Importing foreign metallic raw materials or recovering scrap metal at home?

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Abstract

We estimate the impact of metal scrap recovery on import of metallic raw materials at the country level using a new instrumental variables strategy. We instrument for country metal recovery production with exogenous country characteristics. We employ a panel of 22 developed and developing countries over 1994-2008. To transform economic aggregates from nominal to real value, we develop the appropriate price indices. This allows us to document the actual evolution of the metal recovery industries for 22 countries and to perform a consistent econometric analysis. We find that increasing metal recovery by 10% reduces import of metallic raw material by 2%. This result implies that waste policies that favor waste recycling have not only an impact on pollution emissions but also on trade deficit.

Keywords: raw material trade, waste recovery, recycling, metal, input substitution

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1. Introduction

Waste recycling is a worldwide growing industry. The real annual growth rate of the metal recovery industry is double-digit in several European countries. In Finland, production increased by 50% every year on average between 2002 and 2008[1]. Waste recovery is the activity that transforms waste into secondary raw material. These secondary raw materials such as recovered paper or ferrous scrap are then used as a substitute to virgin raw materials in many industries. The prices of these latter inputs have been rising continuously and challenge more and more the competitiveness of the basic metal industry in many countries. Numerous economies import the largest part of the materials they consume. This is especially the case for metallic materials. At the same time, countries like European Union member states implemented numerous and ambitious waste policies. Some of these policies directly encourage waste recovery. This raises the question of how much metal recovery contributes to reduce the demand for virgin metallic raw materials.

Recycling enhancing policies primary objective is to reduce environmental externalities. By favoring recovery over elimination, these policies support the domestic production of secondary raw materials that can be used as substitutes for virgin raw materials. Thus, besides their direct environmental impacts, these policies may also benefit from an additional justification because they participate to the shift from the “linear economy” to the so-called “circular economy”. Also, recycling enhancing policies would reduce dependency towards foreign raw materials that is considered as being a rising concern by policy-makers in many countries. This paper aims to quantify the relationship between metal recovery output and imports in metallic raw materials.

Our paper is the first empirical study that estimates the impact of waste recovery on the import of raw material. To the best of our knowledge no study has yet quantified the impact of waste recovery on raw material imports. Few studies are directly related to recycling and international trade in waste and raw materials. Beukering and Bouman (2001) study the relationships between international trade of recyclable materials, waste recovery rate, and secondary material utilization rate[2]. In a similar fashion, Berglund and Söderholm (2003) conduct an econometric analysis to estimate the determinants of country recovery and utilization rates[3].

Our work is related to other papers looking at trade in waste and in secondary raw materials. Grace et al. (1978) was the first paper to analyze the international trade dimension of recycling. More recently, Kellenberg (2012) focuses on bilateral waste trade flows and tests empirically whether cross-country differences in environmental policy stringency drive waste

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[1] Fischer and Werge (2009) provide a detailed overview of municipal waste recycling in the European Union member states and find that municipal recycling is progressing in almost every member states. Fischer et al. (2011) find that the EU turnover of seven main recyclables almost double from 2004 to 2008.

[2] Their empirical finding is that developing countries specialize in the utilization of recovered material while developed countries specialize in the recovery of wastepaper and lead scrap.

[3] They find that these recycling rates are mainly driven by non-policy country characteristics such that population density and urbanization rate.

towards lax countries[4]. Other papers study the substitution between virgin raw material and secondary raw material without the international trade dimension. Anderson and Spiegelman (1977) model the substitution of virgin and secondary to investigate various policy options regarding the paper and the steel industries. Di Vita (2007) uses an endogenous growth model to investigate how the degree of technical substitutability between virgin and secondary material impacts the performance of the economy at the aggregate level.

The second contribution of our paper is to document the evolution of metal recovery for many countries. To do so, we build a producer price index that relies on few assumptions to deflate metal recovery production from nominal to real value. As far as we know, no study provides comparable time series of metal recovery production in real terms for as many countries. In comparison, Fischer et al. (2011) provide the production value of several metals in current prices at the European Union level from 2004 and 2008.

The topic deserves sharp attention for several reasons. First, the prices of the exhaustible virgin metallic raw materials have been rising continuously during the past decades. This threatens the competitiveness of the basic metal industry in country with low resource endowment. Second, waste management is heavily regulated in some countries. Waste policies have flourished in the European Union. For example, the EU implemented several waste directives such as the Packaging and Packaging Waste Directive, the End of Life Vehicle Directive, the WEEE Directive and the Landfill Directive. One of their primary objectives is to favor recycling to mitigate pollution emissions. More recently, the policy debate shifts towards resource efficiency[5]. If metal recovery reduces the import of metallic raw materials, these policies could find an additional justification. Third, even if the direction of the effect of metal recovery on metallic raw material import were obvious, its magnitude is not.

Using a panel of 22 developed and developing countries over 1994-2008, we find that increasing metal recovery by 10% reduces import of metallic raw material by 2%. These findings suggest that waste policies may not only address the externalities generated by waste generation but also contribute to improve the balance of payment at the country level.

The remainder of our paper proceeds as follows. Section 2 provides the methodology applied to the trade and to the structural data as well as stylized facts about the size of metal recovery at the country level. In Section 3, we discuss our empirical strategy to quantify the impact of metal recovery on metallic raw materials imports. We provide the estimated coefficient and perform some robustness checks in Section 4. Section 5 discusses the results and Section 6 concludes.

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[4] Kellenberg (2012) does not focus on the substitution between virgin and secondary material.

[5] For example, the European Commission introduced the flagship initiative of a resource-efficient Europe.

2. Data

2.1. Measuring aggregate import and production in real value

Our dependent variable is the annual total import value of metallic raw material for 22 countries. These metallic raw materials include virgin raw materials (iron ore, copper ore, et cetera) and secondary raw materials (ferrous scrap, copper waste and scrap, et cetera)[6]. We cover ferrous metal, every base metal, gold and silver, and more than 10 other non-ferrous metals. Data comes from the United Nations (UN) Comtrade database and are available from 1994 to 2008.

We also observe annual production value of three industries: metal mining, metal recovery, and basic metals manufacturing. Data comes from different sources. We obtain basic metals manufacturing output in current USD from the United Nations Industrial Development Organization (UNIDO) Industrial Statistics Database (INDSTAT2). Data on metal recovery annual output in current USD come from UNIDO INDSTAT4[7].

