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

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Abstract

In countries with limited exhaustible natural resources, reducing the imports of raw material is increasingly viewed as a significant side-benefit of recycling. Using a panel of 20 developed and developing countries over 1994-2008, we seek to measure the size of this benefit by estimating the impact of metal scrap recovery on import of metallic raw materials at the country level. We deal with the endogeneity of metal recovery with exogenous country characteristics including population density, knowledge available in environmental technologies, and productivity. We also develop a strategy for controlling for the price volatility in raw material markets. We find that increasing metal recovery by 10% reduces import of metallic raw material by 2% in our base specification. This result confirms that waste policies that favor waste recycling may have a sizeable impact on the balance of trade.

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

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1. Introduction

Waste recycling involves two steps. The first is waste recovery which consists in collecting and processing recyclable waste in order to obtain secondary raw materials. In the second step, secondary raw materials such as recovered paper or ferrous scrap are used to produce new goods. In many industries, they can perfectly or partially substitute virgin raw materials. As a result, all other things being held equal, an increase in the supply of secondary raw materials expectedly diminishes the demand for virgin materials.

Waste recycling is booming at the world level. For instance, the real annual growth rate of the metal recovery industry is double-digit in the six European countries covered in the present paper. In the developing world, production doubled every two years in China and Malaysia between 2002 and 2008[1].

The introduction of public policies promoting recycling in many countries partly explains why the production secondary materials is growing rapidly. In the European Union, the Packaging and Packaging Waste Directive, the End of Life Vehicle Directive, and the WEEE Directive have established ambitious recovery rate targets to be met by Member States by a specific date. Some policy instruments directly target waste recovery whereas material utilization per se which occurs downstream remains mostly unregulated. Used instruments include subsidies, take-back obligations, and so-called Extended Producer Responsibility Programme (EPR) in which the government assigns to producers the responsibility for collecting and recycling their products at the end of life. Other policies indirectly promote recycling by constraining landfilling and incineration. In particular, many countries have introduced landfill tax to divert waste stream toward recycling and incineration. These policies participate to the shift from a "linear economy" to a resource-efficient "circular economy", a concept of which popularity is growing in policy circles.

These policies primarily aim to reduce environmental externalities generated by waste disposal and the processing of virgin raw materials. But as they reduce the demand for virgin materials, they also diminish imports as most countries are not self-sufficient. More directly, they also reduce the imports of secondary materials. They can thus improve a country's balance of trade. This side-benefit is increasingly viewed in the policy discussions as significant. The goal of the present paper is to measure the size of this impact.

Using a panel of 20 industrialized and developing countries over 1994-2008, we seek to quantify the impact of domestic recovery of metallic waste on the imports of virgin and secondary metallic materials. We find that an increase by 10% of the output of the waste recovery industry reduces import of metallic raw material by 2%. These findings lend support to the argument that waste policies can contribute to improve trade balances at the country level.

[1] Fischer and Werge (2009) 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.

We rely on international trade data and national account data on metal recovery, metal mining, and metal manufacturing. A problem we need to deal with is that these economic aggregates are simultaneously determined as, in a nutshell, the metal manufacturing industry utilize inputs produced by the metal recovery and mining industries. To circumvent the problem, we instrument for country metal recovery production and for country mining with exogenous country characteristics including population density and productivity. A second difficulty is a risk of measurement errors as our aggregates can be dramatically influenced by changes in the relative prices of the different metallic materials. This leads us to build a producer price index to deflate metal recovery production from nominal to real value. As far as we know, no study has yet provided comparable time series of metal recovery production in real terms for as many countries.[2]

To the best of our knowledge no study has already quantified the impact of waste recovery on raw material imports. Beukering and Bouman (2001) study the relationships between international trade of recyclable materials, waste recovery rate, and secondary material utilization rate. They show that developing countries specialize in the utilization of recovered material while developed countries specialize in the recovery of wastepaper and lead scrap. Berglund and Söderholm (2003) conduct a cross-country econometric analysis of the determinants of national recovery and utilization rates. They find that recycling performance is mainly driven by non-policy country characteristics such that population density and urbanization rate.

Other works look at trade in waste and secondary raw materials, without paying attention to the role of domestic activities in waste recovery. Grace et al. (1978) was the first paper to analyze the international trade dimension of recyclates. More recently, Kellenberg (2012) studies whether cross-country differences in environmental policy stringency drive waste towards the laxest countries[3]. Other papers study the substitution between virgin raw material and secondary raw material, but with no attention to trade issues 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 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.

[2] Fischer et al. (2011) provide the production value of several metals in current prices at the European Union level from 2004 and 2008.
[3] Kellenberg (2012) does not focus on the substitution between virgin and secondary material.

2. Analytical framework

Estimating the impact of metal recovery on import of metallic raw material requires taking into account three different industries that gravitate around metal commodities. The first is the basic metal manufacturing industry which consumes metallic raw material such as iron ores and producing finished or semi-finished metal products such as crude steel or steel sheets. Metallic raw materials then come from two different upstream industries: the mining industry which supplies virgin material and the recovery industry which retrieves and processes recyclable waste into secondary raw materials[4]. These material suppliers can be located at home or abroad.

Our research question then amounts to investigate the degree of substitutability between two sources of material inputs of basic metal manufacturing: raw material (both virgin and secondary) that are imported and secondary material produced at home. The two variables of interest are thus the volume of imports of raw materials and the size of waste recovery activities in the country. But a consistent econometric analysis of the relationship between these two variables requires controlling for two other factors: the size of the domestic basic metal manufacturing industry (i.e. the demand), the size of domestic mining activities which can supply virgin material which potentially compete with raw material imports.

