hamilton, 2009a; Kilian and Murphy, 2012). Moreover, the low price elasticity is a key parameter in shaping the incentives of war over resources as Acemoglu et al. (2012) claims.

The paper is structured as follows. Section 2 introduces the data set. Section 3 introduces the econometric model. Section 4 presents the estimation results. Section 5 describes robustness checks, while Section 6 draws conclusions.

2 A new data set

Numerous authors have estimated the income and price elasticities of demand for crude oil, gasoline, aggregate energy, and other mineral commodities using data sets for the period after the Second World War (see Pesaran et al., 1998; Hamilton, 2009b; Pei and Tilton, 1999, for surveys of the current literature). These studies do not include major periods of industrialization for currently industrialized countries, making comparison and inference with respect to emerging economies rather difficult. In this study, I extend the data set to a far longer time horizon. The examined mineral commodities are aluminum, copper, lead, tin, and zinc. My data set consists of a sample of twelve industrialized countries, namely Belgium, Finland, France, Germany, Italy, Japan, South Korea, the Netherlands, Spain, Sweden, the United Kingdom (U.K.), and the United States (U.S.), from 1840 to 2010. I assemble country-by-country annual data regarding demand, mineral commodity prices, and value added by manufacturing.[2] The demand for a mineral commodity, my dependent variable, is derived from the output of the manufacturing sector. The demand data captures those quantities of mineral commodities which are finished but unwrought (e.g., metal in primary shapes, such as cathodes and bars), and which manufacturers use at the first stage of production (e.g., brass mills, foundries). This is also the stage at which mineral commodities are usually traded, and it is the usual data employed for measuring the use of mineral commodities (Tilton, 1990; U.S. Geological Survey, 2011a).

To proxy demand, I collect data on the use of the respective mineral commodities. From the end of the First World War to today, I employ data from the BGR 2012. It is mainly

[2] See Tables 6 to 15 in the Appendix for detailed data sources and description, and Table 16 in the Appendix for summary statistics.

based on direct surveys of the respective manufacturing industries. From 1840 to 1918, I compute the apparent usage of the respective mineral commodities from production, as well as from import and export data from several sources. The data is plotted in Figures 2 through 6 in the Appendix.

Three aspects of the construction of the demand data might cause potential measurement errors. As demand is also regressed on lagged values of itself, it also constitutes an independent variable in the regressions. First, the BGR 2012 has rounded the data. This might lead to slightly larger standard deviations. Second, stocks are not included in the computation of usage before the First World War, due to a lack of data. Third, there is no clear unanimous definition or accounting for the use of mineral commodities across the differing countries and periods. These latter two measurement errors are rather stochastic in their nature and the coefficients might be underestimated to a certain extent.

I employ per capita value added in the manufacturing sector as explanatory variable. In contrast to energy, mineral commodities are only used as an input for the processing of partially finished and finished goods in the manufacturing sector, which are then used in construction, mining equipment, or as consumer goods. Mineral commodities are not directly purchased by consumers. Manufacturing data hence provides the best proxy for the process of industrialization.

I collect national account data from several national and international sources. To obtain a comparable measure of the value added by the manufacturing sector across countries, I compute the share of manufacturing in GDP from the data. I then multiply these percentage shares with GDP data in constant international Geary-Khamis Dollar from the seminal Maddison (2010) data set. The international Geary-Khamis Dollar is a hypothetical unit of currency that allows for international comparison of national accounts across countries and time periods. It relies on purchasing power parity converters and is deflated with the base year 1990.

All historical national account data that is based on later reconstructions and measurement errors are a potential problem. To the extent that measurement errors are stochastic, estimates will be biased towards zero and underestimate the true value. There might also be systematic measurement errors, whose biases are hard to judge, as I have not created the individual country data sets myself. However, I believe it is still constructive to investigate this data over the long-term horizon, given that it is the best available data, but it is necessary to interpret the results carefully.

I use population data from Maddison (2010) to compute the per capita value added by manufacturing and per capita use of the respective mineral commodities.

I assemble historical price data for the U.S., U.K., and Germany from several sources. Unfortunately, there are no price data series available for the other countries. As the London Metal Exchange is the most important metal exchange in the world (Slade, 1991) and sets the world market price, I derive proxies for the national prices of the other countries by using historical exchange rates from standard sources such as Bordo (2001), Officer (2006, 2011), and Denzel (2010). This approach neglects some price differentials due to transport costs. These appear at the price level and decrease gradually over the time period. Finally, to compute real prices for each country, I have collected producer price indices from Mitchell (2003a,b, 1998), the IMF, and national sources.

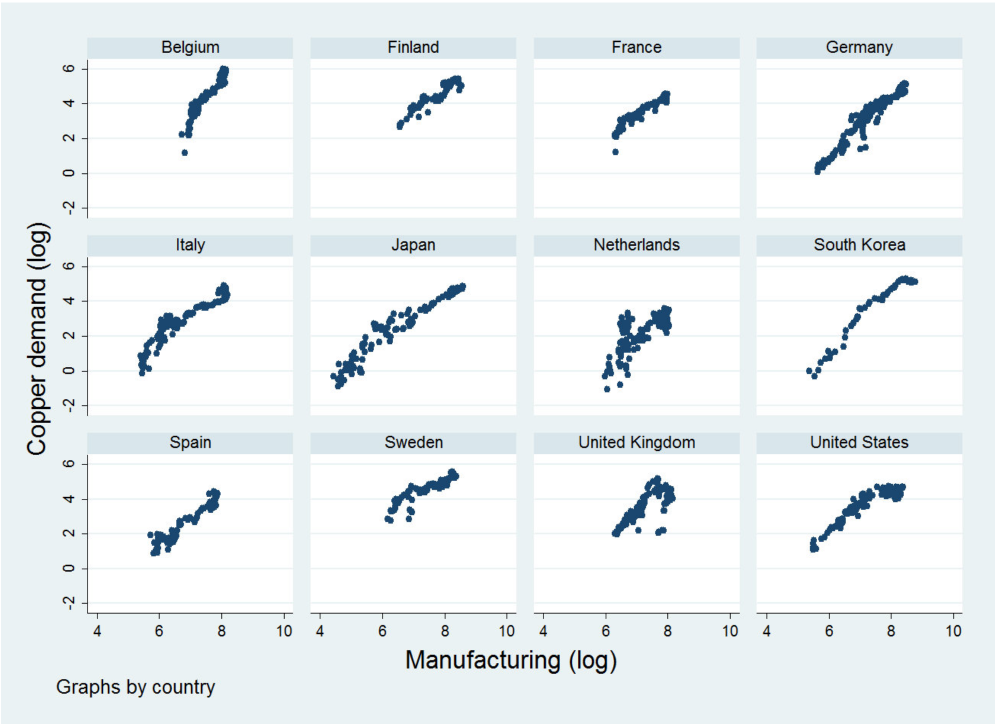

Figure 1: Scatter plot of per capita value added by manufacturing and per capita copper demand.

3 Estimating manufacturing output and price elasticity of demand

My estimation strategy relies on an extension of the partial adjustment model, which is the standard approach in empirical energy demand analysis (Adeyemi and Hunt, 2007). Pesaran et al. (1998) derive a theory-consistent dynamic industrial energy demand function with the share of energy costs in all factor inputs as the dependent variable by solving a multivariate cost of adjustment optimization problem. However, they find that the resultant econometric model fails functional form tests. They weight theoretical consistency and statistical adequacy and decide to pursue estimations with the standard log linear partial adjustment model. I follow the approach by Pesaran et al. (1998) and Pesaran et al. (1999) in the rest of the my study.

I set up an autoregressive distributed lag model (ARDL)(p, q, r) of a log linear demand function, where p, q, and r notify the number of lags included of the three explanatory variables:

$$c_{i,t} = \sum_{j=1}^{p} \lambda_{i,j} c_{i,t-j} + \sum_{l=0}^{q} \delta_{i,l} y_{i,t-l} + \sum_{m=0}^{r} \gamma_{i,m} p_{i,t-m} + \mu_i + \epsilon_{it} \ . \tag{1}$$

I explain the demand for mineral commodities $c_{i,t}$ (measured in metric tons per capita) of country i at time t by real per capita value added in the manufacturing sector $y_{i,t}$, by the real price of the respective mineral commodity $p_{i,t}$, and by its own lagged values. To capture proportional effects, I employ natural logs to all variables. $\lambda_{i,j}$, $\delta_{i,l}$, and $\gamma_{i,m}$ are the respective coefficients. μ_i represents country fixed effects, which capture omitted country-specific variables that are time independent. For example, a strong domestic copper mining industry might cause a generally higher level of copper demand in a country as downstream manufacturing specializes in processing copper.

Reparametrizing Equation 1, I obtain the error correction form

$$\begin{aligned} \Delta c_{i,t} = {} & \Phi_i (c_{i,t-1} - \theta_{0,i} - \theta_{1,i} y_{i,t} - \theta_{2,i} p_{i,t}) \\ & + \sum_{j=1}^{p-1} \lambda^*_{i,j} \Delta c_{i,t-j} + \sum_{l=0}^{q-1} \delta^*_{i,l} \Delta y_{i,t-l} + \sum_{m=0}^{r-1} \gamma^*_{i,m} \Delta p_{i,t-m} + \epsilon_{it} \ , \end{aligned} \tag{2}$$

where the vector θ_i captures the long-run relationship between the variables. $\theta_{1,i}$ is the long-run elasticity of demand with respect to value added by the manufacturing sector and $\theta_{2,i}$ represents the long-run elasticity of demand with respect to price. Φ_i denotes the speed of adjustment towards the long-run equilibrium.

I use the pooled mean group (PMG) estimator proposed by Pesaran et al. (1998) and Pesaran et al. (1999) to accommodate the heterogeneous dynamic of the demand functions across countries. Different economic structures across countries may affect the strength and speed at which manufacturing output and price affect the demand for mineral commodities in the short-run. To account for this heterogeneity, the PMG estimator allows the short-run effects to vary across countries. It only imposes homogeneity of the coefficients for the long-run effects.

My econometric model is potentially subject to the well-known identification problem in estimating energy demand elasticity. There is the problem of reverse causality running from the demand variable to the price variable. The demand curve will only be identified if national prices closely follow international prices and/or supply is highly elastic (Pesaran et al., 1998). In my study, domestic prices follow - partly by construction - international prices as these markets have been fairly well-integrated at the global level (see Stuermer, 2013a). At the same time, the respective shares of the U.S. and the U.K. in world consumption of the mineral commodities in this study were more than forty percent respectively during different sub-periods of my sample (Stuermer and von Hagen, 2012). It is therefore likely that the change in demand in one of these two countries affected world prices. However, it is possible that this impacted prices only in the short-run, as the supply of mineral commodities is highly elastic in the long-run according to Radetzki (2008) and others (see also the theoretical argument in Stuermer and Schwerhoff (2012)). Stuermer (2013a) also provides empirical evidence on this question examining the effect of unexpected changes in world output on price. I find that such a shock affects the price of the different mineral commodities significantly between five and ten years of time. This suggests that supply is inelastic in the short- and medium-run. As I only examine long-run elasticities, I believe it is plausible to make the identifying assumption for the rest of the paper that the long-run supply is elastic and that a single country did not cause long-term price changes. However, I discuss alternative estimation strategies that do not depend on this assumption in the conclusion.

By choosing manufacturing output as an explanatory variable, I accomodate an identification problem often overlooked in studies of energy demand. Most of these studies use GDP or industrial output as explanatory variables. This can potentially cause reverse causality from demand to GPD or industrial output if the domestic extractive sector produces the mineral commodity. The reason is that the extractive sector is part of GDP and industrial production, while it is not included in manufacturing output. Choosing manufacturing output reduces this potential identification problem.

Manufacturing output as an explanatory variable also allows controlling for the effects of structural change in the composition of total GDP on the demand for mineral commodities, e.g., the shift to the service sector, as described by Malenbaum (1978), Tilton (1990), Stuermer and von Hagen (2012), and others. Furthermore, I control for the effect of population growth by using per capita manufacturing output, as well as per capita demand of each mineral commodity. Overall, the scatter plots in Figure 1 for copper and in Figures 13 to 16 in the Appendix illustrate that the use of manufacturing data and controlling for population growth leads to an approximately linear log-log relationship, particularly in the cases of aluminum, copper, and zinc.

In my benchmark specification, the pooling of long-run coefficients shows that there is commonality across countries in the way manufacturing output and prices affect the demand for mineral commodities. The relative price of the respective mineral commodity partly controls for technological change that drives substitution over time. The other factors are implicitly included in the manufacturing output elasticity.

Following Pesaran et al. (1998), I add a common linear time trend and time fixed effects to my benchmark specification in a stepwise manner. I investigate whether there is a common linear trend or common shocks across countries, which reflect technological change in resource saving technology and in new products, as well as changes in consumer preferences. This allows me to take advantage of the panel structure of the databy controlling for ommitted common technological trends and spillover effects (Pesaran et al., 1998). However, time fixed effects also include other effects than technological change, e.g., the effect of the two World Wars on the demand for mineral commodities. I see the comparison between the three specifications also as a misspecification test for the importance of ommitted common trends and shocks in technological change (Pesaran et al., 1998).

I model the time fixed effects by expressing all variables as deviations from their respective cross-sectional means in each period in line with Pesaran et al. (1999). Such a procedure reduces the common time specific effects and also makes PMG estimates consistent. PMG estimation assumes that regression residuals are independent across countries. Non-zero error co-variances may arise due to the omission of these common effects (Pesaran et al., 1999).

The disadvantage of including time fixed effects is that they also control for changes in the world market price, leaving only those price changes in the regression caused by changes in inflation and exchange rates. If market participants assume that these nominal shocks exhibit no long-term impact on prices, the estimated price elasticities will be small and/or statistically insignificant. Moreover, besides technological change in resource efficiency and in the product composition of manufacturing output, they also capture technological change leading to substitution.

The ARDL specification makes no unit root pretesting of the variables necessary. Pesaran and Smith (1995) and Pesaran (1997) show that the method is valid whether or not the variables follow a unit root process or not. This is based on the assumptions that there is in fact a long-run relationship, that regressors are strictly exogenous, and that there is no serial correlation in the residuals. The existence of a long-run relationship requires the adjustment coefficient to fulfil $-2 < \Phi_i < 0$ (Loayza and Rancière, 2006).

Determining the lag order by information criteria on a country-by-country basis reveals significant differences across countries. However, to make regression results for the short-run and long-run parameters comparable, I impose a common lag structure across countries. My benchmark model is an ARDL(4,4,2) model, which means that I include four lags of mineral commodity demand and of manufacturing output, and two lags of mineral commodity prices respectively in Model 2. I use a comparatively long lag structure to allow for rich dynamics and to account for possible serial correlation in the data.

I use unbalanced panel data for each of the five mineral commodities. The time dimension is relatively large, while the cross-sectional dimension is rather small with the number of countries $N = 12$, as Table 16 in the Appendix shows. The incidental parameter problem (Nickell, 1981), which affects dynamic panel data models with small T and large N, is therefore not an issue. The common long-run coefficients of θ_i from the PMG estimator are consistent as long as $T \to \infty$, even if N is small (Pesaran et al., 1999).

I check the robustness of my results with respect to a different choice of lag lengths and the use of other estimators, which impose full heterogeneity and full homogeneity across the coefficients. I present estimation results for ARDL(1,1,1) and ARDL(3,3,3) of Model 2.

Furthermore, I employ the mean group (MG) and the standard dynamic fixed effects (DFE) estimators as robustness checks. The MG estimator proposed by Pesaran and Smith (1995) derives the full panel estimates of θ, Φ, δ, and γ by simply averaging the individual country coefficients θ_i, Φ_i, δ_i, and γ_i. It imposes no homogeneity restrictions on long-run or short-run restrictions. The DFE estimator restricts the long-run and short-run coefficients as well as the adjustment coefficient making them equal across the range of countries. The PMG estimator stands between these two estimators with respect to the homogeneity that it imposes.

I make use of a standard Hausman (1978) test, as proposed by Pesaran et al. (1999), to examine whether or not the long-run elasticity is in fact equal across the countries. If the null hypothesis of equality is not rejected, the PMG estimator is superior to the MG estimator as it is both consistent and efficient in this case, while the MG estimator is only consistent.

4 Estimation results

I present estimates of the three specifications for each of the examined mineral commodities. The first specification is the benchmark model in Equation 2 that I estimated with a pooled mean group estimator that imposes homogeneity on the long-run coefficients. In the second specification, I add a linear time trend to accomodate for common technological change. In the third specification, I make use of time fixed effects to control for common shocks from technological change and other factors such as the two World Wars.

I find pronounced differences in the estimated long-run manufacturing output elasticities of demand across the five examined mineral commodities. Aluminum has a high estimated long-run manufacturing output elasticity of demand, while lead has the lowest. The estimated long-run price elasticities of demand are inelastic for all examined mineral commodities. Changes in prices have either a small impact or no impact on demand.

My results for the estimated long-run manufacturing output elasticity of demand are relatively robust across the three specifications for aluminum, copper, lead, and zinc. The estimation results for the price elasticites of demand are only robust to the second specification. This is as expected as the time fixed effects in the third specification take out the price effects due to changes in the world market price. The common linear trend is statistically significant in the regressions for aluminum and lead. The empirical results are plausible given narrative evidence on the application of the different mineral commodities across time.

Finally, I find evidence for the existence of long-run relationships in all regressions. The estimated speed of demand adjustment is rather slow for all commodities, and it takes more than 10 years to revert back to equilibrium. This is reasonable, given that adjustments in manufacturing capital are rather slow and that inventories play an important role in these markets.