Data availability for the metal mining industry is low in almost every industrial statistics database. To solve this issue, we merge two different datasets to obtain the annual production value for the 22 countries. For each metal available, we simply multiply the annual quantity produced with the world price of this metal. Then, we sum these products across the different metals to obtain annual production value for each country. By doing this, we explicitly assume that world markets for raw materials are sufficiently integrated so that the price in every country does not differ greatly from the world price.

We collect the annual quantity of metals produced in these 22 countries from the U.S. Geological Survey Mineral Commodity Summaries[8]. We proxy the word prices by the average unit values of metal ore imports using trade data from the UN Comtrade database. To check the consistency of our measure, we calculate yearly correlations between our estimated metal mining production value and reported values in the OECD STructural ANalysis Database (STAN) database[9]. For the 11 countries for which both data are available, the yearly correlations are around 0.98 from 1994 to 2007.

We deflate the previous macroeconomic variables: metallic raw material import, metal recovery, metal mining, and metal manufacturing using appropriate price indices. This allows us to control for the evolution of the relative prices of the different metals aggregated in these macroeconomic variables. Using directly nominal import, it could not be possible to identify whether change in import size is due to change in metal composition and relative prices or due to the increase of metal recovery.

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[6] See appendix 8.3.

[7] In the International Standard Industrial Classification of All Economic Activities (ISIC) 3.1, basic metals manufacturing is classified under Division 27 while metal recovery is classified under Class 3710.

[8] We collect the quantity in terms of metal content of Aluminum, Antimony, Chrome, Cobalt, Copper, Gold, Iron, Lead, Molybdenum, Nickel, Silver, Tin, Titanium, Tungsten, and Zinc.

[9] Identified under division 13 in ISIC Rev. 3.1.

We calculate appropriate price indices by applying a consistent methodology for every country. Comparable price indices for the previous macroeconomic variables are not available. These indices may exist in a limited number of countries but the methodology implemented by each country is different except for basic metals manufacturing. For this industry, we use the index numbers of industrial production provided by UNIDO INDSTAT2. Although not specific to the basic metal industry, the index numbers of industrial production has the advantage of being available and comparable for many countries. For import and the other industries considered, we will rely on the following price indices.

We calculate a Tornqvist price index for the import of metallic raw materials. The main reason is that it corresponds to the exact index of flexible cost functions such as translog (Diewert, 1976). We need flexibility because import of metallic raw materials includes two groups of products. The first group contains products that are not close substitutes: different metals whether or not virgin such as iron and tin for example. Their elasticities of substitution are close to 0. The second group contains products that can be close substitutes: virgin iron ore and ferrous scrap. Their elasticities of substitution can be above unity. By using a Tornqvist price index, we do not make a particular assumption on the elasticity of substitution between the goods included in total imports.

We calculate an arithmetic Paasche index for both metal recovery and metal mining. The motivation behind the arithmetic nature of the index is that we assume elasticities of substitution being equal to zero. This is appropriate since products included within each industry aggregate are not close substitutes. We use the Paasche formula rather than Laspeyres because the latter is not appropriate to deflate output at current prices (IMF, 2004)[10]. Finally, all indices we build are fixed-base that is they all have a unique reference year. There are two reasons to do that. First, fixed-base indices are less sensitive to volatile price series than chained-base indices (Gaulier et al., 2008). Price of metal commodities can indeed be highly volatile from one year to another. Second, fixed-base indices assume no change in technology and in composition of baskets of good produced. This latter assumption is fairly plausible regarding mining and metal recovery over 1994-2008.

To build import price indices and producer price indices, one need information on prices and market share. We use trade flows unit value as a proxy for price. This has two main advantages. First, trade flows are available for most countries in the UN Comtrade database. Second, we can identify with a good precision the different metals in the trade nomenclature. Market shares are used as weights for the prices in producer and import price indices. A product market share is defined as the ratio between the sales of this product and the total sales. For the import price index, we use product import share. For the producer price index of metal mining, we combine data on quantity produced and data on price to obtain the share for every product.

However, we do not have the production by product for metal recovery. As a second best, we use metal recovery export shares to build the metal recovery producer price index. By doing so, we make the following assumption: product market shares in metal recovery

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[10] The different formulas used are available in the appendix.

production are identical to product market shares in metal recovery export. Although this assumption could be violated in number of ways, it is not a particularly strong one. Kravis & Lipsey (1974) and Silver (2007) highlight the empirical issues implied by using unit value as proxy for price. We mitigate these issues by applying Gaulier et al., (2008)'s outlier management methodology to get "clean of outliers" price datasets. Figure 1 and 2 of the appendix show the price indices for import, recovery, and mining of Sweden and the United Kingdom. It illustrates that the price of these baskets of goods more than doubled from 1994 to 2008 for some countries. This stresses the importance of deflating these aggregate time series.

2.2. Measuring trade protection and stylized facts

We calculate the trade-weighted average of effectively applied tariffs to proxy the trade protection of each country towards the import of metal raw materials. More specifically, we sum the weighted average of effectively applied tariffs of the HS6 products defined above weighted by their share in total metal raw material import value. Data on weighted average of effectively applied tariffs at the HS 6-digit level come from the United Nations Conference on Trade and Development (UNCTAD) Trade Analysis and Information System (TRAINS) database. Products' shares in total metal raw material import value are calculated using trade data from the UN Comtrade database.

Numerous studies employed trade-weighted average tariff as a proxy for trade protection[11].Trade-weighted average tariff have been nonetheless criticized for lacking theoretical foundation (Anderson and Neary, 1996). More practically weighted average tariff under represents high tariffs as stressed in UNCTAD & WTO (2012). For instance, prohibitive tariffs are not included because their weight is zero. Despite these drawbacks, our indicator of protection is specific to metallic raw materials and thus superior to more general measure such as dummy of WTO membership. It has also the advantage of taking into account Free Trade Agreement and Custom Unions. The country ranking we obtain is consistent with popular belief. As far as we know, data availability does not allow measuring the Non-Tariff Barrier (NTB) of trade for the selected metallic raw materials. Whereas exports related measures are particularly important for some metal products, we assume NTBs for metallic raw material import do not weight much in trade protection.

Table 1 shows the average of the variables described above over the period 2002-2008 for each country. Japan is the first importer of the sample with 14 million current USD and 8 million constant 1994 USD on average[12]. It is followed by Germany with 7.4 million constant 1994 USD. These figures are not surprising given the size of the basic metal industry in these two countries: 165 and 92 billion constant 1994 USD respectively. France is the sample first producer of recovered metal with 9.8 billion constant 1994 USD followed by the Japan with 3.6 billion constant 1994 USD. The production value of the metal recovery industry is higher than the production value of the metal mining industry in 70% of the countries included in the sample. The remaining 30% is countries like Brazil and India with high endowment in virgin

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[11] For instance, Bordo, Eichengreen, and Irwin (1999).

[12] China is the world first importer of metallic raw materials with 45 million current USD.

metallic raw materials. Trade protection does not vary much across countries. It is because 15 of the 22 countries are European Union member states sharing a common trade policy. However, it is worth to indicate that India, Brazil, and South Korea are much more protected than the others.

Table 2 gives the average growth rate of the main economic variables for each country over the same period. With 10% on average, the metal recovery industry grew faster than GDP and metal mining industry. Some countries experienced high growth rate for metal recovery. For instance, metal recovery output increased by 50% in Finland and by 40% in Malaysia during that period. For most countries, the metal recovery industry grew faster than the metal mining industry. The size of the metal recovery industry did not increase in every country. It felt by 12% in India and by 6% in Hungary. Most countries saw their protection provided by tariffs phased out. India and Brazil still have the most stringent trade policy towards metallic raw materials imports although their weighted average tariff decreased significantly over 2002-2008.

Data on population density and GDP per capita come from the World Bank and gross enrollment ratio in tertiary education comes from the UNESCO Institute for Statistics. Table 3 gives the descriptive statistics. The final dataset is an incomplete panel of 227 observations mainly limited by the availability of the metal recovery industry output.

Table 1: Main economic variables average over 2002-2008 (output and import are expressed in constant thousand USD)[13]

Country	Import of metallic raw materials	Metal recovery output	Metal mining output	Basic metal manufacturing output	GDP	Weighted Average Tariff
Austria	866	194,429	28,200	13,228,571	331,428,571	< 0.01
Brazil	393	69,017	7,966,667	35,833,333	2,166,666,667	1.72
Finland	971	301,614	95,629	10,314,286	194,285,714	< 0.01
France	1,407	9,791,429	14,100	42,428,571	2,271,428,571	< 0.01
Germany	7,358	1,970,000	97,283	92,000,000	3,066,666,667	< 0.01
Hungary	109	48,167	34,133	3,333,333	220,000,000	< 0.01
India	2,265	25,333	4,143,333	65,000,000	3,900,000,000	15.35
Ireland	141	100,260	307,200	690,000	192,000,000	< 0.01
Italy	2,248	1,758,571	141,286	67,142,857	2,085,714,286	< 0.01
Japan	8,054	3,658,333	136,833	165,000,000	4,300,000,000	0.00
Korea, Rep.	4,701	964,333	7,862	67,333,333	1,100,000,000	0.85
Malaysia	723	85,233	49,017	7,983,333	468,333,333	< 0.01
Norway	353	314,200	130,200	10,160,000	292,000,000	0.00
Poland	366	396,857	350,143	9,942,857	650,000,000	0.05
Portugal	115	113,080	52,860	2,380,000	268,000,000	< 0.01
Romania	218	958,750	56,150	6,850,000	320,000,000	0.10
Slovak Republic	166	21,480	26,580	3,120,000	107,400,000	< 0.01
Spain	2,676	1,373,000	181,714	36,000,000	1,414,285,714	< 0.01
Sweden	586	349,143	757,571	17,257,143	352,857,143	< 0.01
Turkey	2,479	111,380	223,400	26,000,000	1,074,000,000	0.03
United Kingdom	2,077	3,324,286	153	27,857,143	2,128,571,429	< 0.01
Median	866	314,200	97,283	17,257,143	650,000,000	< 0.01

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[13] Czech Republic does not appear in Table 1 and 2 because data are not available for this period of time.

Table 2 : average growth rate of the main economic variables over 2002-2008

Country	Import of metallic raw materials	Metal recovery output	Metal mining output	Basic metal manufacturing output	GDP	Weighted Average Tariff
Austria	27%	10%	2%	16%	3%	phased out
Brazil	1%	-2%	10%	24%	4%	decreasing
Finland	5%	50%	-5%	21%	3%	phased out
France	-1%	-1%	-2%	15%	2%	phased out
Germany	5%	7%	2%	18%	2%	phased out
Hungary	15%	-6%	5%	15%	2%	phased out
India	26%	-12%	17%	7%	10%	decreasing
Ireland	0%	18.1%	5%	16%	4%	phased out
Italy	3%	12%	7%	28%	1%	phased out
Japan	2%	1%	-4%	12%	2%	phased out
Korea, Rep.	3%	13%	4%	20%	5%	decreasing
Malaysia	4%	40%	-1%	17%	6%	phased out
Norway	0%	5%	3%	15%	2%	phased out
Poland	13%	10%	-3%	20%	5%	phased out
Portugal	22%	-2%	2%	21%	1%	phased out
Romania	-9%	0%	-47%	20%	7%	phased out
Slovak Republic	2%	13%	2%	26%	8%	phased out
Spain	1%	22%	2%	18%	2%	phased out
Sweden	3%	3%	3%	22%	3%	phased out
Turkey	6%	20%	14%	23%	7%	constant
United Kingdom	13%	0%	-13%	11%	3%	phased out
Mean	7%	10%	0%	18%	4%	overall decrease

Table 3: descriptive statistics

Variables	Obs.	Mean	Between Std. Dev.	Within Std. Dev.	Min	Max
$\ln(Import)$	227	13.589	1.396	0.292	9.546	15.991
$\ln(Recovery)$	227	19.618	1.678	0.585	15.969	25.015
$\ln(Mining)$	227	18.228	2.329	0.493	11.460	23.045
$\ln(BasicMetal)$	227	23.379	1.393	0.329	19.596	26.070
$Tariff$	227	0.612	4.009	0.947	0	24.72
$\ln(PopDens)$	227	4.501	0.974	0.027	2.662	6.213
$\ln(PopDens)^2$	227	21.198	8.566	0.233	7.087	38.604
$\ln(GDP\ per\ capita)$	227	10.180	0.609	0.103	7.842	11.081

3. Empirical Strategy

3.1. Deriving the relationship between import of metallic raw materials and metal recovery output

In this section, we seek to test empirically whether the development of the metal recovery industry causes the imports of metallic raw materials to decrease everything else equal. Total import of metallic raw materials is a function of domestic metallic raw materials consumption. Everything else equal, the highest the demand in metallic raw materials, the highest the demand in imported metallic raw materials. Secondary metallic raw materials output and virgin metallic raw materials output depend on the domestic consumption. Metal recovery firms and mining firms produce according to their expectations on metallic raw materials prices that depend on domestic and foreign metallic raw materials demand. When the domestic consumption in metallic raw materials increases, the metal recovery industry and the metal mining industry respond by an increase in output.