4.1 Aluminum

I find a relatively high estimate for the long-run manufacturing output elasticity of aluminum demand. A one percent increase in manufacturing output leads to a more than 1.5 percent increase in aluminum demand. Including a linear time trend increases the estimated elasticity to about 1.8. This means that the demand for aluminum increases at a higher rate than manufacturing output and hence the material intensity of use in the manufacturing sector increases over the course of industrialization. Aluminum is mainly used for the production of high technology goods such as airplanes, electronics, or machinery, and for the packaging of consumer goods (Stuermer and von Hagen, 2012; Krebs, 2006). It is plausible that changing consumer preferences increases the demand for aluminum in manufacturing production over the course of industrialization. The large estimates for the manufacturing output elasticity of demand imply that aluminum demand fluctuates significantly higher than manufacturing output. As a consequence, prices will be strongly driven by these large demand shocks.

	1	2	3
Time fixed effects	No	No	Yes
Manufacturing (log)	1.551***	1.759***	1.518***
	(0.092)	(0.173)	(0.073)
Aluminum price (log)	-0.706***	-0.883***	-0.836***
	(0.184)	(0.221)	(0.236)
Constant	-0.056	1.411***	0.054
	(0.059)	(0.421)	(0.083)
Linear trend		-0.012*	
		(0.007)	
Adjustment coefficient	-0.117***	-0.113***	-0.142***
	(0.023)	(0.023)	(0.031)
Observations	973	973	973
Log likelihood	404.4	405.2	432.4

Notes: The table shows results from the pooled mean group (PMG) estimations of the preferred ARDL(4,4,2) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 1: Estimates of the long-run manufacturing output and price elasticities of aluminum demand.

The estimated long-run price elasticity of aluminum demand is significant and ranges between -0.7 and -0.8 across the three specifications. This is a low estimate of the long-run price elasticity in comparison to manufacturing goods. Compared to the other examined mineral commodities, the estimated long-run price elasticity of aluminum demand is by far the largest. This is in line with the fact that aluminum has substituted for many different materials such as composites, glass, paper, plastics, copper, and steel in a wide range of appliances in manufacturing production over the course of history (Radetzki, 2008; Krebs, 2006). Aluminum has been widely used since the end of the 19th century as production costs have decreased dramatically due to the invention of the electrolysis by Charles Martin Hall in 1886 (Chandler, 1990).

My regression results provide evidence for a negative linear time trend at a statistical significance of ten percent. This might reflect that there is a common technological trend across countries towards more resource efficiency in the use of aluminum over time. It is reassuring that imposing common time fixed effects does not change the results. I find evidence for the existence of long-term relationships as the coefficients of adjustment are statistically significant and negative in all specifications. The estimates suggest a speeds of convergence to equilibrium of about fourteen percent per year for aluminum.

4.2 Copper

Copper is very versatile in its uses in human history (Krebs, 2006). The manufacturing sector employs copper in the production of a broad variety of products in electronics, construction, transportation, and machinery (Krebs, 2006; Stuermer and von Hagen, 2012).

The estimates for copper yield a point elasticity of demand to manufacturing output of about one across the three specifications. The demand for copper increases at the same rate as manufacturing output. This is plausible as copper is used in many different applications (Krebs, 2006). In the past, it was important in the production of hardware and cooking utensils in the form of alloys, such as brass and bronze. It has been, and is still essential in construction, roofing, and plumbing (Krebs, 2006). As an excellent conductor of electricity, it has become more and more important in the use of technological goods and electronics (see Radetzki, 2009; Mardones et al., 1985). The estimated elasticity of demand with respect to manufacturing output of copper is relatively large compared to those of lead, tin, and zinc. This helps to explain why copper shows the strongest effect of "world output-driven demand shock" on price compared to lead, tin, and zinc as Stuermer (2013a) finds.

	1	2	3
Time fixed effects	No	No	Yes
Manufacturing (log)	0.914***	1.104***	1.128***
	(0.061)	(0.145)	(0.067)
Copper price (log)	-0.400***	-0.453***	-0.009
	(0.093)	(0.095)	(0.049)
Constant	-0.161***	0.474***	0.010
	(0.052)	(0.182)	(0.030)
Linear trend		-0.005	
		(0.004)	
Adjustment coefficient	-0.132***	-0.131***	-0.180***
	(0.028)	(0.028)	(0.057
Observations	1,206	1,206	1,206
Log likelihood	502.3	502.8	434.2

Notes: The table shows results from the pooled mean group (PMG) estimations of the preferred ARDL(4,4,2) model. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 2: Estimates of the long-run manufacturing output and price elasticities of copper demand.

The estimated long-run price elasticity of demand of copper is rather low with a point estimate of -0.4 in the the first and second specification. This shows that copper is only moderately substitutable in its major applications. Although aluminum and plastics have been substitutes for copper, especially in building materials, its substitutabiliy is very low in applications as a conductor of electricity (see Krebs, 2006).

Including time fixed effects leads to a statistically insignificant estimated long-run price elasticity. As time fixed effects control for changes in world prices, they only leave those price changes in the regression that are due to changes in inflation and exchange rates. If market participants assume that these nominal shocks exhibit no long-term impact on prices, the estimated price elasticity will be small and/or statistically insignificant. Hence, this result is not a big surprise. At the same time, it is reassuring that the estimate for the manufacturing output elasticity of demand does not substantially change.

The estimated coefficient for the linear trend is negative and not statistically significant different from zero. I find evidence for the existence of long-run relationships, as the coefficients of adjustment are statistically significant and negative in all specifications. Overall, the estimated speed of demand adjustment is rather slow. The estimates suggest speeds of convergence to reach equilibrium at about fourteen percent per year for copper.

4.3 Lead

The manufacturing sector employs lead for the production of a broad variety of manufactured goods such as TV screens, pipes, and batteries. It is an important alloy, especially in solder that is applied in electronics (Krebs, 2006). However, its use has been phased-out in many appliances such as in gasoline, paint pigments, and pipes due to health and environmental reasons (see Smith, 1999). At the same time, its use has strongly shifted to automobile batteries.

The estimated long-run manufacturing output elasticity of lead demand is estimated to be far below one. It ranges from about 0.4 to 0.7 across the three specifications. This shows that the demand for lead increases at a slower rate than manufacturing output and hence, its intensity of use tends to decline over the course of industrialization. As per capita manufacturing output increases, consumers tend to change their preferences to prefer products with minimal health and environmental effects. However, comparing the results of the three specifications shows that the demand is also driven by shocks that are common to all countries over time. The estimated coefficicent for the linear time trend is negative and highly significant. This suggests that the decreasing use of lead due to negative health and environmental impacts is also strongly driven by time-related common shocks, as different governments started regulating at the same time in the 1960s and 1970s.

	1	2	3
Time fixed effects	No	No	Yes
Manufacturing (log)	0.435***	0.675***	0.745***
	(0.057)	(0.110)	(0.112)
Lead price (log)	-0.220**	-0.215***	-0.014
	(0.093)	(0.080)	(0.204)
Constant	0.048**	0.393***	0.028
	(0.022)	(0.095)	(0.022)
Linear trend		-0.005***	
		(0.002)	
Adjustment coefficient	-0.094***	-0.121***	-0.148***
	(0.021)	(0.026)	(0.033)
Observations	1,059	1,059	1,059
Log likelihood	474.7	476.9	435.3

Notes: The table shows results from the pooled mean group (PMG) estimation of the preferred ARDL(4,4,2) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Estimates of the long-run manufacturing output and price elasticities of lead demand.

My estimates for the price elasticity of lead demand are far lower than those for copper and aluminum. They are about -0.2 for Specifications 1 and 2. This hints at the low substitutability of lead. As in the case of copper, the estimate of the price elasticity in the specification with time fixed effects is not statistically significant.

I find evidence for the existence of long-run relationships, as the coefficients of adjustment are statistically significant and negative in all specifications. Overall, the estimated speed of demand adjustment is even lower than for copper and aluminum. It takes up to 10 years before demand reaches equilibrium after a shock. This is reasonable, given that adjustments in manufacturing capital are rather slow and that inventories play an important role.

4.4 Tin

Tin is mainly used in the packaging industry as tinplate, which is thin steel coated by tin. It is also employed as an alloy with lead as solder in electronics. Furthermore, it is applied in different alloys, of which bronze is the most important (Krebs, 2006; Stuermer and von Hagen, 2012).

The estimated manufacturing output elasticity and the estimated price elasticity of tin demand varies strongly across the three specifications. In Specifications 1 and 2, the output elasticity of demand is about 0.6 to 0.7. However, in the third specification with time fixed effects, it is far lower, about 0.3. For the price elasticity, the estimated elasticity is positive at about 0.1 in Specifications 1 and 2, while it is negative and about 0.4 in Specification 3.

	1	2	3
Time fixed effects	No	No	Yes
Manufacturing (log)	0.616***	0.712***	0.295**
	(0.035)	(0.080)	(0.141)
Tin price (log)	0.169**	0.110	-0.384***
	(0.085)	(0.084)	(0.046)
Constant	-0.522**	-0.149	0.006
	(0.209)	(0.118)	(0.026)
Linear trend		-0.004	
		(0.003)	
Adjustment coefficient	-0.132***	-0.131***	-0.180***
	(0.028)	(0.028)	(0.057
Observations	1,142	1,142	1,142
Log likelihood	399.5	400.1	408.9

Notes: The table shows results from the pooled mean group (PMG) estimations of the preferred ARDL(4,4,2) model. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4: Estimates of the long-run manufacturing output and price elasticities of tin demand.

These results might point to a misspecification of the model. As the scatter plot in Figure 15 in the Appendix shows, there is a broad variety of different patterns in the relationship between per capita manufacturing output and tin demand. In addition, they do not show a linear log-log relationship. Several reasons might explain this result. First, in comparison to the other mineral commodities examined, it is the one with the most narrow range of applications in manufacturing production. Second, it has strongly lost its importance due to aluminum substitution (see Thoburn, 1994; Krebs, 2006; Stuermer and von Hagen, 2012). Finally, the strong turbulences in its price due to the collapse of the "International Tin Agreement" in 1985 (see Rudolf Wolff & Co Lt., 1987) might have caused further problems in the estimation.

I find evidence for the existence of long-run relationships, as the coefficients of adjustment are statistically significant and negative in all three specifications. Overall, the estimated speed of demand adjustment is, as in the case for lead and zinc, very slow. It takes up to 10 years before demand reaches equilibrium after a shock.

4.5 Zinc

Zinc is mainly used in the galvanization of steel, as an alloy with copper in brass, casting, batteries, paint, and zinc sheet for roofing (see Gupta, 1982; Jolly, 1997).

The long-run manufacturing output elasticity of zinc demand is estimated to be between 0.7 and 0.8 in the three specifications. Hence, demand increases at a slower rate than manufacturing output over the course of industrialization, pointing to a slight decrease in the intensity of use. Thisis plausible as zinc demand closely follows industrial and economic conditions (see Gupta, 1982; Jolly, 1997). As its main appliance is in galvanization, the use of zinc is strongly linked to products of the steel industry that lose importance over the course of industrialization.

	1	2	3
Time fixed effects	No	No	Yes
Manufacturing (log)	0.734***	0.852***	0.834***
	(0.033)	(0.101)	(0.132)
Zinc price (log)	-0.064	-0.066	0.207**
	(0.088)	(0.084)	(0.083)
Constant	-0.204***	-0.090	-0.017
	(0.209)	(0.118)	(0.026)
Linear trend		-0.004	
		(0.003)	
Adjustment coefficient	-0.132***	-0.131***	-0.180***
	(0.055)	(0.062)	(0.022)
Observations	1,216	1,216	1,216
Log likelihood	579.2	579.8	518.9

Notes: The table shows results from the pooled mean group (PMG) estimations of the preferred ARDL(4,4,2) model. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 5: Estimates of the long-run manufacturing output and price elasticities of zinc demand.

The estimates for the price elasticity of zinc demand are different between the specifications with and without the time fixed effects. In Specifications 1 and 2 the estimates are not statistically significantly different from zero. Inclusion of time fixed effects in Specification 3 leads to a positive, statistically significant value of about 0.2. Yet, this result has no plausible explanation, and is hard to interpret, as price only includes changes from inflation and exchange rates when applying time fixed effects. The time trend is not statistically significant.

I find evidence for the existence of long-run relationships, as the coefficients of adjustment are statistically significant and negative in all three specifications. It takes up to ten years before demand reaches equilibrium after a shock.

5 Sensitivity analysis

I check the robustness of my results with respect to a different choice of lag lengths and the use of other estimators.

I reestimate the model using an ARDL(1,1,1) and an ARDL(3,3,3) configuration (see Tables 22 to 31 in the Appendix). Smaller lag lengths yield qualitatively similar results for all mineral commodities except tin, where the price elasticity becomes insignificant in the case of ARDL(3,3,3). The null hypothesis of the Hausman test is not rejected in any of the specifications with the mean substracted data. The adjustment coefficients are statistically significant in all estimations, showing strong evidence for long-run relationships between the variables.

Tables 17 to 21 in the Appendix present the results from the alternative pooled estimators. The two alternative pooled estimators are the mean group estimator (MG), which does not impose any homogeneity, and the dynamic fixed effects (DFE) estimator, which imposes homogeneity across all slopes and error variances.

The estimated long-run price and manufacturing output elasticities of demand are relatively robust across the different estimators. As expected, the standard errors of the MG estimates are larger and the coefficients are not often statistically significant. Pooling sharpens the estimates considerably as they are more robust to outliers. In the case of aluminum, the effect of the outlier Belgium is obvious and distorts the estimates. The estimated coefficients for the speed of adjustment are in all cases fairly low but significant.

The joint Hausman tests in Tables 17 to 21 do not reject the hypothesis of homogeneity of all long-run coefficients at conventional levels of significance, when the PMG estimates are compared to the MG estimates for results with country fixed effects. As PMG estimates are more efficient than MG estimates, they ought to be preferred. Overall, the joint Hausman tests provide evidence that I am not violating the data by relying on PMG estimates rather than MG estimates for all mineral commodities in the regressions with time fixed effects (Pesaran et al., 1999).

6 Conclusion

This paper is the first to provide empirical evidence from a panel data set that covers the nexus of industrialization and the derived demand for mineral commodities for a time period spanning partly back to 1840. I focus on the demand for aluminum, copper, lead, tin, and zinc, because they have been used in many applications throughout history. I employ the pooled mean group estimator to the standard partial adjustment model to estimate the manufacturing output elasticity of demand and the price elasticity of demand of each of the commodities examined. The pooled mean group estimator allows me to account for the heterogeneity in the short-run effects. I control for possible ommitted technology development that is common across countries and time dependent, by implementing a linear time trend and time-fixed effects in a stepwise manner.

I find strong differences in the estimated long-run manufacturing output elasticities of demand across the five examined mineral commodities. Aluminum has an estimated long-run manufacturing output elasticity of demand of about 1.5. This means that its demand increases at a higher rate than manufacturing output over time. I estimate the long-run manufacturing output elasticitiy of copper demand to be about one, while it is below one for lead, tin, and zinc demands. This causes the intensity of use of these mineral commodities to decline over time in the manufacturing sector.

My results suggest that the structural change in the relationship between per capita manufacturing output and the demand for mineral commodities over the course of industrialization is driven by changes in technology and consumer preferences specific to the stage of industrialization. Controlling for ommitted common technology and spillover effects across countries by employing specifications with a time trend and country fixed effects shows that common effects only play a role in decreasing aluminum and lead demands over time. The model for tin seems to be misspecified.

The estimated long-run demand of the examined mineral commodities is fairly inelastic with respect to price. This points to the low effect of technological change in substitution. It illustrates that the examined mineral commodities are fairly essential to manufacturing output, as the processing industry does not change its use in response to price.

The empirical results are plausible, given narrative evidence on the application of the different mineral commodities over time. I find evidence for the existence of long-run relationships in all regressions. The estimated speed of demand adjustment is fairly slow for all commodities, and it takes more than ten years in the cases of lead, tin, and zinc to revert back to equilibrium. This is reasonable, given that adjustments in manufacturing capital are rather slow and that inventories play an important role in these markets.

My estimates of the long-run manufacturing output elasticity of demand suggest that industrialization in China will cause aluminum and copper demands to increase while the demand for lead, tin, and zinc decrease relative to manufacturing output in the long-term. As mining firms face high upfront costs and long lead times to open up new mines, my results are important for developing long-term production strategies and allowing for smooth markets. Moreover, countries dependent on mineral commodity exports may better judge the long-term perspective of the respective markets and adjust their macroeconomic and fiscal policies accordingly. My results suggest that demand is a larger contributor to the volatility of aluminum and copper prices than to that of lead, tin, zinc, and energy prices (see Slade, 1991). Moreover, the manufacturing output elasticities of demand for all examined mineral commodities except tin are higher than the income elasticities of oil demand (which is 0.55 according to Gately and Huntington (2002) for twenty-five OECD countries from 1971 to 1997) .

Acemoglu et al. (2012) claim that the low price elasticity leads to an increase in the value of the outstanding stock over time. Therefore, the incentives of war increase, making war even inevitable in the long run. It is questionable whether this is really the case as a low price inelasticity of derived demand might also be driven by the fact that the costs of these inputs as a share of total costs of manufacturing are relatively small, as the law of derived demand by Hicks (1932) and Marshall (1890) suggests. Furthermore, the model by Acemoglu et al. (2012) depends on the assumption of a finite stock, which my coauthor and I question in Stuermer and Schwerhoff (2012). Following models of commodity price speculation, the low price elasticity of demand makes these markets prone to speculation (see Hamilton, 2009a; Kilian and Murphy, 2012).