In the end, we can write total import value of metallic raw materials ($Import$) as a function of domestic production value of secondary metals ($Recovery$), domestic production value of virgin metals ($Mining$), and domestic consumption in metallic raw materials ($Consum$).

$$Import = F(Recovery, Mining, Consum) \qquad (1)$$

Assuming that imported metallic raw materials, domestic secondary metals, and domestic virgin metals are imperfect substitutes for the production of basic metals, we expect a negative relationship between $Import$ and $Recovery$ as well as between $Import$ and Y_{VM}.

We approximate (1) by a log linear model such that

$$\ln(Import_{it}) = \alpha_0 + \alpha_1 \ln(Recovery_{it}) + \alpha_2 \ln(Mining_{it}) + \alpha_3 \ln(Consum_{it}) + \alpha_4 Tariff_{it} + \delta_i + \gamma_t + u_{it} \quad (2)$$

Where $Tariff_{it}$ is the trade-weighted average tariff for country i at year t, δ_i is a set of country dummies, γ_t is a set of year dummies, and u_{it} is the error term. Our aim is to estimate parameter α_1. To do so, we must control for trade policy that seeks to impede the import of metallic raw materials. δ_i allows us to control for any time invariant factors that may affect the import of metallic raw materials and may be correlated with the other regressors. For instance, remote countries tend to import less than the other countries. γ_t allows us to control for any time-varying factors such as word industrial output, energy price, et cetera that impact every country and may be correlated with the other regressors. Finally, we use the production value of the basic metal industry ($BasicMetal$) to proxy the domestic consumption of metallic raw materials.

3.2. Identification strategy

At a given a level of domestic metallic raw materials consumption, $Import$, $Recovery$, and $Mining$ are simultaneously determined. These macroeconomic outputs are the results of choices made simultaneously by numerous local and foreign economic agents in the different industries. In other words, Y_{SM}, and Y_{VM} are endogenous in (2). Estimating (2) using fixed effects would yield biased estimates. To solve this empirical issue, we employ a two stage least square (2SLS) strategy to properly estimate α_1. More specifically, we use a General Method of Moments (GMM) Instrumental Variable (IV) estimator. We need at least 2 instrumental variables to identify equation (2). In our base specification, we use the following instruments: log of population density ($\ln(PopDens)$), its square value ($\ln(PopDens)^2$), ($\ln(GDPpercapita)$), and percentage of tertiary enrollment ($Tertiary$).

At a given level of domestic metallic raw materials consumption, we expect population density to have a significant positive effect on the metal recovery output. Densely populated countries are more inclined to engage in waste recovery activities. It is because the alternative waste elimination activities generate more damages in densely populated. Berglund and Söderholm (2003) find that population density has a positive and significant impact on waste recovery. We expect mining to be facilitated in country with high population density at a given level of domestic metallic raw materials consumption. The intuition behind is that mining requires high logistic means and in particular labor force at an acceptable distance from the mines. As recovery and especially mining remain pollution intensive activities, we expect that the square value of population density to have a negative effect on both production activities. Polluting activities generate bigger environmental external costs in densely populated countries. Moreover, large areas with few inhabitants are easier place to perform metal ores extraction.

We use GDP per capita to proxy country inhabitant preference for the environment. We expect rich countries to have more stringent environmental policy everything else equal. Rich countries should favor metal recovery over metal mining. Additionally, we use the percentage of tertiary enrollment which is the percentage of high school graduates that successfully enroll into university as an additional instrument. Tertiary enrollment aims to proxy overall productivity and should have a positive impact on both metal recovery and metal mining. Finally, we think that population density, GDP per capita, and tertiary enrollment are valid instrument since they do not enter equation (2) and should not be correlated with any unobserved factors contained in the error term u_{it}[14].

As pointed out by Saito (2004), GMM-IV can be highly biased when the data exhibit non stationary series. We employ the group mean unit root test of Im, Pesaran, and Shin (2003) to test for stationarity of the macroeconomic variables. Whether assuming or not serial correlation, the tests indicate that we cannot accept the null hypothesis of non-stationary series for any variables except the metal mining production. The usual procedure is to include the non-stationary variable in first difference in the equation but this has no significant impact on the estimates. To preserve as many observations as we can, our base estimation keeps metal mining production variable as a contemporaneous regressor. As both the dependent variable and the variable of interest are stationary, our results should not suffer from this issue. In aggregate data like the one we use, the assumption of homogeneity of serial correlation dynamics does not probably hold. GMM usually relies on this assumption. To get consistent estimates, we compute standard errors that are robust to heteroskedasticity and autocorrelation.

4. Results

4.1. Recovering scrap metal decreases metallic raw materials imports

Table 4 shows that the expansion of the metal recovery industry reduces total import in metallic raw materials. The size of the coefficient estimate as an elasticity is substantial. All things equal, an increase of 10% in the output of the metal recovery industry is associated with a 2% decrease in total import in metallic raw materials. Column 1 contains the OLS fixed-effect estimates. This naïve approach does not deal with the simultaneity issue and yields biased estimates. Column 2, 3, 4, 5 and 6 contain generalized method of moments instrumental variables estimator (GMM-IV) estimates with different sets of instruments. Column 2 which is our base specification includes the instruments presented in the previous section except tertiary enrollment. Including the latter instrument variable leads to lose 11% of the observations. Column 3 includes tertiary enrollment and the logarithm of population density along with its squared value. Column 4 contains only the logarithm of population density and tertiary enrollment. Column 5 comprises every instrument except the square value of the logged population density. Finally, column 6 includes all the instruments.