Measurement errors might lead to an underestimation of coefficients and larger standard errors. One possible way to correct for these errors would be to use instrumental variables. I could employ historical labor dispute data from Mitchell (2007) as an instrument for manufacturing output. Labor disputes are correlated to manufacturing output, but are not directly correlated to the demand of the respective mineral commodities. I could use historical price data for gold (data is available from Schmitz (1979)), wheat (data is available from Uebele (2011)), or other mineral commodities, as an instrument for the five mineral commodity prices examined here. The seminal article by Pindyck and Rotemberg (1990) shows that there is "excess co-movement" between prices of commodities whose markets are otherwise unrelated. The correlation due to the "excess co-movement" of commodity markets could be used to mitigate the effect of measurement errors in prices. This approach would also check the robustness of my identifying assumption that supply is highly elastic in the long run. Another way to correct for the latter problem would be to explicitly model the possible endogeneity of prices with respect to demand in a structural panel vector error correction model. I leave these robustness checks to further research.

My results show that it is relatively difficult to separate and interpret the different effects of technological change and consumer preferences on the dynamic relationship between manufacturing output and the demand for mineral commodities. This offers directions for further research. First, I could explicitely use variables that control for specific uses of the different mineral commodities, e.g., the number of telephones (data available from Mitchell (2003a) and others) in the case of copper use. This would help to separate the effect of technological change on the production composition of manufacturing output from the technological change in resource efficiency. Secondly, as substitution effects play an important role, I might include prices of close substitutes in the regressions, e.g., the price of aluminum as a control variable in the regression on copper demand. Third, I could try to find more direct proxies for technological change in resource efficiency, e.g., Considine (1991) uses automotive fuel economy as a proxy to technological change in resource efficiency in mineral commodity demand. Finally, applying time-varying parameter regression could help to better account for the dynamic structure of the relationship between manufacturing output and the derived demand for mineral commodities.

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7 Appendix

7.1 Data sources

Table 6: Data sources for the mineral commodity prices.

Mineral Comm.	Country	Time	Units	Sources	Notes
Aluminum	U.K.	1904-75	£/mt	Schmitz 1979, pp. 263-5	1913-45: Ingots, 99-99.5% metal cont., London market; 1946-75: Ingots, min. 99.5% metal cont., London market.
	U.K.	1976-2010	US-$/mt	BGR 2011a	1976-Nov 78: Primary aluminum, cash, in London Metal Exchange (LME) warehouse, min. 99.5% metal content; Dec 1978-Jul 87: Primary aluminum, cash, in LME warehouse, min. 99.5% metal cont.; Aug 1987-2010: High grade primary aluminum, cash, in LME warehouse, min. 99.7% metal cont.
Aluminum	U.S.	1895-1976	US-$/mt	Schmitz 1979, pp. 263-5	1895-1945: Ingots, min. 99% metal cont., New York market; 1946-76: Ingots, min. 99.5% metal cont., New York market.
	U.S.	1977-98	US-$/mt	Sachs 1999, p. 3	1977-82: New York market, 1983-98: New York market, 99.7% pure aluminum ingot.
	U.S.	1999-2000	US-$/mt	U.S. Geological Survey 2001	New York market, 99.7% pure aluminum ingot.
	U.S.	2001-5	US-$/mt	U.S. Geological Survey 2007	New York market, 99.7% pure aluminum ingot.
	U.S.	2006-10	US-$/mt	U.S. Geological Survey 2011b	New York market, 99.7% pure aluminum ingot.

Aluminum	Germany	1854-1975	Marks/mt	Schmitz 1979, pp. 263-5	1854-89: Continental European price, selling price of refined aluminum, Deville Co. France; 1858, 1860-3, 1865-73, 1875-7, 1879-83, 1887: linear trend; 1890-Mar 1958: Ingots, min. 99% metal cont., av. selling price of German primary aluminum; Apr 1958-75: Ingots, min. 99.5% metal cont., av. selling price of German primary aluminum; 1914: Jan-Jul only; 1915-8, 1942-7: Official max. price.
	Germany	1976-2010	US-$/mt	BGR 2011a	1976-Nov 78: Primary aluminum, cash, in LME warehouse Hamburg, min. 99.5% metal cont.; Dec 1978-Jul 87: Primary aluminum, cash, in LME warehouse Hamburg, min. 99.5% metal cont.; Aug 1987-2010: High grade primary aluminum, cash, in LME warehouse Hamburg, min. 99.7% metal cont.
Copper	U.K.	1840-1976	£/mt	Schmitz 1979, pp. 268-72	1790-1879: Tough copper, fire-refined, av. 99.25% metal cont., London market; 1880-1914: Best selected copper, fire-refined, av. 99.75% metal cont., London market; 1915-76: Electrolytic wirebars, min. 99.9% metal cont., London market; 1939: Price av. Jan-Aug only as LME dealings were suspended; Sep 1940-Aug 53: controlled selling price of the Ministry of Supply.
	U.K.	1977-2010	US-$/mt	BGR 2011a	Grade A, cash, in LME warehouse, min. 99.99% metal cont.

Copper	U.S.	1850-1976	US-$/mt	Schmitz 1979, pp. 268-72	1850-99: Lake copper, fire-refined, New York market, min. 99.9% metal cont.; 1900-1934: Electrolytic wirebars, min. 99.9% metal cont., New York market; 1935-1976: Electrolytic wirebars (domestic), net Atlantic seaboard refinery, min. 99.9% metal cont.; Sep 1967-Apr 68: U.S. producer strike, so 1967 is the average of Jan-June and 1968 is the average of May-Dec.
	U.S.	1977-90	U.S.-$/mt	U.S. Bureau of Mines 1981, 1987, 1993	Cathode, min. 99.99% metal cont., U.S. producer price.
	U.S.	1991-2010	U.S.-$/mt	U.S. Geological Survey 1996, 2001, 2007, 2011b	Cathode, min. 99.99% metal cont., U.S. producer price.
Copper	Germany	1845-57	Marks/mt	Schmitz 1979, pp. 270-2	Price of Mansfeld copper, Berlin market; 1847-50: linear trend.
	Germany	1858	Marks/mt	Ministerium für Handel, Gewerbe und öffentliche Arbeiten 1859, p. 14	Price of Mansfeld copper, Berlin market.
	Germany	1859-1975	Marks/mt	Schmitz 1979, pp. 270-2	1859: lin. trend; 1860-1913: Mansfeld fire-refined copper ex-works; 1914-23: Source unknown; 1924-75: Electrolytic wirebars, FOB, av. selling price of German refineries; Oct 1939 - Jun 50 official max. price.
	Germany	1976-2010	US-$/mt	BGR 2011a	Grade A, cash, in LME warehouse Hamburg, min. 99.99% metal cont.

Lead	U.K.	1840-1976	£/mt	Schmitz 1979, pp. 226-37	1790-1886: English pig lead, mostly prices in provincial markets pre-1850, then mainly London prices; 1887-1945: Good soft pig lead, London market; 1946-76: Refined pig lead, min. 99.97% metal cont., London market; 1914: Average Jan-July and Nov-Dec only; 1940-Sept 52: Fixed selling price, Ministry of Supply.
	U.K.	1977-2010	U.S.-$/mt	BGR 2011a	Lead, min. 99.97% metal cont., cash, in LME warehouse.
Lead	U.S.	1840-1976	U.S.-$/mt	Schmitz 1979, pp. 274-8	1820-79: Pig lead, New York; 1880-1976: Common grade lead, min. 99.73% metal cont., New York.
	U.S.	1977-90	U.S.-$/mt	U.S. Bureau of Mines 1981, 1987, 1993	Min. 99.97% metal cont., North American producer price, delivered.
	U.S.	1991-2010	U.S.-$/mt	U.S. Geological Survey 1996, 2001, 2007, 2011b	Min. 99.97% metal cont., North American producer price, delivered.
Lead	Germany	1840-1976	Marks/mt	Schmitz 1979, pp. 274-8	1840-98: Silesian lead, ex-works at Tarnowitz; 1899-1918: Rhenish refined lead ex-smelter, min 99.9% metal cont.; 1924-39: Good soft pig lead, min. 99.9% metal cont., Berlin Metal Exchange; Oct 1939-Aug 50: Officially regulated price; 1950-76: Soft pig lead, min. 99.9% metal cont.
	Germany	1977-2010	U.S.-$/mt	BGR 2011a	Min. 99.97% metal cont., cash, in LME warehouse Hamburg.

Tin	U.K.	1840-1976	£/mt	Schmitz 1979, pp. 240-1	1790-1837: Common refined tin, Cornwall; 1838-72: Standard tin, London market; 1873-1976: Standard tin, min. 99.75% metal cont., London market; 1914: Average price of Jan-July and Oct-Dec only; 1942-9: controlled price, Ministry of Supply.
	U.K.	1977-8	U.S.-$/mt	U.S. Bureau of Mines 1980, p. 915	Standard tin, min. 99.75% metal cont., London market.
	U.K.	1979-2010	U.S.-$/mt	BGR 2011a	Min. 99.85% metal cont., in LME warehouse, cash.
Tin	U.S.	1841-55	U.S.-$/mt	House of Commons 1853,	Computed from quantities and values of U.S. imports of tin in blocks and pigs; 1851-5: lin. trend.
	U.S.	1856-1962	U.S.-$/mt	Secretary of the Treasury 1864, pp. 46-8	Computed from quantities and values of U.S. imports of tin in blocks and pigs.
	U.S.	1863	U.S.-$/mt	House of Commons 1866, p. 358	Computed from quantities and values of U.S. imports of tin in blocks and pigs.
	U.S.	1864-9	U.S.-$/mt	House of Commons 1868, p. 378	Computed from quantities and values of U.S. imports of tin in blocks and pigs; 1866-9: lin. trend.
	U.S.	1870-1976	U.S.-$/mt	Schmitz 1979, pp. 293-8	1869-80: Block tin, New York; 1881-1919: Ordinary brands, min. 99% metal cont., New York; 1920-76: Straits tin, Grade A, min. 99.85% metal cont., New York; 1918: median price; 1976: av. Jan, Jul, & Dec.
	U.S.	1977-90	U.S.-$/mt	U.S. Bureau of Mines 1981, 1987, 1993	Contained tin, New York market.
	U.S.	1991-2010	U.S.-$/mt	U.S. Geological Survey 1996, 2001, 2007, 2011b	Contained tin, New York market.

Tin	Germany	1840-1975	Marks/mt	Schmitz 1979, pp. 293-8	1840-1902: Saxon tin at Freiberg; 1903-14: Banca tin (from Dutch East Indies) in Frankfurt am Main; 1925-75: Banca and Straits tin, Hamburg, min. 99.9% metal cont.; Oct 1939-47: Official max. price; 1973: Jan-June average only; 1974: Mar-Dec average only.
	Germany	1976-8	U.S.-$/mt	U.S. Bureau of Mines 1980, p. 915	Standard tin, min. 99.75% metal cont., in LME warehouse Hamburg.
	Germany	1979-2010	U.S.-$/mt	BGR 2011a	Min. 99.85% metal cont., in LME warehouse Hamburg, cash.
Tin	Japan	1950-86	Yen/mt	Ministry of Internal Affairs and Communication of Japan 2012	Computed from data on the quantity and value of tin ore.
Zinc	U.K.	1840-1976	£/mt	Schmitz 1979, pp. 299-303	1823-1951: Ordinary brands zinc, London market; 1940-4: controlled price, U.K. Ministry of Supply; 1952-76: virgin zinc, min. 98% metal cont., London market.
	U.K.	1977-8	U.S.-$/mt	U.S. Bureau of Mines 1980, p. 981	Prime Western grade, min. 98% metal cont., London market.
	U.K.	1979-2010	U.S.-$/mt	BGR 2011a	Special high grade, min. 99.995% metal cont., cash, LME warehouse.
Zinc	U.S.	1872-4	U.S.-$/mt	U.S. Bureau of Mines 1883	U.S. import price of zinc in blocks or pigs.
	U.S.	1875-1976	U.S.-$/mt	Schmitz 1979, pp. 300-3	1875-99: Prime Western spelter, min. 98% metal cont., New York; 1900-76: Prime Western spelter, Saint Louis, min. 98% metal cont.

	U.S.	1977-90	U.S.-\$/mt	U.S. Bureau of Mines 1981, 1987, 1993	1977-9: Prime Western spelter, delivered, min. 98% metal cont.; 1980-90: High grade, min. 99.9% metal cont., delivered.
	U.S.	1991-2010	U.S.-\$/mt	U.S. Geological Survey 1996, 2001, 2007, 2011b	Special high grade, delivered, min. 99.99% metal cont.
Zinc	Germany	1840-1975	Marks/mt	Schmitz 1979, pp. 299-303	1840-1914: Upper Silesian zinc ex-works at Breslau; 1924-34: Berlin Metal Exchange quotation for primary zinc, min. 97% metal cont.
	Germany	1977-8	U.S.-\$/mt	U.S. Bureau of Mines 1980, p. 981	Prime Western grade, min. 98% metal cont., LME warehouse, Hamburg.
	Germany	1979-2010	U.S.-\$/mt	BGR 2011a	Special high grade, min. 99.995% metal cont., cash, LME warehouse, Hamburg.

Note: Parts of the data described in the table above are based on a revised and extended version of data used in figures in Stuermer and von Hagen (2012).

Table 7: Data sources for the producer price indices.

Country	Time	Source	Notes
Belgium	1840-1980	Mitchell 2003a, pp. 857-8	Wholesale price index
	1981-2011	IMF, 2012a	Wholesale price index/ producer price index
Finland	1913-48	Mitchell 2003a, pp. 858-60	Wholesale price index
	1949-2011	IMF, 2012a	Wholesale price index/ producer price index
France	1850-1980	Mitchell 2003a, pp. 857-8	1850-1974: Wholesale price index; 1974-80: No general index published, producer price index for metals products.
	1981-96	IMF, 2012a	Producer price index for intermediate goods
	1997-2010	IMF, 2012a	Wholesale price index/ producer price index
Germany	1850-1991	Mitchell 2003a, pp. 857-8	Wholesale price index
	1992-2011	IMF, 2012a	Wholesale price index/ producer price index
Italy	1861-1981	Mitchell 2003a, pp. 857-60	Wholesale price index
	1982-2011	IMF, 2012a	Wholesale price index/ producer price index
Japan	1901-60	Mitchell 1998, pp. 945-8	Wholesale price index
	1961-2011	IMF, 2012a	Wholesale price index/ producer price index
Netherlands	1901-53	Mitchell 2003a, pp. 857-60	Wholesale price index
	1954-2011	IMF, 2012a	Wholesale price index/ producer price index
South Korea	1930-53	Mitchell 1998, pp. 945-8	Wholesale price index; value for 1952: crude estimate by author
	1954-2011	IMF, 2012a	Wholesale price index/ producer price index
Spain	1850-1948	Mitchell 2003a, pp. 857-60	Wholesale price index
	1949-2011	IMF, 2012a	Wholesale price index/ producer price index
Sweden	1860-1968	Mitchell 2003a, pp. 857-60	Wholesale price index

	1969-2011	IMF, 2012a	Wholesale price index/ producer price index
U.K.	1820-1913	Mitchell 1988, pp. 722-4	Rousseaux price index constructed from wholesale prices and unit-value of imports of vegetable, animal, agricultural, and industrial products.
	1914-59	Mitchell 1988, pp. 725-7	Sauerbeck-Statist price index constructed from wholesale prices and unit-value of food (vegetable and animnal) and raw materials (minerals, textile fibres, sundry).
	1960-2010	World Bank 2012	Wholesale price index
U.S.	1850-9	Mitchell 2003b, p. 702	Wholesale price index
	1860-1912	Hanes 1998	Wholesale price index
	1913-2010	U.S. Bureau of Labor Statistics 2011	Producer price index: all commodities.

Table 8: Data sources for the exchange rates between the British-£ and other currencies.

Country	**Currencies**	**Time**	**Source**	**Notes**
Belgium	British-£ per 1000 Guilders	1840-3	Denzel 2010, p. 21	
	British-£ per 1000 France	1844-1914	Denzel 2010, pp. 21-3	
France	British-£ per 1000 Old Francs	1840-1914	Denzel 2010, pp. 21-3	
Italy	British-£ per 1000 Piedmontese Lire Nuovo	1840-60	Denzel 2010, pp. 41-2	
	British-£ per 1000 Italian Lire	1861-1914	Denzel 2010, pp. 42-3	
Japan	British-£ per 100 Yen	1862-1914	Denzel 2010, pp. 533-4	No data available for 1872.
Netherlands	British-£ per 1000 Guilders	1840-1914	Denzel 2010, pp. 21-3	
Spain	British-£ per 100 Pesos de Plata Antigua	1840-7	Denzel 2010, p. 34	
	British-£ per 100 Pesos Duros	1848-98	Denzel 2010, pp. 34-5	

	British-£ per 1000 Pesetas	1899-1914	Denzel 2010, pp. 35-6
Sweden	British-£ per 1000 Rixdollars Species	1840-57	Denzel 2010, pp. 346-7
	British-£ per 1000 Rixdollars Rixmynt	1858-74	Denzel 2010, p. 347
	British-£ per 1000 Crowns	1875-1914	Denzel 2010, pp. 347-8

Table 9: Data sources for the exchange rates between the U.S.-$ and other currencies.

Country	**Currencies**	**Time**	**Source**	**Notes**
Belgium	Francs per U.S.-$	1915-9	Bordo 2001	
	Francs per U.S.-$	1920-99	Officer 2006	From 1927-40 the exchange rate is expressed in belgas.
	Euro per U.S.-$	2000-11	Officer 2011	
Finland	New Markaa per U.S.-$	1911-70	Bordo 2001	Bordo et al (2001) transformed the original Old Markaa data into New Markaa.
	New Markaa per U.S.-$	1971-99	Officer 2006	
	Euro per U.S.-$	2000-11	Officer 2011	
France	Old Francs per U.S.-$	1915-40	Officer 2006	
	Old Francs per U.S.-$	1941-4	Officer 2011	
	Old Francs per U.S.-$	1945-59	Officer 2006	
	Francs per U.S.-$	1960-99	Officer 2006	
	Euro per U.S.-$	2000-2011	Officer 2011	
Germany	Mark per U.S.-$	1976-1999	Officer 2006	
	Euro per U.S.-$	2000-2011	Officer 2011	
Italy	Lire per U.S.-$	1915-1940	Officer 2006	
	Lire per U.S.-$	1941-7	Bordo 2001	
	Lire per U.S.-$	1948-99	Officer 2006	
	Euro per U.S.-$	2000-11	Officer 2011	
Japan	Yen per U.S.-$	1915-55	Bordo 2001	
	Yen per U.S.-$	1956-2011	Officer 2011	
Netherlands	Guilder per U.S.-$	1915-40	Officer 2006	

	Guilder per U.S.-$	1941	Bordo 2001
	Guilder per U.S.-$	1945-99	Officer 2006
	Euro per U.S.-$	2000-11	Officer 2011
South Korea	Won per U.S.-$	1971-81	Bordo 2001
	Won per U.S.-$	1982-2009	Officer 2011
	Won per U.S.-$	2010	IMF, 2012a
	Won per U.S.-$	2011	Officer 2011
Spain	Loyalist Peseta per U.S.-$	1915-38	Officer 2006
	National Peseta per U.S.-$	1939-41	Officer 2006
	National Peseta per U.S.-$	1947-78	Bordo 2001
	National Peseta per U.S.-$	1979-99	Officer 2006
	Euro per U.S.-$	2000-11	Officer 2011
Sweden	Kronor per U.S.-$	1915-41	Officer 2006
	Kronor per U.S.-$	1942-5	Bordo 2001
	Kronor per U.S.-$	1946-99	Officer 2006
	Kronor per U.S.-$	2000-11	Officer 2011
U.K.	British-£per U.S.-$	1791-2011	Officer 2013

Table 10: Data sources for the manufacturing data.

Country	**Time**	**Source**	**Notes**
Belgium	1850-1988	Smits et al. 2009	GDP in current prices, total industry (incl. mining, manufacturing, energy, and construction).
	1989-94	OECD, 2012	GDP in current prices, total industry (incl. mining, manufacturing, energy, and construction).

	1995-2011	OECD, 2012	GDP in current prices, manufacturing.
Finland	1860-2001	Smits et al. 2009	GDP in current prices, manufacturing.
	2002-10	OECD, 2012	GDP in current prices, manufacturing.
France	1850-1913	Smits et al. 2009	GDP in current prices, total industry (incl. mining, manufacturing, energy, and construction).
	1920-38	Smits et al. 2009	GDP in current prices, total industry (incl. mining, manufacturing, energy, and construction).
	1950-60	United Nations, Statistical Office 1963, p. 270	GDP in current prices, manufacturing (incl. also fishing and the quarring of building materials).
	1961-9	United Nations, Statistical Office 1972	GDP in current prices, manufacturing.
	1970-98	Groningen Growth and Development Centre 2008	GDP in current prices, manufacturing.
	1999-2009	OECD, 2012	GDP in current prices, manufacturing.
	2010	OECD, 2012	GDP in current prices, manufacturing.
Germany	1850-1949	Hoffmann 1965	NDP at factor costs in constant 1913 prices, Industry and handcraft (incl. no mining, but possibly energy and construction); 1914-24 and 1939-49: linear trends.
	1950-90	Groningen Growth and Development Centre 2008	GDP at constant prices (base year = 1991); manufacturing; West Germany.
	1991-2011	Statistisches Bundesamt der Bundesrepublik Deutschland 2012	GDP in current prices, manufacturing.
Italy	1861-69	Baffigi 2011	GDP in current prices, manufacturing.
	1970-2010	OECD, 2012	GDP in current prices, manufacturing.
Japan	1885-1940	Timmer and de Vries 2007, p. 283	NDP in current prices, mining and manufacturing.

	1941-54	Ohkawa and Rosovsky 1973	NDP in current prices, manufacturing.
	1955-98	Ministry of Internal Affairs and Communication of Japan 2012	GDP in current prices, manufacturing.
	1999-2008	Japan Cabinet Office 2010	GDP in current prices, manufacturing.
	2009-2010	OECD, 2012	GDP in current prices, manufacturing.
Netherlands	1850-1912	Groningen Growth and Development Centre 2008	GDP in current prices, manufacturing.
	1913-39	Smits and Van der Bie 2001, pp. 90-3	GDP in current prices, manufacturing, data for the ceramic, glass, and diamonds sectors has been computed based on data from Smits et al. (2000).
	1948-55	United Nations, Statistical Office 1963	GDP in current prices, manufacturing, 1949: linear trend.
	1956-62	United Nations, Statistical Office 1966	GDP in current prices, manufacturing.
	1963-68	United Nations, Statistical Office 1977	GDP in current prices, manufacturing. 1964 and 1966: linear trend.
	1969-2010	OECD, 2012	GDP in current prices, manufacturing.
South Korea	1911-40	Smits et al. 2009	GDP in current prices, manufacturing.
	1953-2011	Bank of Korea 2012	Manufacturing as a percentage share of GDP.
Spain	1850-1954	Smits et al. 2009	GDP in current prices, manufacturing.
	1955-9	United Nations, Statistical Office 1966	GDP in current prices, manufacturing.
	1960-9	United Nations, Statistical Office 1972	GDP in current prices, manufacturing.
	1970-94	Groningen Growth and Development Centre 2008	GDP in current prices, manufacturing.
	1995-2009	OECD, 2012	GDP in current prices, manufacturing.
Sweden	1850-1969	Smits et al. 2009	GDP in current prices, manufacturing.
	1970-92	Groningen Growth and Development Centre 2008	GDP in current prices, manufacturing.

	1993-2010	OECD, 2012	GDP in current prices, manufacturing.
U.K.	1840-1919	Mitchell 2003a	GDP in current prices, total industry.
	1920-59	Mitchell 1988	GDP in current prices, total industry.
	1960-2010	OECD, 2012	GDP in current prices, total industry.
U.S.	1869-89	Smits et al. 2009	GNP in current prices, manufacturing, 1870-8 and 1880-8: linear trend.
	1890-8		Linear trend.
	1899-1937	Martin 1939	GNP in current prices, manufacturing.
	1938-46		Linear trend.
	1947-97	Groningen Growth and Development Centre 2008	GNP in current prices, manufacturing.
	1998-2010	OECD, 2012	GDP in current prices, manufacturing.

Table 11: Data sources for the usage of aluminum.

Country	**Time**	**Source**	**Notes**
Belgium	1930-2010	BGR 2012	Refined aluminum; including Luxembourg.
Finland	1946-2010	BGR 2012	Refined aluminum.
France	1893-9	Metallgesellschaft 1905, p. 30	Computed from import, export, and production data for aluminum.
	1900-2010	BGR 2012	Refined aluminum.
Germany	1892-5	Metallgesellschaft 1905, p. 30	Usage equals refined aluminum production; no imports and exports according to Metallgesellschaft; production includes Austria-Hungary and Switzerland as it is based on data of the Aluminium Industrie AG with production facilities in Neuhausen (Switzerland), Rheinfelden (Germany), and Lend-Gastein (Austria).
	1895-9	Metallgesellschaft 1905, p. 30	Computed from German exports and imports of refined aluminum and refined aluminum production for Austria-Hungary, Switzerland, and Germany, as it is based on data of the Aluminium Industrie AG with production facilities in Neuhausen (Switzerland), Rheinfelden (Germany), and Lend-Gastein (Austria).
	1900-9	Metallgesellschaft 1910, p. 16	Aluminum; estimates by Metallgesellschaft.
	1910-2	Metallgesellschaft 1913, p. 16	Aluminum.
	1913	Metallgesellschaft 1927, p. 4	Aluminum.
	1914-9	Metallgesellschaft 1922, p. 4	Aluminum.
	1920-2010	BGR 2012	Refined aluminum. 1949-90: West Germany.
Italy	1908-2010	BGR 2012	Refined aluminum.
Japan	1911-2010	BGR 2012	Refined aluminum.
Netherlands	1946-2010	BGR 2012	Refined aluminum.

South Korea	1962-2010	BGR 2012	Refined aluminum. 1964: linear trend.
Spain	1938-2010	BGR 2012	Refined aluminum.
Sweden	1929-2010	BGR 2012	Refined aluminum.
U.K.	1890-1	Metallgesellschaft 1899, p. 32	Usage equal to production of aluminum. No data on imports and exports available. I assume no considerable amounts of imports and exports.
	1892-9	Metallgesellschaft 1905, p. 30	Usage equal to production of aluminum. No data on imports and exports available. I assume no considerable amounts of imports and exports. 1895: lin. trend.
	1900-2010	BGR 2012	Refined aluminum.
U.S.	1890-1	Metallgesellschaft 1899, p. 32	Computed from imports and domestic production of aluminum. No export data available.
	1892-9	Metallgesellschaft 1905, p. 30	Computed from imports and domestic production of aluminum. Export data only in U.S.-$ terms. According to this data, quantities seem to be not considerable.
	1900-2010	BGR 2012	Refined aluminum.

Note: Parts of the data described in the Table above and in Tables 12, 14, 15 are based on a revised and extended version of data used in figures in Stuermer and von Hagen (2012).

Table 12: Data sources for the usage of copper.

Country	**Time**	**Source**	**Notes**
Belgium	1900-2010	BGR 2012	Refined copper.
Finland	1941-2010	BGR 2012	Refined copper.
France	1881-4	Metallgesellschaft 1899, p. 53	Unwrought copper including changes in apparent stocks.
	1885-1902	Metallgesellschaft 1905, p. 51	Unwrought copper including changes in apparent stocks.
	1903-12	Metallgesellschaft 1913, p. 50	Unwrought copper including changes in apparent stocks.
	1913-2010	BGR 2012	Refined copper.

Germany	1850-64	Bienengräber 1868, pp. 303-4, Schmitz 1979, p. 63	Computed from imports and exports of unwrought copper and brass (Bienengräber, 1868), and the production of primary copper (Schmitz, 1979).
	1865-6	Schmitz 1979, p. 63	Exports and imports: linear trends; computed from imports and exports and the production of primary copper (Schmitz, 1979).
	1867	Hirth 1869, p. 122, Schmitz 1979, p. 63	Computed from imports and exports of primary and secondary copper (Hirth, 1869), and the production of primary copper (Schmitz, 1979).
	1868-71	Hirth 1871, p. 560 and 670, Schmitz 1979, p. 63	Computed from imports and exports of primary and secondary copper (Hirth, 1871), and the production of primary copper (Schmitz, 1979); imports in 1871: linear trend; exports in 1870-1: linear trend.
	1872-5	Kaiserliches Statistisches Amt 1890, p. 144	Computed from imports and exports of primary and secondary copper, and the production of primary copper of the German Reich, excluding Hamburg.
	1876-80	Kaiserliches Statistisches Amt 1890, p. 131	Computed from imports and exports of primary and secondary copper, and the production of primary copper of the German Reich, excluding Hamburg. Hamburg joined the German customs area in 1881, but maintained a free trade zone. Copper production in Hamburg started in 1878 with a relatively small amount of 40t p.a.
	1881-4	Metallgesellschaft 1899, p. 49	Computed from imports, exports, and the production of unwrought copper of the German Reich, excluding Hamburg.
	1885-94	Metallgesellschaft 1913, p. 30	Computed from imports, exports, and the production of unwrought copper of the German Reich, excluding Hamburg.
	1895-9	Metallgesellschaft 1913, p. 45	Computed from imports, exports, and the production of unwrought copper of the German Reich, excluding Hamburg.
	1900-2010	BGR 2012	Refined copper.
Italy	1881-4	Metallgesellschaft 1899, p. 55	Unwrought copper and copper alloys.
	1885-1902	Metallgesellschaft 1905, p. 53	Unwrought copper and copper alloys.
	1903-11	Metallgesellschaft 1913, p. 54	Unwrought copper.
	1912-2010	BGR 2012	Refined copper.

Japan	1885-8	House of Commons 1892b, pp. 128-9, Mitchell 1998, p. 387	Computed from imports, exports (House of Commons, 1901), and the mine production of copper (Mitchell, 1998). 1886: linear trend.
	1889-91	House of Commons 1901, pp. 156-7, Mitchell 1998, p. 387	Computed from imports, exports (House of Commons, 1901), and the mine production of copper (Mitchell, 1998).
	1892-1900	House of Commons 1901, pp. 156-7, House of Commons 1914, p. 485	Computed from imports, exports (House of Commons, 1901), and the production of copper (House of Commons, 1914); Exports 1900: linear trend.
	1901-10	House of Commons 1914, pp. 238-9, BGR 2012b	Computed from imports and exports of unwrought copper and the domestic production of refined copper.
	1911-2010	BGR 2012	Refined copper.
Netherlands	1864-9	House of Commons 1874, pp. 40-5	Computed from imports and exports of unwrought copper; no domestic production.
	1870-80	House of Commons 1881, pp. 62-4	Computed from imports and exports of unwrought copper; no domestic production; no reasonable data in 1872.
	1881-90	House of Commons 1892b, pp. 82-5	Computed from imports and exports of unwrought copper; no domestic production; no reasonable data in 1882.
	1891-9	House of Commons 1901, pp. 92-5	Computed from imports and exports of unwrought copper; no domestic production.
	1900		Linear trend.
	1901-12	House of Commons 1914, pp. 136-9	Computed from imports and exports of unwrought copper; no domestic production.
	1913	House of Commons 1915, pp. 32-4	Computed from imports and exports of unwrought copper; no domestic production; quantities during the eleven months ended in November.
	1914-6	House of Commons 1917, pp. 26-8	Computed from imports and exports of unwrought copper; no domestic production.
	1918-20	House of Commons 1921, p. 38	Computed from imports and exports of unwrought copper; no domestic production.
	1921	House of Commons 1922, p. 34	Computed from imports and exports of unwrought copper; no domestic production.
	1924-2010	BGR 2012	Refined copper.
South Korea	1964-2010	BGR 2012	Refined copper.
Spain	1922-2010	BGR 2012	Refined copper.

Sweden	1922-2010	BGR 2012	Refined copper.
U.K.	1850	House of Commons 1852, pp. 87-9, Schmitz 1979, p. 209	Computed from imports of unwrought and partly wrought copper, exports of unwrought copper, and the domestic smelter production.
	1851	House of Commons 1853, pp. 99-100, Schmitz 1979, p. 209	Computed from imports of unwrought and partly wrought copper, exports of unwrought copper, and the domestic smelter production.
	1852	House of Commons 1854c, pp. 101-2, Schmitz 1979, p. 209	Computed from imports of unwrought and partly wrought copper, exports of unwrought copper, and the domestic smelter production.
	1853	House of Commons 1855, pp. 2-3, Schmitz 1979, p. 209	Computed from imports of unwrought and partly wrought copper, exports of unwrought copper, and the domestic smelter production.
	1854-80	House of Commons 1882, pp. 110-21, Schmitz 1979, p. 209	Computed from imports of unwrought and partly wrought copper, exports of unwrought copper, and the domestic smelter production. Production data from 1877-80: House of Commons (1884a, p. 44), copper produced (computed by source from copper ores and precipitat from mines in the UK, colonial and foreign ores imported, copper precipitate and regulus imported and burnt ores from imported cupreous pyrites, deducting British copper ores exported to foreign countries).
	1881	House of Commons 1885a, p. 23, House of Commons 1884a, p. 44	Computed from imports of unwrought and partly wrought copper, exports of unwrought copper, and the domestic copper production (computed by House of Commons (1884a) from copper ores and precipitat from mines in the UK, colonial and foreign ores imported, copper precipitate and regulus imported and burnt ores from imported cupreous pyrites, deducting British copper ores exported to foreign countries).
	1882	House of Commons 1884a, pp. 41-4	Computed from imports of unwrought and partly wrought copper, exports of unwrought copper, and domestic copper production (computed by source from copper ores and precipitat from mines in the UK, colonial and foreign ores imported, copper precipitate and regulus imported and burnt ores from imported cupreous pyrites, deducting British copper ores exported to foreign countries).
	1883	House of Commons 1884b, pp. 43-5, House of Commons 1885b, p. 42	do.

	1884	House of Commons 1885b, pp. 39-41	do.
	1885	House of Commons 1886, pp. 39-41	do.
	1885	House of Commons 1886, pp. 39-41	do.
	1886	House of Commons 1887, pp. 45-7, House of Commons 1888, p. 33	do.
	1887	House of Commons 1888, pp. 28-33	do.
	1888-9	House of Commons 1891a, pp. 30-2	do.
	1890	House of Commons 1891b, pp. 32-5	do.
	1891	House of Commons 1892a, pp. 34-7	do.
	1892-3	House of Commons 1894, pp. 42-6	do.
	1894-5	House of Commons 1896, pp. 43-7	do.
	1896-7	House of Commons 1898, pp. 187-90	do.
	1898-9	House of Commons 1900, pp. 189-92	do.
	1900-2010	BGR 2012	Refined copper.
U.S.	1847-9	House of Commons 1854b, p. 2, Carter et al. 2006	Computed from imports of unwrought copper from the U.K., and smelter production from domestic ores. No imports or exports from other countries declared.
	1850-5	House of Commons 1856, p. 351, Carter et al. 2006	do.
	1856-62	Secretary of the Treasury 1864, pp. 44-8, Carter et al. 2006	Computed from imports of copper from the U.K., exports of copper to different countries and smelter production from domestic ores. No imports from other countries declared.
	1863	House of Commons 1866, p. 357, Carter et al. 2006	Computed from imports of pig copper and smelter production from domestic ores. No exports declared.
	1864-8	Weed 1916, p. 1315, House of Commons 1868, p. 377, Carter et al. 2006	Computed from imports of pig copper, exports of refined copper, and smelter production from domestic ores. Imports 1866-8: linear trend.