Estimations in column 2, 3, 4, 5, and 6 report coefficient of similar size for metal recovery real output and suggests that our result is not specific to one set of instruments. The control variables have the expected signs except for metal mining which coefficient is positive for three estimations. For every GMM-IV estimates in Table 4, both the Hansen J-statistic for over identification and the Kleibergen-Paap rk LM statistic for under identification are reported. The joint null hypothesis of the Hansen J-statistic is that the instruments are valid.

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[14] As explained by Rodrik (1995), poor countries are generally more protectionist. GDP per capita remains a valid instrument since we account for protection in the main equation.

The joint null hypothesis of the Kleibergen-Paap rk LM statistic is that equation (2) is under identified. Both tests provide strong support for the instrument sets.

Table 5 contains the first stage regressions performed during the GMM-IV estimation of table 4. The results are line with our expectations except for the effect of $Tariff$ on metal recovery output. Densely populated countries produce more secondary raw metal through metal recovery and more virgin raw metal through mining. When population density reaches a certain level, both activities tend to be deterred by a further increase of population density. Rich countries tend to do more metal recovery and less mining. Finally, countries with higher productivity levels consistently produce more everything else equal. However, we find that $Tariff$ have a significant and negative effect on metal mining and a significant and positive impact on metal recovery. We would expect that protection benefits to both industries. This suggests that Tariff could capture an omitted factor in the reduced form equation where mining production is the dependent variable. Eventually, the results of the first stage regressions of the excluded instruments on the endogenous variables are jointly and individually significant.

4.2. Robustness checks

Table 6 indicates that our results are not sensitive to the price index used to deflate nominal metal recovery output into real terms. Table 6 shows our base estimation with three versions of the variable of interest. In column 7, the production of the metal recovery industry is deflated using an arithmetic Paasche index. Column 7 is identical to column 2. In column 8, metal recovery output is deflated using a Tornqvist index. In column 9, a geometric Paasche index is used to obtain the real output of the metal recovery industry. All estimations provide coefficients of similar size.

Table 7 shows there is no particular country in the sample that drives the results presented in the previous section. In column 10, we replicate our base estimation but we drop Japan because it is the biggest importer, metal recycler, and basic metal producer in the sample. In column 11, we drop Brazil and India for three reasons. First, they are the most protected countries and have the largest mining industries. Second, they differ from the other countries because they are big emerging economies. Third, they have the lowest GDP per capita in our sample of countries. In column 12, we drop the Republic of Korea, India, and Japan because significantly more densely populated than the other countries. In column 13, we drop Norway because it is significantly richer than the other countries. The coefficients obtained from the estimations on these restricted are of similar size to the one obtained from the full sample.

Finally, we replace total import value of metallic raw materials by the total import value of every goods as dependent variable to perform a placebo test in column 14. The joint null hypothesis of the Hansen J-statistic is that the instruments are valid is rejected at 1%. This provides some evidence that our approach is valid for metallic raw materials import in particular.

Table 4: OLS and GMM-IV estimates of country total imports value of metallic raw materials

	Dependent variable: ln (Import of metallic raw materials)					
	OLS FE	**GMM-IV**				
	1	**2**	**3**	**4**	**5**	**6**
	Coefficient Std. Error	**Coefficient Std. Error**	**Coefficient Std. Error**	**Coefficient Std. Error**	**Coefficient Std. Error**	**Coefficient Std. Error**
ln (Recovery)	0.011	-0.239**	-0.225**	-0.226**	-0.195**	-0.194**
	(0.043)	(0.116)	(0.104)	(0.105)	(0.092)	(0.093)
ln (Mining)	0.102**	-0.232	0.108	0.129	-0.049	0.020
	(0.041)	(0.177)	(0.131)	(0.235)	(0.166)	(0.091)
ln (BasicMetal)	-0.276	0.437	0.064	0.040	0.223	0.142
	(0.229)	(0.333)	(0.248)	(0.332)	(0.279)	(0.220)
Tariff	-0.027	-0.037	-0.019	-0.018	-0.030*	-0.025*
	(0.020)	(0.021)	(0.015)	(0.019)	(0.016)	(0.014)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes
Instruments		ln (PopDens)	ln (PopDens)	ln (PopDens)	ln (PopDens)	ln (PopDens)
		ln (PopDens)^2	ln (PopDens)^2			ln (PopDens)^2
		ln (GDP/capita)			ln (GDP/capita)	ln (GDP/capita)
			Tertiary	Tertiary	Tertiary	Tertiary
Hansen J-statistic		0.24	0.01		0.73	0.99
Kleibergen-Paap rk LM statistic		11.00***	7.91**	3.80*	8.11**	12.50***
R^2	0.47	-0.01	0.25	0.24	0.21	0.26
No. obs.	227	227	201	201	201	201

Standard errors robust to heteroskedasticity and autocorrelation in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Import of metallic raw materials is expressed in constant 1994 USD. Nominal import is deflated using a Tornqvist price index. Recovery is expressed in constant 1994 USD. Nominal recovery is deflated using an arithmetic Paasche price index. Mining is expressed in constant 1994 USD. Nominal mining is deflated using an arithmetic Paasche price index. BasicMetal is expressed in constant 2005 USD. Nominal BasicMetal is deflated using the index numbers of industrial production provided in UNIDO INDSTAT2. Data on nominal production come from UNIDO INDSTAT2 except for mining where production results from the merge between USGS data (for quantities produced) and UN Comtrade data (for material prices). Price indices are built using data on unit value that come from UN Comtrade. Tariff is the weighted average of effectively applied tariff. Data on tariff come from the TRAINS database and data on trade flows come from UN Comtrade.