	1869-78	U.S. Bureau of Statistics 1879, p. 73 & 92, Carter et al. 2006	Computed from imports of copper pigs, bars, ingots, old, and other unmanufactured, exports of pigs, bars, sheets and old, and smelter production from domestic ores. Export and import data: years ended June 30th.
	1879-81	U.S. Bureau of Statistics 1889, p. 87 & 102, Carter et al. 2006	Computed from imports of copper pigs, bars, ingots, old, and other unmanufactured, exports of ingots, bars, sheets and old, and smelter production from domestic ores. Export and import data: years ended June 30th.
	1882-8	U.S. Bureau of Statistics 1889, p. 87 & 102 Schmitz 1979, p. 210	Computed from imports of copper pigs, bars, ingots, old, and other unmanufactured, exports of ingots, bars, and old, and domestic smelter production. Export and import data: years ended June 30th.
	1889-98	U.S. Bureau of Statistics 1899, p. 196 & 168, Schmitz 1979, p. 212	Computed from imports of copper pigs, bars, ingots, old, and other unmanufactured, exports of pigs, ingots, bars, and old, and domestic smelter production. Export and import data: years ended June 30th.
	1899	U.S. Bureau of Statistics 1909, p. 437 & 406, Schmitz 1979, p. 212	Computed from imports of copper pigs, bars, ingots, plats, and old, exports of pigs, ingots, plats, and old, and domestic smelter production. Export and import data: years ended June 30th.
	1900-2010	BGR 2012	Refined copper.

Table 13: Data sources for the usage of refined lead.

Country	**Time**	**Source**	**Notes**
Belgium	1900-2010	BGR 2012	Including Luxembourg.
Finland	1929-2010	BGR 2012	
France	1900-2010	BGR 2012	
Germany	1900-2010	BGR 2012	
Italy	1900-2010	BGR 2012	

Japan	1900-2010	BGR 2012
Netherlands	1906-2010	BGR 2012
South Korea	1967-2010	BGR 2012
Spain	1909-2010	BGR 2012
Sweden	1927-2010	BGR 2012
U.K.	1900-2010	BGR 2012
U.S.	1900-2010	BGR 2012

Table 14: Data sources for the usage of tin.

Country	**Time**	**Source**	**Notes**
Belgium	1900-2010	BGR 2012	Refined tin, including Luxembourg.
Finland			No data available.
France	1889-96	Metallgesellschaft 1899, p. 68	Unwrought tin.
	1897-1902	Metallgesellschaft 1907, p. 83	Unwrought tin.
	1903-2010	BGR 2012	Refined tin.
Germany	1850-64	Bienengräber 1868, pp. 337-8, Neumann 1904, pp. 251-3	Computed from imports and exports of tin in bars, blocks, and old tin, and the production of tin.
	1865-6	Königlich Preussisches Statistisches Bureau 1868, p. 211, Neumann 1904, pp. 251-3	Computed from imports and exports of tin in bars, blocks, and old tin, and the production of tin.
	1867	Hirth 1869, p. 130, Neumann 1904, pp. 251-3	Computed from imports and exports of tin in bars and blocks, and the production of tin. Exports: linear trend.
	1868-9	Hirth 1871, p. 567, Neumann 1904, pp. 251-3	Computed from imports and exports of tin in blocks etc, and the production of tin.
	1870-1	Neumann 1904, pp. 251-3	Computed from imports and exports of tin in blocks etc, and the production of tin. Exports and Imports: linear trends.
	1872-83	Kaiserliches Statistisches Amt 1885, p. 144	Tin.
	1884-5	Metallgesellschaft 1899, p. 66	Unwrought tin.
	1886-1902	Metallgesellschaft 1905, p. 64	Unwrought tin.
	1903-5	Metallgesellschaft 1913, p. 81	Unwrought tin.
	1906-2010	BGR 2012	Refined tin, 1949-90: West-Germany.
Italy	1889-96	Metallgesellschaft 1899, p. 27	Unwrought tin.
	1897-1902	Metallgesellschaft 1907, p. 84	Unwrought tin.
	1900-2010	BGR 2012	Refined tin.
Japan	1902-2010	BGR 2012	Refined tin.

Netherlands	1904-2010	BGR 2012	Refined tin.
South Korea	1969-2010	BGR 2012	Refined tin.
Spain	1900-2010	BGR 2012	Refined tin.
Sweden	1900-2010	BGR 2012	Refined tin.
U.K.	1850-96	Mitchell 1988, pp. 313-21, Schmitz 1979, pp. 164-8, House of Commons 1884a, p. 120	Computed from imports and exports (including re-exports) of unmanufactured tin and the production of metallic tin (equiv. to mine production).
	1897-9	Metallgesellschaft 1907, p. 81	Use of unwrougth tin including changes in apparent stocks.
	1900-2010	BGR 2012	Refined tin.
U.S.	1853-8	House of Commons 1859, p. 29	Tin in pigs and bars; consumption equal to imports as there seems to be no production and exports at the time. Imports: Crude estimates based on the value of imports; year ended 30th June.
	1859-60		Linear trend.
	1861-2	House of Commons 1864, p. 341	Tin in pigs, blocks and bars; consumption equal to imports as there seems to be no production and exports at the time; year ended 30th June.
	1863	House of Commons 1866, p. 358	Tin in blocks and pigs; consumption equal to imports as there seems to be no production and exports at the time, supposed error in data source corrected; year ended 30th June.
	1864-5	House of Commons 1868, p. 378	Tin in blocks and pigs; consumption equal to imports as there seems to be no production and exports at the time, 1864: obvious error in data source corrected; year ended 30th June.
	1866-7	House of Commons 1870, p. 368	Tin in bars, blocks, or pigs; consumption equal to imports as there seems to be no production and exports at the time; year ended 30th June.
	1868	National Bureau of Economic Research 2013	Tin; consumption equal to imports as there seems to be no production and exports at the time; year ended 30th June.
	1869-78	U.S. Bureau of Statistics 1879, pp. 71 and 77	Tin in bars, blocks, pigs, grain, or granulated; consumption equal to imports as there seems to be no production and exports at the time; year ended June 30th.
	1879-88	U.S. Bureau of Statistics 1889, p. 85	Tin in bars, blocks, pigs, grain, or granulated; consumption equal to imports as there seems to be no production and exports at the time; year ended June 30th.

1889-96	Metallgesellschaft 1899, p. 69	Use of unwrougth tin including changes in apparent stocks.
1897-9	Metallgesellschaft 1907, p. 81	Use of unwrougth tin including changes in apparent stocks.
1900-2010	BGR 2012	Refined tin.

Table 15: Data sources for the usage of zinc.

Country	**Time**	**Source**	**Notes**
Belgium	1900-2010	BGR 2012	Refined zinc; including Luxembourg.
Finland	1946-2010	BGR 2012	Refined zinc.
France	1903-2010	BGR 2012	Refined zinc.
Germany	1850-9	Bienengräber 1868, p. 310, Neumann 1904, p. 314	Computed from imports and exports of unwrought zin and the production of zinc.
	1860-78	Kaiserliches Statistisches Amt 1880, p. 136	Unwrought zinc.
	1879-83	Kaiserliches Statistisches Amt 1885, p. 144	Unwrought zinc.
	1884-8	Kaiserliches Statistisches Amt 1890, p. 131	Unwrought zinc.
	1889-96	Metallgesellschaft 1905, p. 56	Unwrought zinc.
	1897-9	Metallgesellschaft 1913, p. 65	Unwrought zinc, no scrap.
	1900-2010	BGR 2012	Refined zinc; 1945-90: West Germany.
Italy	1889-94	Metallgesellschaft 1898, p. 57	Unwrought zinc.
	1895-1902	Metallgesellschaft 1905, p. 61	Unwrought zinc.
	1903-2010	BGR 2012	Refined zinc.
Japan	1911-2010	BGR 2012	Refined zinc.
Netherlands	1889-90	Metallgesellschaft 1897, p. 31	Unwrought zinc; estimate by Metallgesellschaft.
	1891-9	Metallgesellschaft 1901, p. 27	Unwrought zinc; estimate by Metallgesellschaft.
	1900-2010	BGR 2012	Refined zinc.
South Korea	1962-2010	BGR 2012	Refined zinc.
Spain	1900-2010	BGR 2012	Refined zinc.
Sweden	1911-2010	BGR 2012	Refined zinc.
U.K.	1840-9	Mitchell 1988, pp. 312-23	Computed from imports and exports of unmanufactured zinc. No domestic zinc production according to Neumann (1904) and Schmitz (1979) before 1855.

	1850-1	House of Commons 1853, p. 108, Mitchell 1988, pp. 320-3, Neumann 1904, p. 314	Computed from imports of zinc and spelter, and exports of unmanufactured zinc. No domestic zinc production according to Neumann (1904) and Schmitz (1979) before 1855.
	1852-4	Mitchell 1988, pp. 312-7	Computed from imports and exports of unmanufactured zinc. No domestic zinc production according to Neumann (1904) and Schmitz (1979) before 1855.
	1855-9	House of Commons 1882, pp. 17-21, Mitchell 1988, pp. 320-3, Neumann 1904, p. 314	Computed from imports of zinc or spelter, crude, and in cakes, exports of unmanufactured zinc, and the domestic mine production.
	1860-1	House of Commons 1882, pp. 17-21, Mitchell 1988, pp. 320-3, Schmitz 1979, p. 184	Computed from imports of zinc or spelter, crude, and in cakes, exports of unmanufactured zinc, and the domestic mine production.
	1862-9	House of Commons 1882, pp. 17-21, Schmitz 1979, p. 184	Computed from imports and exports of zinc or spelter, crude, and in cakes, and the domestic mine production.
	1870-6	House of Commons 1882, pp. 17-21, BGR 2012b	Computed from imports and exports of zinc or spelter, crude, and in cakes, and the domestic smelter production; 1871: linear trend.
	1877-9	House of Commons 1882, pp. 17-21, Schmitz 1979, p. 184	Computed from imports and exports of zinc or spelter, crude, and in cakes, and the domestic mine production.
	1880	House of Commons 1882, pp. 17-21, Metallgesellschaft 1898, p. 16	Computed from imports and exports of zinc or spelter, crude, and in cakes, and the domestic unwrought zinc production.
	1881-3	House of Commons 1885a, p. 6 and p. 14, Metallgesellschaft 1898, p. 16	Computed from imports and exports of zinc or spelter, crude, and in cakes, and the domestic unwrought zinc production.
	1884-8	Mitchell 1988, pp. 312-23, Metallgesellschaft 1898, p. 16	Computed from imports and exports of unmanufactured zinc, and the domestic unwrought zinc production.
	1889-94	Metallgesellschaft 1899, p. 60	Unwrought zinc; no changes in apparent stocks included.
	1895-1901	Metallgesellschaft 1905, p. 58	Unwrought zinc; no changes in apparent stocks included.
	1902-2010	BGR 2012	Refined zinc.
U.S.	1849-51	House of Commons 1853, p. 109	Usage equal to imports of British zinc or spelter. No production according to Mitchell (1988, p. 366) and Schmitz (1979, p. 184). No export data available. I suppose there have not been considerable amounts of exports.

1852-3	House of Commons 1854a, p. 9	Usage equal to imports of British zinc or spelter. No production according to Mitchell (1988, p. 366) and Schmitz (1979, p. 184). No export data available. I suppose there have not been considerable amounts of exports. Imports 1852: linear trend.
1854-8	House of Commons 1855, p. 9	Usage equal to imports of British zinc or spelter. No production according to Mitchell (1988, p. 366) and Schmitz (1979, p. 184). No export data available. I suppose there have not been considerable amounts of exports. Imports 1855-8: linear trend.
1859	House of Commons 1862, p. 277, Jolly 1992, p. 20	Computed from imports of zinc and spelter and the domestic production of zinc. No export data available. I suppose there have not been considerable amounts of exports.
1860-2	House of Commons 1862, p. 277, BGR 2012b	Computed from imports of zinc and spelter and the domestic refined production of zinc. No export data available. I suppose there have not been considerable amounts of exports. Imports 1861-2: linear trend.
1863	House of Commons 1866, p. 358, BGR 2012b	Computed from imports of zinc in blocks and sheets and the domestic refined production of zinc. No export data available. I suppose there have not been considerable amounts of exports.
1864-6	House of Commons 1868, p. 378, Carter et al. 2006, BGR 2012b	Computed from imports of zinc in blocks and sheets, exports of refined zinc in blocks, pigs, and slabs, and the domestic refined production of zinc. Imports 1866: linear trend.
1867-79	Carter et al. 2006, BGR 2012b	Computed from imports and exports of refined zinc in blocks, pigs, and slabs, and the domestic refined production of zinc.
1880-8	Carter et al. 2006, Metallgesellschaft 1898, p. 16	Computed from imports and exports of refined zinc in blocks, pigs, and slabs, and the domestic production of unwrought zinc.
1889-94	Metallgesellschaft 1899, p. 60	Unwrought zinc.
1895-1904	Metallgesellschaft 1905, p. 63	Unwrought zinc.
1905-2010	BGR 2012	Refined zinc.

7.2 Tables

Variable		Mean	Std. Dev.	Min	Max	Observations	
Per capita GDP	overall	8341	6698	860	31618	N =	1454
(Geary-Khamis $)	between		1562	6098	11200	n =	12
	within		6523	-1053	28759	T-bar =	121.1
Per capita value	overall	1807	1273	83	6565	N =	1414
added by manu-	between		320	1209	2266	n =	12
facturing (GK-$)	within		1241	-276	6109	T-bar =	117.8
Per capita use	overall	.0068	.0078	.0000	.0490	N =	1094
of aluminum	between		.0037	.0036	.0171	n =	12
(mt/person)	within		.0071	-.0102	.0388	T-bar =	91.1
Per capita use	overall	.0056	.0063	.0000	.0402	N =	1401
of copper	between		.0038	.0013	.0139	n =	12
(mt/person)	within		.0053	-.0080	.0319	T-bar =	116.8
Per capita use	overall	.0032	.0018	.0001	.0079	N =	1189
of lead	between		.0012	.0015	.0051	n =	12
(mt/person)	within		.0014	-.0009	.0076	T-bar =	99.1
Per capita use	overall	.0002	.0001	.0000	.0008	N =	1292
of tin	between		.0001	.0001	.0004	n =	11
(mt/person)	within		.0001	-.0001	.0007	T-bar =	117.4
Per capita use	overall	.0038	.0045	.0000	.0384	N =	1391
of zink	between		.0034	.0017	.0146	n =	12
(mt/person)	within		.0031	-.0102	.0276	T-bar =	115.9
Real price of	overall	1046	5333	.77	140411.3	N =	1288
aluminum (local	between		1995	8.50	6491	n =	12
currencies per mt)	within		4976	-4545	134966	T-bar =	107.3
Real price of	overall	602	1330	0.92	8358	N =	1381
copper (local	between		1234	2.73	3804	n =	12
currencies per mt)	within		566	-2577	5156	T-bar =	115.1
Real price of	overall	180	392	.28	2633	N =	1376
lead (local	between		366	.73	1116	n =	12
currencies per mt)	within		161	-656	1698	T-bar =	114.7
Real price of	overall	1856	4155	2.53	29042	N =	1368
tin (local	between		3750	6.55	11799	n =	12
currencies per mt)	within		1925	-6920	19099	T-bar =	114
Real price of	overall	238	518	.47	3798	N =	1364
zinc (local	between		480	.81	1477	n =	12
currencies per mt)	within		218	-949	2837	T-bar =	113.7

Table 16: Detailed summary statistics.

7.3 Additional figures

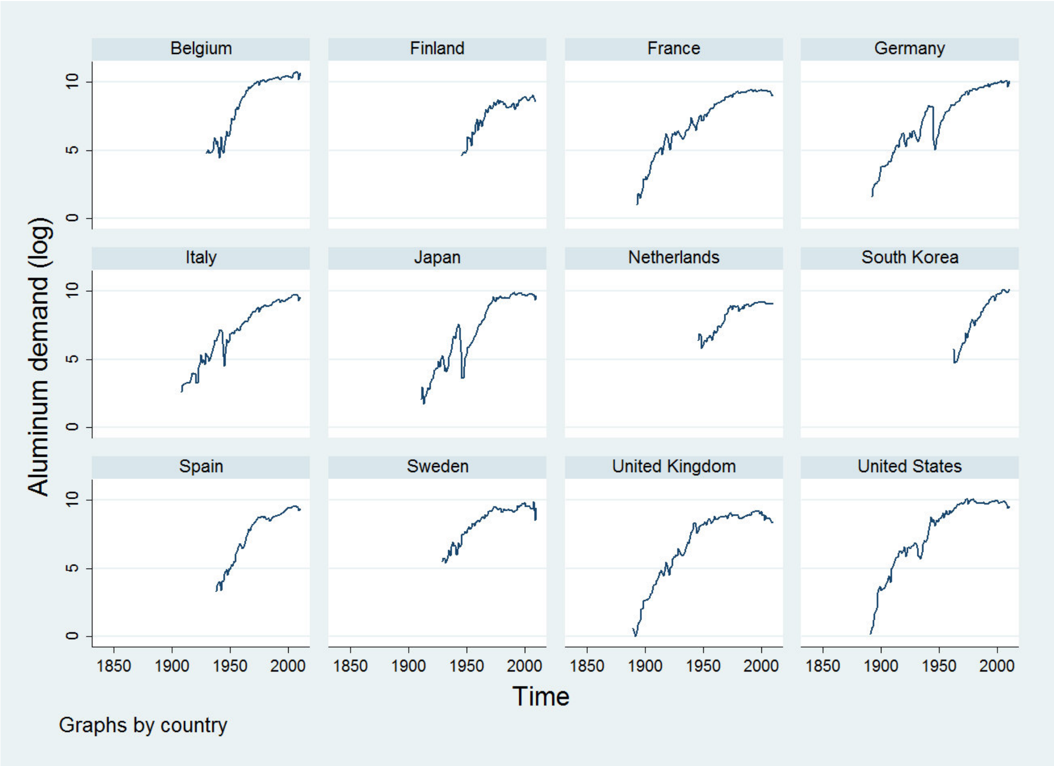

Figure 2: Per capita use of aluminum (log).

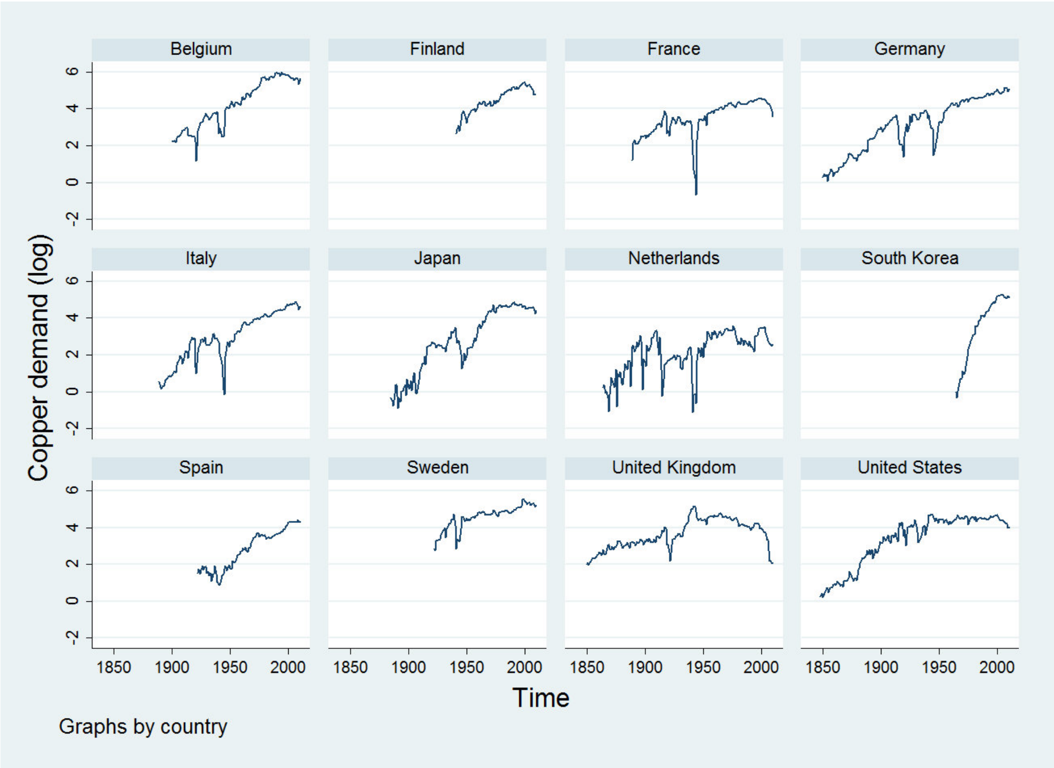

Figure 3: Per capita use of copper (log).

Figure 4: Per capita use of lead (log).

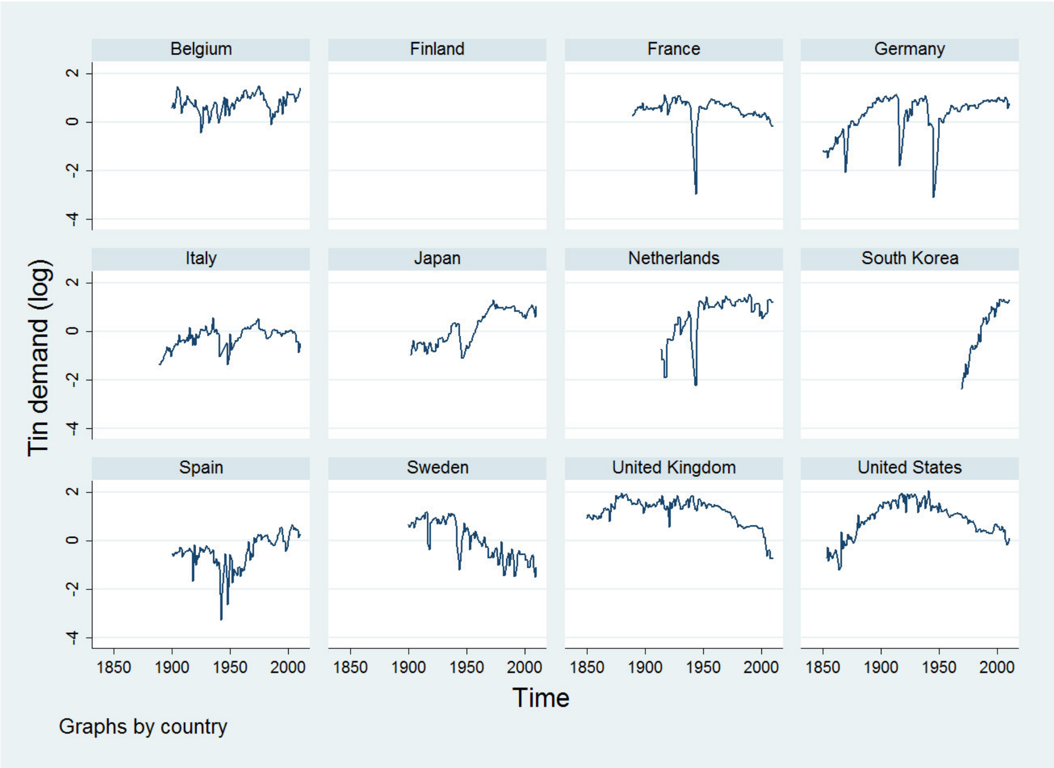

Figure 5: Per capita use of tin (log).

Figure 6: Per capita use of zinc (log).

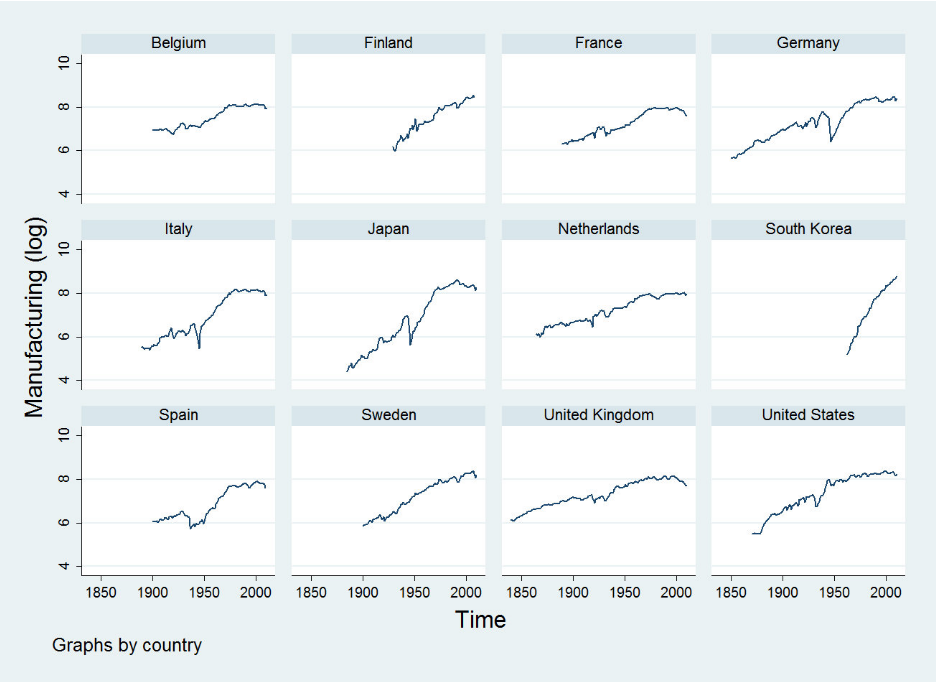

Figure 7: Per capita value added by the manufacturing sector (log).

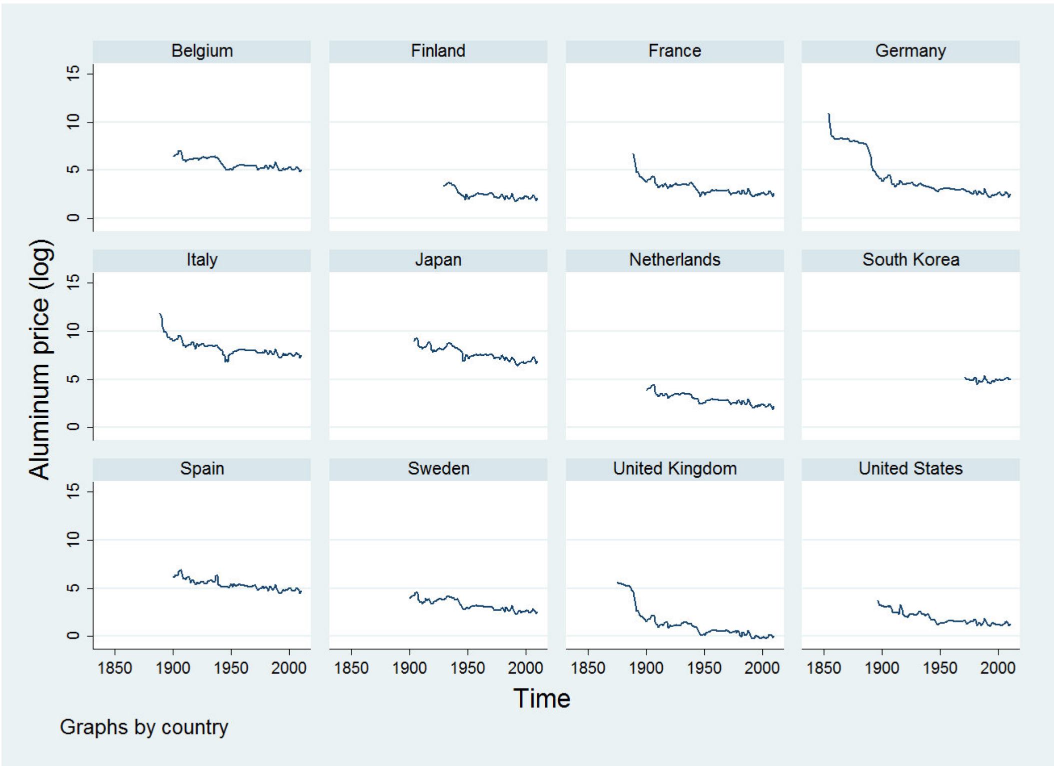

Figure 8: Real price of aluminum (log).

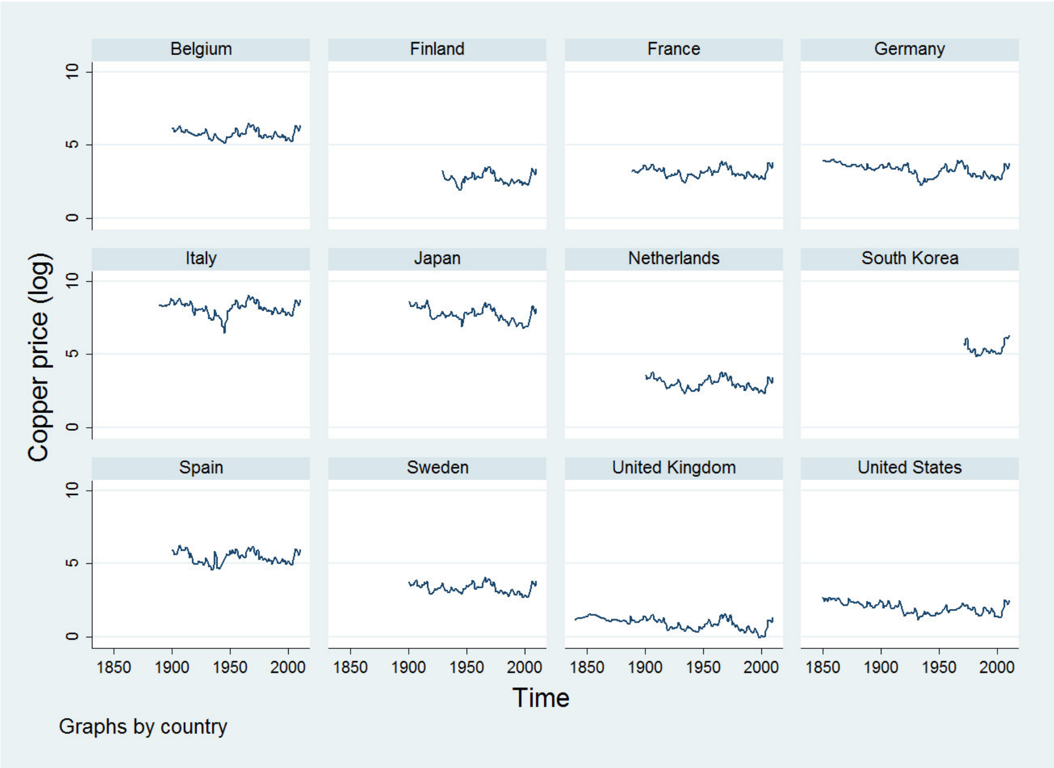

Figure 9: Real price of copper (log).

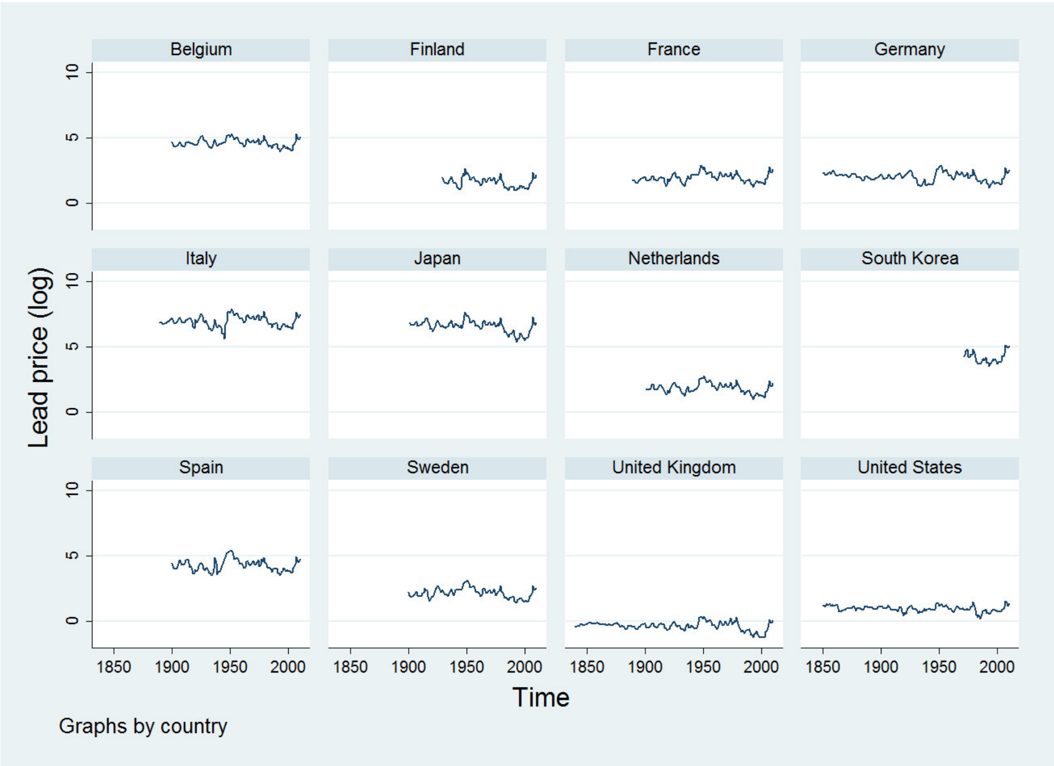

Figure 10: Real price of lead (log).

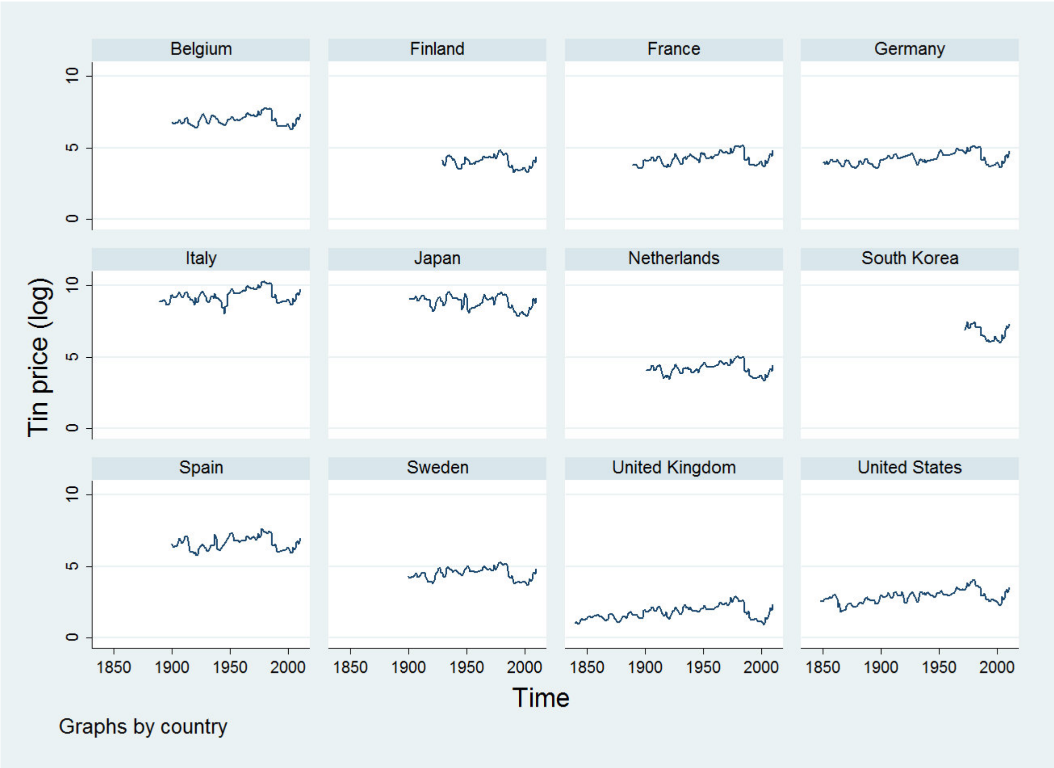

Figure 11: Real price of tin (log).