Table 5: 1st stage regression results

Excluded instruments	1st stage dependent variable									
	2		3		4		5		6	
	ln (Recovery)	ln (Mining)	ln (Recovery)	ln (Mining)	ln (Recovery)	ln (Mining)	ln (Recovery)	ln (Mining)	ln (Recovery)	ln (Mining)
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
	Std. Error	Std. Error	Std. Error	Std. Error	Std. Error	Std. Error	Std. Error	Std. Error	Std. Error	Std. Error
ln (PopDens)	-1.369	23.842***	22.663**	38.357**	11.219***	1.104	11.168***	1.367	22.034**	44.438***
	(7.792)	(8.499)	(9.741)	(14.914)	(2.840)	(1.783)	(2.903)	(2.104)	(9.373)	(16.250)
ln (PopDens)²	1.086	-3.004***	-1.353	-4.404**					-1.283	-5.084***
	(0.945)	(1.038)	(1.114)	(1.699)					(1.079)	(1.838)
ln (GDP/capita)	1.877**	-1.458					0.485	-2.541**	0.328	-3.167**
	(0.744)	(0.984)					(0.887)	(1.214)	(0.848)	(1.295)
Tertiary			0.023***	0.019*	0.025***	0.025**	0.023***	0.036***	0.022***	0.031***
			(0.007)	(0.010)	(0.007)	(0.011)	(0.008)	(0.013)	(0.008)	(0.012)
ln (BasicMetal)	1.116***	1.094**	0.780**	0.729*	0.864**	1.001**	0.485	1.073**	0.775**	0.777**
	(0.344)	(0.446)	(0.349)	(0.419)	(0.371)	(0.461)	(0.887)	(0.445)	(0.349)	(0.377)
Tariff	0.117***	-0.132***	0.073**	-0.138***	0.096***	-0.062***	0.104**	-0.103***	0.079**	-0.201***
	(0.041)	(0.040)	(0.349)	(0.038)	(0.036)	(0.013)	(0.040)	(0.024)	(0.039)	(0.057)
F-test on excluded instruments	4.86***	2.98**	6.21***	3.28**	9.12***	2.67*	5.86***	2.78**	4.70***	3.03**
No. obs.	227	227	201	201	201	201	201	201	201	201

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Data on population density (people per sq. km of land area) and GDP per capita (constant 2011 USD PPP) come from the World Bank and gross enrollment ratio in tertiary education comes from the UNESCO Institute for Statistics.

5. Discussion

Our results indicate that the development of the metal recovery industry has an important economic impact on the import of metallic raw materials. Between 2002 and 2003, German metallic raw material imports felt from 6.7 million to 5.7 million constant 1994 USD. At the same period, the metal recovery industry grew by 7.7%. This increase was responsible for 12% of the total decrease in import which corresponds to 124 thousand constant 1994 USD. Similarly, the 5.1% increase of the Japan metal recovery industry between 2004 and 2005 was accountable for a decrease of 100 thousand constant 1994 USD in import. While these yearly savings may seem small at first glance, the cumulated value of yearly savings over a decade can reach millions of USD.

Our results show that increasing the size of the metal recovery industry by 10% allows decreasing import in metallic raw materials by 2%. The effect can be seen as smaller than expected. They are two plausible explanations. First, virgin raw material and secondary raw material are not perfect substitutes (Radetzki and Van Duyne, 1985; Blomberg and Hellmer, 2000; Beureking et al., 2000). For instance, several final products of metals of high quality require inputs with a high percentage of purity. There are several grades of secondary raw metal resulting from waste metal recovery. The lowest grades with low degrees of purity cannot enter the production of complex metal products. Second, in most developed countries, a significant part of the secondary raw metal produced domestically is exported towards foreign markets. Effectively, only the part that is not exported can serve as a substitute to imported metallic raw materials.

Nonetheless, recovering more waste metal at home can reduce the import of metallic raw material significantly. In many countries, the expansion of recycling is supported by numerous waste policies. If the primary objective of waste policies is to mitigate pollution emissions, they may also contribute to lower the raw material trade deficit at the country level by fostering recycling activities. This is a desirable feature for countries with low resource endowment seeking to tackle their dependence on foreign imports.

While our results provide some evidence that the development of the metal recovery industry is associated with a significant decrease in metallic raw materials import, it is important to note some limitations. First, we only have a relatively small number of observations. Second, the functional form used in the estimation does not allow for the inclusion of country that does not produce metal ores. This means that our results are valid within the sphere of countries that still produce metal ores and we don’t know if it applies to the population of countries that have no mining production. Lastly, although our sample contains 8 developing countries we do not cover low income countries mainly because statistics on the output of metal recovery are not available. For data availability reasons, our analysis does not include big economies like the United States and China. However, we believe that our sample contain sufficiently heterogeneous countries to be representative of a major part of the developed and emerging countries population.

Recovery also exists for nonmetal material such as paper, plastic, glass, et cetera. Further research could investigate the impact of waste recovery on virgin raw material import for this material. Study at the material level could provide more accurate and specific results. Yet the major difficulty remains the availability of sufficiently detailed economic data about the waste recovery that are comparable across countries.

Table 6: GMM-IV estimates with alternative fixed-base price indices for metal recovery

	Dependent variable: ln (Import of metallic raw materials)		
	GMM-IV		
	Arithmetic Paasche	**Tornqvist**	**Geometric Paasche**
	7	**8**	**9**
	Coefficient **Std. Error**	**Coefficient** **Std. Error**	**Coefficient** **Std. Error**
ln (Recovery)	-0.239**	-0.205**	-0.231**
	(0.116)	(0.092)	(0.109)
ln (Mining)	-0.232	-0.173	-0.231
	(0.177)	(0.138)	(0.175)
ln (BasicMetal)	0.437	0.305	0.392
	(0.333)	(0.262)	(0.310)
Tariff	-0.037*	-0.037**	-0.036*
	(0.021)	(0.018)	(0.020)
Year dummies	Yes	Yes	Yes
Country fixed-effect	Yes	Yes	Yes
Instruments	ln (PopDens) ln (PopDens)² ln (GDP/capita)	ln (PopDens) ln (PopDens)² ln (GDP/capita)	ln (PopDens) ln (PopDens)² ln (GDP/capita)
Hansen J-statistic	0.24	0.22	0.34
Kleibergen-Paap rk LM statistic	11.00***	9.67***	10.14***
R^2	0.02	0.14	0.18
No. obs.	227	227	227

Standard errors robust to heteroskedasticity and autocorrelation in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Import of metallic raw materials is expressed in constant 1994 USD. Nominal import is deflated using a Tornqvist price index. Recovery is expressed in constant 1994 USD. Nominal recovery is deflated using a different price index for each column. Mining is expressed in constant 1994 USD. Nominal mining is deflated using an arithmetic Paasche price index. BasicMetal is expressed in constant 2005 USD. Nominal BasicMetal is deflated using the index numbers of industrial production provided in UNIDO INDSTAT2. Data on nominal production come from UNIDO INDSTAT2 except for mining where production results from the merge between USGS data (for quantities produced) and UN Comtrade data (for material prices). Price indices are built using data on unit value that come from UN Comtrade. Tariff is the weighted average of effectively applied tariff. Data on tariff come from the TRAINS database and data on trade flows come from UN Comtrade.

Table 7: Robustness tests with the exclusion of potential outlying countries and placebo test

	GMM-IV				
	Dependent variable: ln (Import of metallic raw materials)				**Dependent variable: ln (Import of every goods)**
	Japan dropped	**Brazil and India dropped**	**Republic of Korea, India, and Japan dropped**	**Norway dropped**	**All countries**
	10	**11**	**12**	**13**	**14**
	Coefficient **Std. Error**	**Coefficient** **Std. Error**	**Coefficient** **Std. Error**	**Coefficient** **Std. Error**	**Coefficient** **Std. Error**
ln (Recovery)	-0.319**	-0.188*	-0.334**	-0.246**	-0.086
	(0.131)	(0.102)	(0.131)	(0.125)	(0.104)
ln (Mining)	-0.252	0.000	-0.084	-0.185	-0.364
	(0.196)	(0.101)	(0.126)	(0.187)	(0.196)
ln (BasicMetal)	0.448	0.155	0.259	0.387	0.935***
	(0.416)	(0.282)	(0.382)	(0.365)	(0.326)
Tariff	-0.033	-0.049	0.086**	-0.031	-0.056***
	(0.024)	(0.163)	(0.037)	(0.021)	(0.018)
Year dummies	Yes	Yes	Yes	Yes	Yes
Country fixed-effect	Yes	Yes	Yes	Yes	Yes
Instruments	ln (PopDens) ln $(\text{PopDens})^2$ ln (GDP/capita)	ln (PopDens) ln $(\text{PopDens})^2$ ln (GDP/capita)	ln (PopDens) ln $(\text{PopDens})^2$ ln (GDP/capita)	ln (PopDens) ln $(\text{PopDens})^2$ ln (GDP/capita)	ln (PopDens) ln $(\text{PopDens})^2$ ln (GDP/capita)
Hansen J-statistic	< 0.01	0.49	0.12	0.27	4.00**
Kleibergen-Paap rk LM statistic	10.14***	8.81**	17.16***	10.10***	11.00***
R^2	-0.11	0.26	0.09	0.07	0.74
No. obs.	213	210	205	217	227

Standard errors robust to heteroskedasticity and autocorrelation in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Import of metallic raw materials is expressed in constant 1994 USD. Nominal import is deflated using a Tornqvist price index. Recovery is expressed in constant 1994 USD. Nominal recovery is deflated using an arithmetic Paasche price index. Mining is expressed in constant 1994 USD. Nominal mining is deflated using an arithmetic Paasche price index. BasicMetal is expressed in constant 2005 USD. Nominal BasicMetal is deflated using the index numbers of industrial production provided in UNIDO INDSTAT2. Data on nominal production come from UNIDO INDSTAT2 except for mining where production results from the merge between USGS data (for quantities produced) and UN Comtrade data (for material prices). Price indices are built using data on unit value that come from UN Comtrade. Tariff is the weighted average of effectively applied tariff. Data on tariff come from the TRAINS database and data on trade flows come from UN Comtrade. Data on import of every goods are expressed in current USD and come from UN Comtrade.

6. Conclusions

In this paper, we find that the expansion of the metal scrap recovery industry significantly decreases the import of metallic raw materials. The impact is of economic importance. A 10% increase in the metal recovery output is associated with a 2% decrease in the import value of metallic raw materials. To deal with the empirical issue that import of metallic raw materials, metal mining output, and metal recovery output are simultaneously determined, we employ an instrumental variable strategy. We instrument for metal recovery output and metal mining output with population density, percentage enrollment in tertiary education, and GDP per capita.

The importance of waste policies has been continuously rising in recent years. Because waste policies favor the development of metal recovery, our work documents the likely impact of these policies on an aspect that has not received much attention so far: trade in raw materials. Waste policies have clear environmental objectives, but they could also have attractive side effects. Reducing trade deficit in raw material is a desirable characteristic for countries with low natural resource endowment.

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8. Appendices

8.1. Price Index formulas

$Tornqvist_{t/0} = \left(gP_{t/0} . gL_{t/0}\right)^{1/2}$

$gP_{t/0} = \prod_k \left(\frac{p_{kt}}{p_{k0}}\right)^{w_{kt}}$ is the geometric Paasche Index where p_{kt} denotes the price of product k at year t and p_{k0} denotes the price of product k at the reference year, and w_{kt} is the share of product k in total sales at year t.

$gL_{t/0} = \prod_k \left(\frac{p_{kt}}{p_{k0}}\right)^{w_{k0}}$ is the geometric Laspeyres Index where w_{k0} is the share of product k in total sales at the reference year.

$aP_{t/0} = \left(\sum_k w_{kt} \frac{p_{k0}}{p_{kt}}\right)^{-1}$ is the arithmetic Paasche Index.