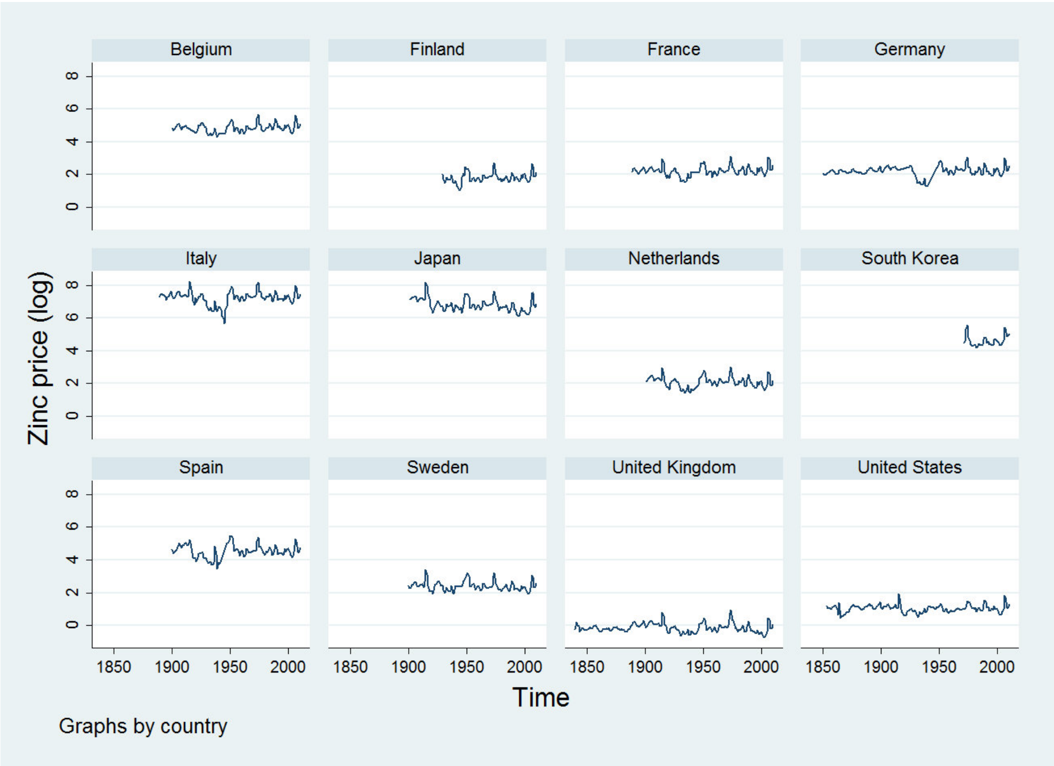

Figure 12: Real price of zinc (log).

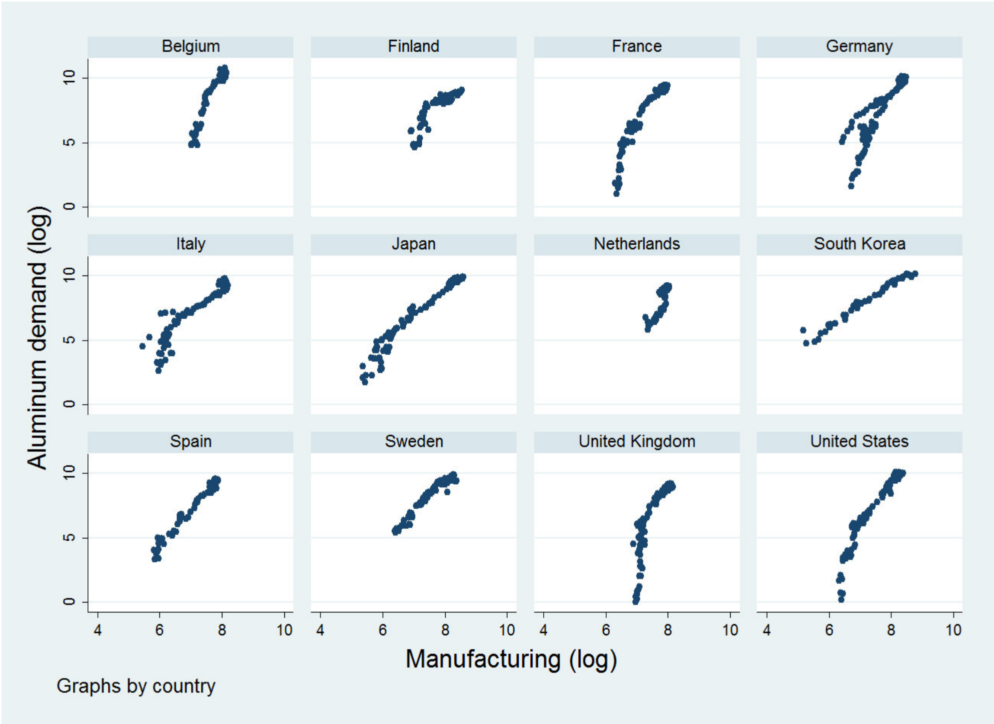

Figure 13: Scatter plot of per capita value added by manufacturing (horizontal axis) and per capita aluminum use (vertical axis).

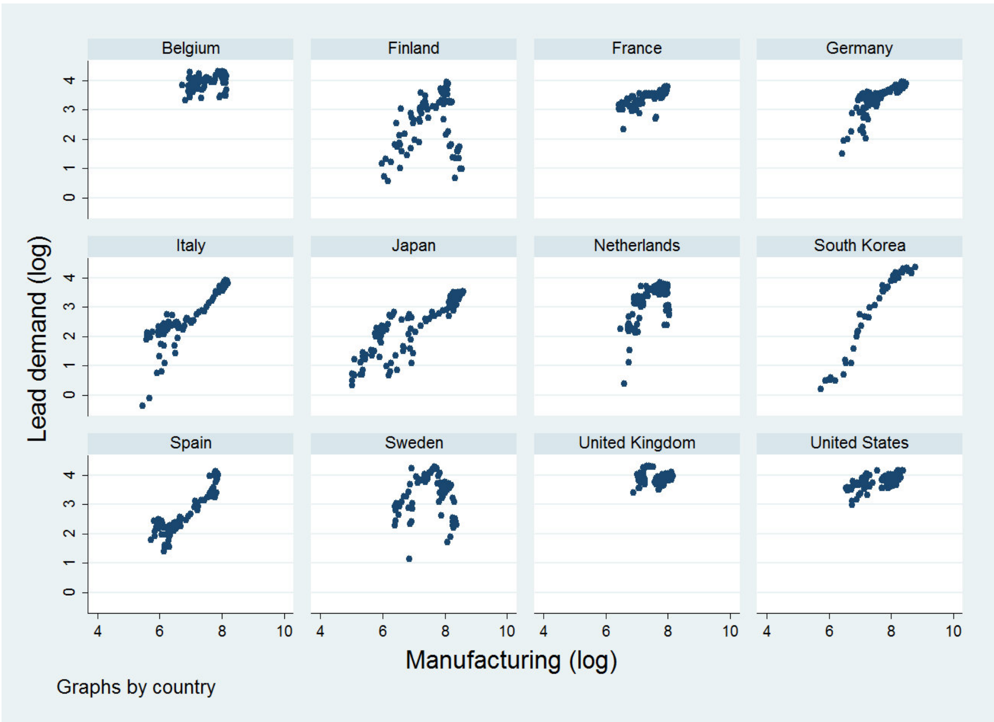

Figure 14: Scatter plot of per capita value added by manufacturing (horizontal axis) and per capita lead use (vertical axis).

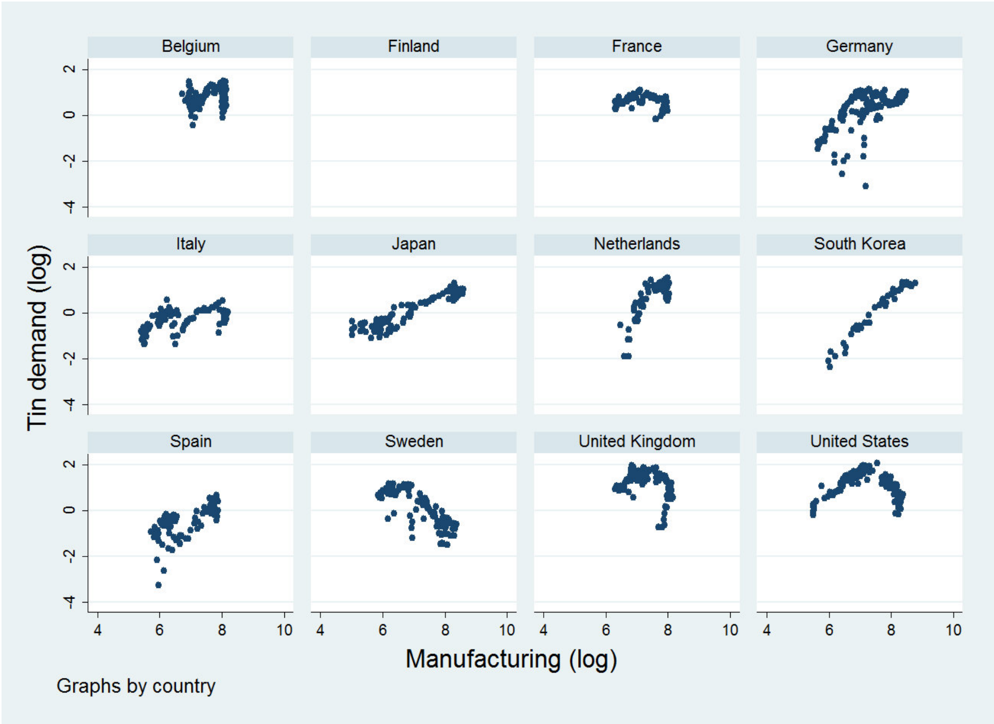

Figure 15: Scatter plot of per capita value added by manufacturing (horizontal axis) and per capita tin use (vertical axis).

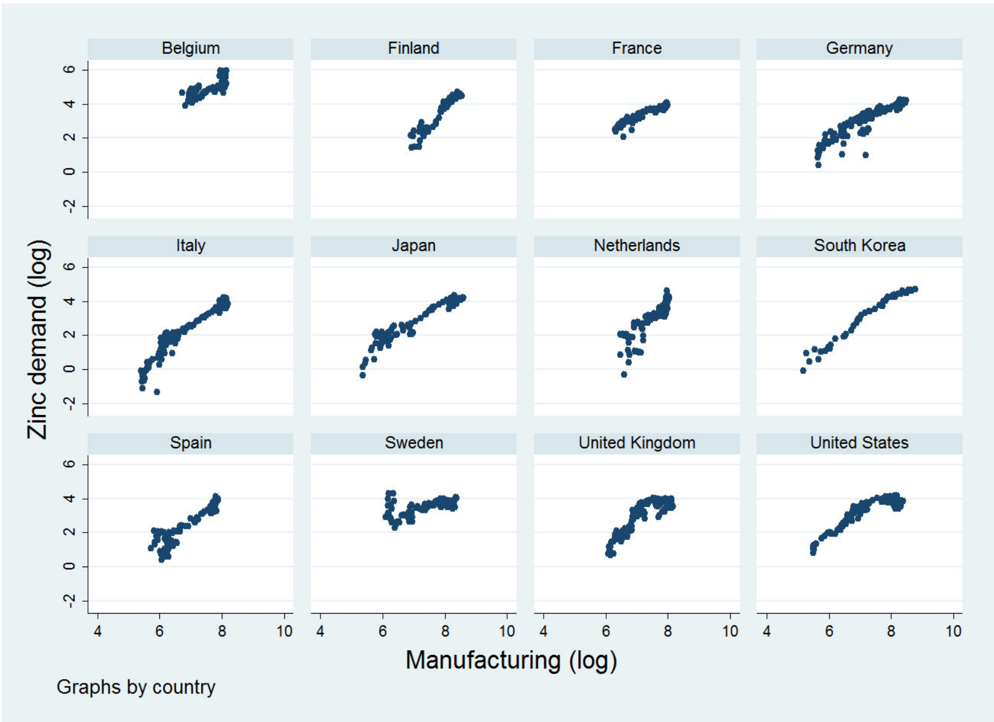

Figure 16: Scatter plot of per capita value added by manufacturing (horizontal axis) and per capita zinc use (vertical axis).

7.4 Regression results

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	0.287	1.551***	1.542***	0.565	1.759***	1.439***	0.792	1.518***	1.353***
	(1.315)	(0.092)	(0.194)	(1.411)	(0.173)	(0.248)	(0.521)	(0.073)	(0.200)
Aluminum price (log)	-0.363	-0.706***	-0.919***	-1.076	-0.883***	-0.801**	-1.474***	-0.836***	-1.258***
	(1.621)	(0.184)	(0.267)	(0.809)	(0.221)	(0.322)	(0.526)	(0.236)	(0.355)
Linear trend				0.006	-0.012*	0.005			
				(0.017)	(0.007)	(0.008)			
Adjustment coefficient	-0.124***	-0.117***	-0.080***	-0.150***	-0.113***	-0.083***	-0.189***	-0.142***	-0.107***
	(0.027)	(0.023)	(0.010)	(0.032)	(0.023)	(0.011)	(0.035)	(0.031)	(0.016)
Constant	0.028	-0.056	0.014	2.291	1.411***	-0.413	0.169	0.054	-0.005
	(0.743)	(0.059)	(0.177)	(2.907)	(0.421)	(0.717)	(0.149)	(0.083)	(0.007)
Observations	973	973	973	973	973	973	973	973	973
Joint Hausman Test-stat.		2.161			3.115			3.024	
p-value		0.339			0.374			0.220	
Log likelihood		404.4			405.2			432.4	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(4,4,2) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 17: Preferred estimates of the long-run manufacturing output and price elasticities of aluminum demand.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	1.053***	0.914***	1.080***	1.020***	1.104***	1.091***	0.932***	1.128***	1.164***
	(0.175)	(0.061)	(0.087)	(0.188)	(0.145)	(0.178)	(0.341)	(0.067)	(0.173)
Copper price (log)	-0.097	-0.400***	-0.142	-0.177	-0.453***	-0.145	-0.523	-0.009	0.222**
	(0.176)	(0.093)	(0.176)	(0.125)	(0.095)	(0.182)	(0.440)	(0.049)	(0.101)
Linear trend				0.006	-0.005	-0.000			
				(0.005)	(0.004)	(0.004)			
Adjustment coefficient	-0.200***	-0.132***	-0.102***	-0.236***	-0.131***	-0.102***	-0.240***	-0.180***	-0.114***
	(0.039)	(0.028)	(0.015)	(0.036)	(0.028)	(0.015)	(0.064)	(0.057)	(0.016)
Constant	-0.754***	-0.161***	-0.387***	-3.733*	0.474***	-0.366	0.094	0.010	0.003
	(0.229)	(0.052)	(0.134)	(2.021)	(0.182)	(0.334)	(0.137)	(0.030)	(0.006)
Observations	1,206	1,206	1,206	1,206	1,206	1,206	1,206	1,206	1,206
Joint Hausman Test-stat.		3.799			98.01			1.693	
p-value		0.150			0			0.429	
Log likelihood		502.3			502.8			434.2	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(4,4,2) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 18: Preferred estimates of the long-run and short-run manufacturing output and price elasticities of copper demand.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	0.208	0.435***	0.436***	1.949***	0.675***	0.795***	1.971	0.745***	0.761***
	(0.202)	(0.057)	(0.144)	(0.664)	(0.110)	(0.256)	(1.657)	(0.112)	(0.259)
Lead price (log)	0.061	-0.220**	0.212	-0.174	-0.215***	0.186	1.893	-0.014	0.113
	(0.606)	(0.093)	(0.277)	(0.111)	(0.080)	(0.249)	(1.727)	(0.204)	(0.510)
Linear trend				-0.046**	-0.005***	-0.009			
				(0.023)	(0.002)	(0.006)			
Adjustment coefficient	-0.158***	-0.094***	-0.074***	-0.214***	-0.121***	-0.083***	-0.211***	-0.148***	-0.086***
	(0.028)	(0.021)	(0.015)	(0.029)	(0.026)	(0.017)	(0.047)	(0.033)	(0.017)
Constant	0.128	0.048**	-0.061	9.787	0.393***	0.507	0.210	0.028	0.002
	(0.173)	(0.022)	(0.111)	(7.065)	(0.095)	(0.408)	(0.157)	(0.022)	(0.007)
Observations	1,059	1,059	1,059	1,059	1,059	1,059	1,059	1,059	1,059
Joint Hausman Test-stat.		1.332			3.423			1.524	
p-value		0.514			0.331			0.467	
Log likelihood		474.7			476.9			435.3	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(4,4,2) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 19: Preferred estimates of the long-run manufacturing output and price elasticities of lead demand.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	-0.302	0.616***	-0.091	0.760***	0.712***	0.517*	0.397	0.295**	0.709***
	(0.475)	(0.035)	(0.151)	(0.226)	(0.080)	(0.268)	(0.445)	(0.141)	(0.273)
Tin price (log)	-0.109	0.169**	-0.569**	-0.138	0.110	-0.454*	-0.166	-0.384***	-0.216
	(0.248)	(0.085)	(0.284)	(0.166)	(0.084)	(0.237)	(0.303)	(0.046)	(0.157)
Linear trend				–0.017***	-0.004	-0.013**			
				(0.005)	(0.003)	(0.005)			
Adjustment coefficient	-0.268***	-0.095**	-0.061***	-0.341***	-0.105**	-0.072***	-0.196***	-0.096***	-0.071***
	(0.082)	(0.040)	(0.012)	(0.126)	(0.043)	(0.013)	(0.038)	(0.030)	(0.013)
Constant	-0.820	-0.522**	0.241***	8.264	-0.149	0.944***	0.222*	0.006	0.008
	(0.756)	(0.209)	(0.093)	(7.147)	(0.118)	(0.338)	(0.123)	(0.026)	(0.006)
Observations	1,142	1,142	1,142	1,142	1,142	1,142	1,142	1,142	1,142
Joint Hausman Test-stat.		7.675			11.37			0.672	
p-value		0.0215			0.00987			0.715	
Log likelihood		399.5			400.1			408.9	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(4,4,2) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 20: Preferred estimates of the long-run manufacturing output and price elasticities of tin demand.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	0.765***	0.734***	0.862***	1.059***	0.852***	0.898***	1.151	0.834***	0.905***
	(0.229)	(0.033)	(0.095)	(0.341)	(0.101)	(0.206)	(0.928)	(0.132)	(0.226)
Zinc price (log)	0.708	-0.064	0.042	0.186	-0.066	0.041	1.005	0.207**	0.123
	(1.223)	(0.088)	(0.253)	(0.397)	(0.084)	(0.253)	(1.540)	(0.083)	(0.116)
Linear trend				-0.007	-0.002	-0.001			
				(0.009)	(0.002)	(0.004)			
Adjustment coefficient	-0.216***	-0.113***	-0.085***	-0.286***	-0.119***	-0.085***	-0.137***	-0.085***	-0.083***
	(0.062)	(0.030)	(0.013)	(0.062)	(0.031)	(0.013)	(0.029)	(0.019)	(0.013)
Constant	-1.247*	-0.204***	-0.269***	1.779	-0.090	-0.218	0.140	-0.017	0.002
	(0.719)	(0.055)	(0.103)	(4.597)	(0.062)	(0.275)	(0.135)	(0.022)	(0.005)
Observations	1,216	1,216	1,216	1,216	1,216	1,216	1,216	1,216	1,216
Joint Hausman Test-stat.		0.759			14.68			0.248	
p-value		0.684			0.00211			0.883	
Log likelihood		579.2			579.8			518.9	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(4,4,2) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 21: Preferred estimates of the long-run manufacturing output and price elasticities of zinc demand.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	2.216***	1.601***	1.737***	2.283***	1.750***	1.602***	1.123***	1.518***	1.371***
	(0.344)	(0.069)	(0.205)	(0.275)	(0.142)	(0.144)	(0.352)	(0.051)	(0.145)
Aluminum price (log)	-0.515**	-0.823***	-1.019***	-0.462	-0.913***	-0.879**	-0.881***	-0.771***	-0.786***
	(0.258)	(0.132)	(0.267)	(0.287)	(0.165)	(0.370)	(0.324)	(0.169)	(0.253)
Linear time trend				-0.004	-0.007	0.006			
				(0.006)	(0.006)	(0.007)			
Adjustment coeff.	-0.192***	-0.135***	-0.082***	-0.224***	-0.131***	-0.085***	-0.284***	-0.200***	-0.128***
	(0.038)	(0.035)	(0.012)	(0.052)	(0.035)	(0.015)	(0.054)	(0.050)	(0.032)
Constant	-1.335***	-0.051	-0.078	2.709	0.986***	-0.591	0.038	0.066	-0.007***
	(0.508)	(0.064)	(0.219)	(3.520)	(0.364)	(0.786)	(0.135)	(0.107)	(0.003)
Observations	1,018	1,018	1,018	1,018	1,018	1,018	1,018	1,018	1,018
Joint Hausman Test-stat.		3.583			3.668			1.153	
p-value		0.167			0.300			0.562	
log likelihood		206.1			206.5			280.0	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(1,1,1) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 22: Estimated long-run manufacturing output and price elasticities of aluminum demand in the ARDL(1,1,1) model.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	1.098***	1.055***	1.097***	1.392***	0.983***	1.113***	0.859***	1.165***	1.248***
	(0.193)	(0.039)	(0.097)	(0.249)	(0.095)	(0.206)	(0.306)	(0.072)	(0.210)
Copper price (log)	-0.182	-0.219***	-0.201*	-0.205*	-0.208***	-0.205*	0.188	0.053	0.232
	(0.121)	(0.072)	(0.107)	(0.115)	(0.071)	(0.107)	(0.201)	(0.051)	(0.157)
Linear trend				-0.004	0.002	-0.000			
				(0.006)	(0.002)	(0.006)			
Adjustment coefficient	-0.238***	-0.168***	-0.132***	-0.274***	-0.168***	-0.132***	-0.253***	-0.199***	-0.145***
	(0.032)	(0.030)	(0.026)	(0.033)	(0.032)	(0.027)	(0.047)	(0.051)	(0.029)
Constant	-1.097***	-0.524***	-0.483***	-0.097	-0.742***	-0.443	0.075	0.010	0.007***
	(0.284)	(0.107)	(0.169)	(1.719)	(0.146)	(0.725)	(0.077)	(0.029)	(0.002)
Observations	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253
Joint Hausman Test-stat.		0.161			15.28			2.332	
p-value		0.923			0.00159			0.312	
log likelihood		352.8			353.1			305.1	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(1,1,1) model. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 23: Estimated long-run manufacturing output and price elasticities of copper demand in the ARDL(1,1,1) model.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	0.454***	0.349***	0.525***	1.553***	0.664***	0.975***	3.540	0.888***	0.966***
	(0.128)	(0.048)	(0.157)	(0.450)	(0.094)	(0.203)	(3.444)	(0.102)	(0.237)
Lead price (log)	0.140	-0.094	0.268	-0.081	-0.092	0.217	5.719	0.067	0.345
	(0.253)	(0.075)	(0.347)	(0.080)	(0.065)	(0.293)	(5.498)	(0.194)	(0.358)
Linear trend				-0.035**	-0.005***	-0.012***			
				(0.016)	(0.002)	(0.004)			
Adjustment coefficient	-0.204***	-0.128***	-0.098***	-0.255***	-0.148***	-0.111***	-0.205***	-0.152***	-0.117***
	(0.029)	(0.024)	(0.016)	(0.030)	(0.027)	(0.020)	(0.041)	(0.026)	(0.024)
Constant	-0.048	0.130***	-0.150	8.441	0.475***	0.829***	0.126	0.017	0.002
	(0.243)	(0.035)	(0.156)	(6.360)	(0.131)	(0.283)	(0.144)	(0.024)	(0.002)
Observations	1,110	1,110	1,110	1,110	1,110	1,110	1,110	1,110	1,110
Joint Hausman Test-stat.		2.541			6.082			2.514	
p-value		0.281			0.108			0.285	
log likelihood		405.6			410.0			358.8	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(1,1,1) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 24: Estimated long-run manufacturing output and price elasticities of lead demand in the ARDL(1,1,1) model.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	0.200	0.257***	0.083	0.683***	0.778***	0.560*	0.248	0.469***	0.814***
	(0.214)	(0.060)	(0.194)	(0.237)	(0.124)	(0.335)	(0.481)	(0.108)	(0.306)
Tin price (log)	-0.031	-0.061	-0.163	-0.014	-0.194**	-0.128	0.221	-0.364***	-0.124
	(0.100)	(0.115)	(0.168)	(0.107)	(0.099)	(0.130)	(0.534)	(0.040)	(0.155)
Linear trend				-0.013*	-0.015***	-0.011*			
				(0.007)	(0.003)	(0.006)			
Adjustment coefficient	-0.254***	-0.118***	-0.089***	-0.292***	-0.127***	-0.102***	-0.267***	-0.137***	-0.100***
	(0.045)	(0.035)	(0.019)	(0.058)	(0.028)	(0.023)	(0.043)	(0.034)	(0.024)
Constant	-0.757	-0.160***	0.057	5.927	1.505**	0.862	0.370**	0.015	0.005**
	(0.535)	(0.050)	(0.131)	(5.246)	(0.599)	(0.592)	(0.168)	(0.032)	(0.002)
Observations	1,194	1,194	1,194	1,194	1,194	1,194	1,204	1,204	1,204
Joint Hausman Test-stat.		-0.541			21.70			1.480	
p-value		1			7.53e-05			0.477	
log likelihood		233.4			236.7			299.4	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(1,1,1) model. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 25: Estimated long-run manufacturing output and price elasticities of tin demand in the ARDL(1,1,1) model.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	1.064***	0.818***	0.965***	0.951***	0.959***	0.945***	0.619	0.951***	1.012***
	(0.146)	(0.030)	(0.143)	(0.212)	(0.076)	(0.257)	(0.526)	(0.090)	(0.282)
Zinc price (log)	-0.288**	-0.148**	-0.178	-0.199*	-0.153**	-0.176	-0.199	0.174***	0.106**
	(0.118)	(0.073)	(0.173)	(0.102)	(0.070)	(0.165)	(0.720)	(0.050)	(0.045)
Linear Trend				-0.000	-0.003*	0.000			
				(0.005)	(0.001)	(0.004)			
Adjustment coefficient	-0.265***	-0.144***	-0.121***	-0.317***	-0.152***	-0.121***	-0.208***	-0.135***	-0.110***
	(0.069)	(0.030)	(0.022)	(0.069)	(0.032)	(0.022)	(0.037)	(0.024)	(0.019)
Constant	-1.495*	-0.319***	-0.399*	-1.528	-0.131	-0.440	0.204*	-0.008	0.002
	(0.827)	(0.069)	(0.208)	(2.594)	(0.086)	(0.299)	(0.122)	(0.023)	(0.001)
Observations	1,266	1,266	.	1,266	1,266	.	1,266	1,266	.
Joint Hausman Test-stat.		2.703			0.478			0.580	
p-value		0.259			0.924			0.748	
log likelihood		456.6			458.1			426.2	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(1,1,1) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 26: Estimated long-run manufacturing output and price elasticities of zinc demand in the ARDL(1,1,1) model.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	0.985*	1.528***	1.618***	1.017	1.740***	1.562***	1.089**	1.584***	1.493***
	(0.548)	(0.042)	(0.203)	(0.929)	(0.131)	(0.271)	(0.499)	(0.072)	(0.208)
Aluminum price (log)	-1.224**	-0.824***	-0.967***	-1.280**	-0.931***	-0.902***	-1.347**	-1.038***	-1.438***
	(0.482)	(0.138)	(0.277)	(0.624)	(0.175)	(0.348)	(0.549)	(0.242)	(0.376)
Linear trend				0.006	-0.012*	0.003			
				(0.018)	(0.007)	(0.009)			
Adjustment coeff.	-0.151***	-0.134***	-0.076***	-0.175***	-0.125***	-0.077***	-0.192***	-0.142***	-0.104***
(0.054)	(0.051)	(0.010)	(0.054)	(0.044)	(0.011)	(0.037)	(0.032)	(0.015)	
Constant	0.073	0.057	-0.019	0.956	1.738**	-0.228	0.110	0.077	-0.009
	(0.515)	(0.081)	(0.177)	(2.087)	(0.776)	(0.715)	(0.143)	(0.107)	(0.007)
Observations	980	980	980	980	980	980	980	980	980
Joint Hausman Test-stat.		0.934			11.31			0.985	
p-value		0.627			0.0102			0.611	
log likelihood		378.2			379.4			422.1	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(3,3,3) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 27: Estimated long-run manufacturing output and price elasticities of aluminum demand in the ARDL (3,3,3) model.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	1.117***	0.963***	1.063***	1.142***	1.399***	1.053***	0.957***	1.047***	1.131***
	(0.160)	(0.055)	(0.085)	(0.139)	(0.097)	(0.175)	(0.321)	(0.063)	(0.177)
Copper price (log)	-0.096	-0.285***	-0.116	-0.130	-0.468***	-0.113	-0.139	-0.041	0.263**
	(0.142)	(0.087)	(0.174)	(0.130)	(0.065)	(0.181)	(0.290)	(0.053)	(0.102)
Linear trend				0.002	-0.012***	0.000			
				(0.004)	(0.003)	(0.004)			
Adjustment coefficient	-0.217***	-0.141***	-0.105***	-0.241***	-0.147***	-0.105***	-0.259***	-0.179***	-0.112***
	(0.048)	(0.028)	(0.015)	(0.047)	(0.041)	(0.015)	(0.067)	(0.049)	(0.016)
Constant	-0.924***	-0.291***	-0.395***	-3.604*	1.514***	-0.416	0.170	0.017	0.005
	(0.218)	(0.059)	(0.134)	(2.176)	(0.586)	(0.341)	(0.170)	(0.028)	(0.006)
Observations	1,213	1,213	1,213	1,213	1,213	1,213	1,213	1,213	1,213
Joint Hausman Test-stat.		2.827			20.72			0.125	
p-value		0.243			0.000120			0.939	
log likelihood		481.2			485.1			427.5	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(3,3,3) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 28: Estimated long-run manufacturing output and price elasticities of copper demand in the ARDL (3,3,3) model.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	0.382***	0.023	0.499***	1.609***	0.779***	0.833***	3.456	0.829***	0.813***
	(0.085)	(0.067)	(0.124)	(0.496)	(0.127)	(0.227)	(3.033)	(0.119)	(0.228)
Lead price (log)	0.070	-0.053	0.289	-0.062	-0.257***	0.244	6.764	-0.014	0.253
	(0.480)	(0.082)	(0.251)	(0.138)	(0.091)	(0.229)	(5.547)	(0.224)	(0.459)
Linear trend				-0.037**	-0.008***	-0.008			
				(0.018)	(0.002)	(0.005)			
Adjustment coefficient	-0.151***	-0.085***	-0.083***	-0.201***	-0.117***	-0.092***	-0.207***	-0.143***	-0.095***
	(0.019)	(0.026)	(0.015)	(0.017)	(0.023)	(0.016)	(0.043)	(0.026)	(0.016)
Constant	0.150	0.287***	-0.126	6.902	0.692***	0.471	0.281	0.025	0.001
	(0.164)	(0.103)	(0.112)	(4.594)	(0.167)	(0.402)	(0.171)	(0.022)	(0.007)
Observations	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068
Joint Hausman Test-stat.		40.09			2.956			2.321	
p-value		1.97e-09			0.398			0.313	
log likelihood		490.8			491.7			444.8	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(3,3,3) model. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 29: Estimated long-run manufacturing output and price elasticities of lead demand in the ARDL (3,3,3) model.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	-0.203	0.611***	-0.010	0.988***	-0.490	0.815***	0.406	1.158***	0.834***
	(0.422)	(0.041)	(0.163)	(0.296)	(0.358)	(0.279)	(0.500)	(0.081)	(0.276)
Tin price (log)	-0.273	0.019	-0.736**	-0.224*	-0.229	-0.561**	-0.094	-0.124	-0.131
	(0.190)	(0.114)	(0.340)	(0.135)	(0.187)	(0.262)	(0.317)	(0.093)	(0.157)
Linear trend				-0.019***	-0.008	-0.018***			
				(0.007)	(0.009)	(0.006)			
Adjustment coefficient	-0.228***	-0.086**	-0.054***	-0.283***	-0.063*	-0.068***	-0.195***	-0.106***	-0.068***
	(0.060)	(0.035)	(0.011)	(0.081)	(0.032)	(0.012)	(0.035)	(0.026)	(0.013)
Constant	-0.591	-0.388**	0.227**	6.782	1.001*	1.137***	0.213*	0.009	0.004
	(0.607)	(0.153)	(0.092)	(5.190)	(0.594)	(0.332)	(0.121)	(0.018)	(0.006)
Observations	1,152	1,152	1,152	1,152	1,152	1,152	1,152	1,152	1,152
Joint Hausman Test-stat.		6.140			41.56			2.210	
p-value		0.0464			4.97e-09			0.331	
log likelihood		392.7			395.0			399.0	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(3,3,3) model. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 30: Estimated long-run manufacturing output and price elasticities of tin demand in the ARDL (3,3,3) model.

VARIABLES	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Time fixed effects	No	No	No	No	No	No	Yes	Yes	Yes
Manufacturing (log)	0.885***	0.749***	0.866***	1.107***	0.894***	0.895***	-1.686	0.709***	0.934***
	(0.184)	(0.031)	(0.096)	(0.316)	(0.090)	(0.210)	(2.547)	(0.117)	(0.224)
Zinc price (log)	0.629	-0.085	0.025	0.188	-0.098	0.023	1.359	0.146*	0.102
	(1.017)	(0.085)	(0.269)	(0.400)	(0.080)	(0.270)	(1.393)	(0.082)	(0.114)
Linear trend				-0.007	-0.003	-0.001			
				(0.008)	(0.002)	(0.004)			
Adjustment coefficient	-0.190***	-0.114***	-0.084***	-0.260***	-0.121***	-0.084***	-0.136***	-0.090***	-0.084***
	(0.049)	(0.033)	(0.013)	(0.053)	(0.035)	(0.013)	(0.032)	(0.019)	(0.013)
Constant	-1.094*	-0.207***	-0.266**	0.572	-0.056	-0.226	0.112	-0.007	0.001
	(0.566)	(0.062)	(0.106)	(3.655)	(0.063)	(0.279)	(0.110)	(0.015)	(0.005)
Observations	1,224	1,224	1,224	1,224	1,224	1,224	1,224	1,224	1,224
Joint Hausman Test-stat.		1.664			12.12			1.377	
p-value		0.435			0.00697			0.502	
log likelihood		563.4			564.6			512.5	

Notes: The table shows results from the mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimations of the preferred ARDL(3,3,3) model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 31: Estimated long-run manufacturing output and price elasticities of zinc demand in the ARDL (3,3,3) model.