8.2. The evolution of price index for Sweden and the United Kingdom

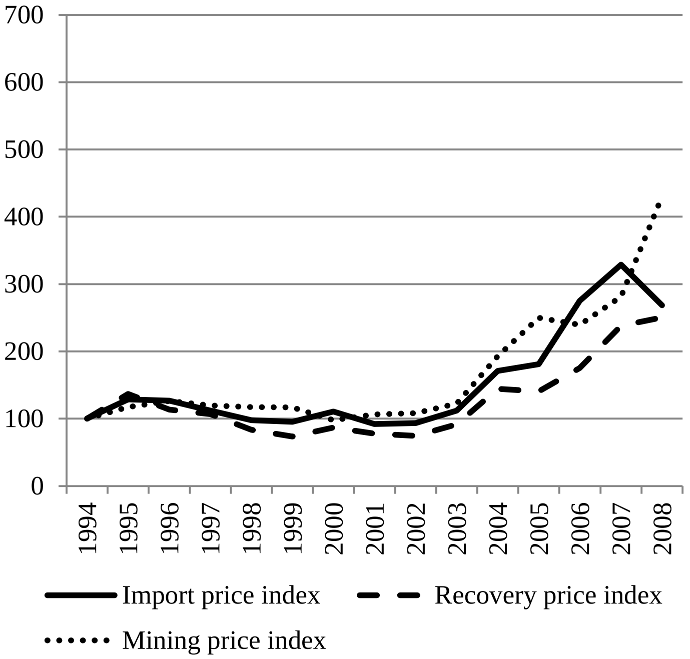

Figure 1: Calculated Price indices for Sweden

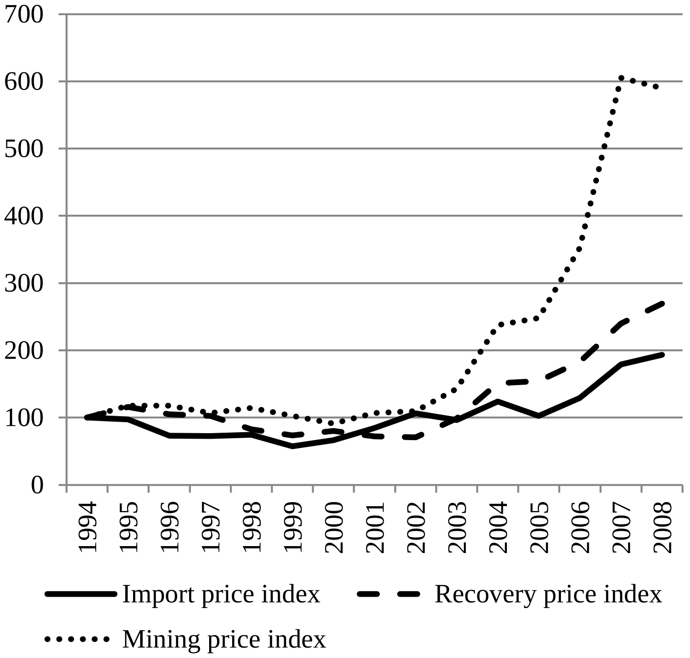

Figure 2: Calculated Price indices for the United Kingdom

8.3. Metallic raw commodities by material and by harmonized system code

Material	6-digit HS code	Raw material	Description
Aluminum	260600	virgin	Aluminum ores and concentrates.
Aluminum	760200	secondary	Aluminum waste & scrap
Antimony	261710	virgin	Antimony ores and concentrates
Antimony	811020	secondary	Antimony waste & scrap
Beryllium	811213	secondary	Beryllium waste & scrap
Cadmium	810730	secondary	Cadmium waste & scrap
Chromium	261000	virgin	Chromium ores and concentrates.
Chromium	811222	secondary	Chromium waste & scrap
Cobalt	260500	virgin	Cobalt ores and concentrates.
Cobalt	810530	secondary	Cobalt waste & scrap
Copper	260300	virgin	Copper ores and concentrates.
Copper	740200	virgin	Unrefined copper; copper anodes for electrolytic refining.
Copper	740400	secondary	Copper waste & scrap
Gold	711210	secondary	Waste or scrap containing gold as sole precious metal
Gold	711291	secondary	Waste & scrap of gold, incl. metal clad with gold
Iron & Steel	260111	virgin	Iron ores and concentrates, other than roasted iron pyrites :-- Non-agglomerated
Iron & Steel	260112	virgin	Iron ores and concentrates, other than roasted iron pyrites :-- Agglomerated
Iron & Steel	720410	secondary	Waste & scrap of cast iron
Iron & Steel	720421	secondary	Waste & scrap of stainless steel
Iron & Steel	720429	secondary	Waste & scrap of alloy steel other than stainless steel
Iron & Steel	720430	secondary	Waste & scrap of tinned iron/steel
Iron & Steel	720441	secondary	Ferrous turnings, shavings, chips, milling waste, sawdust, filings
Iron & Steel	720449	secondary	Ferrous waste & scrap (excl. of 7204.10-7204.41)
Iron & Steel	720450	secondary	Ferrous waste & scrap
Lead	260700	virgin	Lead ores and concentrates.
Lead	780200	secondary	Lead waste & scrap
Magnesium	251910	virgin	Natural magnesium carbonate (magnesite)
Magnesium	810420	secondary	Magnesium waste & scrap
Molybdenum	261390	virgin	Molybdenum ores and concentrates (excl. Roasted)
Molybdenum	810297	secondary	Molybdenum waste & scrap
Nickel	260400	virgin	Nickel ores and concentrates.
Nickel	750300	secondary	Nickel waste & scrap
Other non-ferrous metals	260200	virgin	Manganese ores and concentrates
Other non-ferrous metals	261590	virgin	Niobium, tantalum or vanadium ores and concentrates

Material	6-digit HS code	Raw material	Description
Other non-ferrous metals	261790	virgin	Ores and concentrates (excl. iron, manganese, copper, nickel, cobalt, aluminum, lead, zinc, tin, chromium, tungsten, uranium, thorium, molybdenum, titanium, niobium, tantalum, vanadium, zirconium, precious metal or antimony ores and concentrates)
Other non-ferrous metals	280519	virgin	Alkali or alkaline-earth metals (excl. Sodium and calcium)
Other non-ferrous metals	280530	virgin	Rare-earth metals, scandium and yttrium, whether or not intermixed or inter-alloyed
Other precious	261690	virgin	Precious metal ores and concentrates (excl. Silver ores and concentrates)
Other precious	711290	secondary	Waste & scrap of precious metal or of metal clad
Platinum	711220	secondary	Waste/scrap containing platinum as sole precious metal
Platinum	711292	secondary	Waste & scrap of platinum
Precious metal	711299	secondary	Waste & scrap of precious metal/metal clad with precious metal
Silver	261610	virgin	Silver ores and concentrates
Tantalum	810330	secondary	Tantalum waste & scrap
Thallium	811252	secondary	Thallium waste & scrap
Tin	260900	virgin	Tin ores and concentrates.
Tin	800200	secondary	Tin waste & scrap
Titanium	261400	virgin	Titanium ores and concentrates.
Titanium	810830	secondary	Titanium waste & scrap
Tungsten	261100	virgin	Tungsten ores and concentrates.
Tungsten	810197	secondary	Tungsten (wolfram) waste & scrap
Zinc	260800	virgin	Zinc ores and concentrates.
Zinc	790200	secondary	Zinc waste & scrap
Zirconium	261510	virgin	Zirconium ores and concentrates
Zirconium	810930	secondary	Zirconium waste & scrap