Formally, 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 $Mining$. We also expect that $Import$ increases with $Consum$.

An econometric specification that approximates (1) by a log linear model

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

Indices *i* and *t* respectively indicate the country and the year. In comparison with (1), we essentially add controls: time dummies (γ_t), fixed effects (δ_i) and $Protection_{it}$ which captures trade policy that possibly impede the import of metallic raw materials (e.g. tariffs). It will be proxied by either by $\ln(GDPpercapita)_{it}$ or $Tariff_{it}$, the trade-weighted average tariff for country *i* in the estimations for reasons we will explain below. u_{it} is the error term that captures unobserved heterogeneity that varies over time and across countries. Our aim is to estimate parameter α_1. We now explain in detail how we construct the variables using the data available.

[4] The degree of substitutability between secondary and virgin raw materials varies significantly.

3. Data and measurement issues

3.1. Measuring material import and production

The dependent variable $Import_{it}$ is the annual total import value of metallic raw material for 20 countries[5] over the period 1994-2008. These metallic raw materials include virgin raw materials (iron ore, copper ore…) and secondary raw materials (ferrous scrap, copper waste and scrap…)[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. While our sample does not include some large importers like the United States and Canada, we nevertheless cover 75% of total world trade[7].

Ideally we would like perform the analysis for each different metal in order to control for material-specific factors. This is not feasible. Trade statistics can actually give a highly disaggregated description of imports. In particular the Comtrade database relies on the 6-digit Harmonized Commodity Description and Coding System (HS) developed by the World Customs Organization (WCO). But the limiting factor is the data describing domestic production (waste recovery, mining, and basic metal manufacturing) which is available only at the aggregate level. A consequence is that the dependent variable is not expressed in quantity, but in value as summing up the quantity of different metals would be meaningless (think of tons of steel and gold).

Data on the annual production value of metal recovery and basic metals manufacturing which is used to construct the variables $Recovery_{it}$ and $Consumer_{it}$ is extracted from different sources. We obtain basic metals manufacturing output from the United Nations Industrial Development Organization (UNIDO) Industrial Statistics Database (INDSTAT2). Data on metal recovery annual output come from UNIDO INDSTAT4[8].

Data on the metal mining industry to measure $Mining_{it}$ has proved much more difficult to collect. For the 20 countries included in our sample, the only reliable source is the U.S. Geological Survey Mineral Commodity Summaries which gives the annual quantity of metals produced[9]. The problem is that we need the output of the mining sector in value. To estimate this output value, we have thus multiplied for each metal the annual quantity with a proxy of its world price. The estimate of the world price is the average unit value of metal ore imports using trade data from the UN Comtrade database. To check the consistency of our measure, we have calculated yearly correlations between our estimated metal mining production value and reported values in the OECD STructural ANalysis Database (STAN) database[10] in the 9

[5] The list of the countries is available in appendix 8.1.
[6] See appendix 8.2.
[7] Based on current imports of 2007. The actual figure is slightly lower because our calculation is based on 72 countries for which the data are available. The excluded economies should not weight much in total trade.
[8] 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.
[9] 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 because metal content per gram of ores differs from a mine to another.
[10] Identified under division 13 in ISIC Rev. 3.1.

countries for which both data are available. The yearly correlations are around 0.98 from 1996 to 2006.

Aggregating different metals into a single metrics by summing metal-specific values may generate measurement errors for relative prices of the different metals can vary a lot. Changes in the value of imports or outputs can thus simply be driven by changes in market prices while quantities remain stable. To circumvent the problem, we use deflated values. As price indices are not readily available for the set of countries and years included in the sample, we calculate our own indices.

For imports, we calculate a Tornqvist price index (see the formula in Appendix 8.3). The advantage of this index is that it corresponds to flexible cost functions such as translog functions (Diewert, 1976). We need flexibility because the degree of substitutability across products varies a lot. Different metals are generally not substitutes (e.g., iron and copper) contrary to a virgin material and its secondary variant (e.g., virgin iron ore and ferrous scrap) of which elasticities of substitution can exceed unity. The Tornqvist price index does not impose any restriction on the size of the elasticities of substitution between the goods. For waste recovery and metal mining, we rely on an arithmetic Paasche index as elasticities of substitution are very low, arguably zero (see the formula in Appendix 8.3)[11].

All indices we calculate are fixed-base, that is, they all have a unique reference year. The main reason is that fixed-base indices are less sensitive to volatile price series than chained-base indices (Gaulier et al., 2008). We proxy prices with the unit values of trade flows as we did for computing the output values of the mining sector. Kravis & Lipsey (1974) and Silver (2007) have highlighted the empirical problems implied by using this solution. We mitigate these issues by applying Gaulier et al. (2008)'s outlier management methodology to get "clean of outliers" price datasets. Their method consists in identifying two types of outliers. The first contains trade flow observations that are likely to be rounded due to reporting. The second type groups observations that have unrealistic price variations over time for each importing country and product bundle. Observations of these two kinds are not used when calculating average unit value since they could yield unrealistic unit value[12].

Figure 1 and 2 in Appendix 8.4 illustrate the necessity to deflate the variables. The two graphs present the price indices for import, recovery, and mining of Sweden and the United Kingdom and shows that prices more than doubled from 1994 to 2008 for some countries.

Figure 1 shows the output level of the metal recovery industry and the Gross Domestic Product of different countries. Unsurprisingly, both variables are positively correlated. There are however significant differences in the relative size of the metal recovery industry with countries like Russia, the Czech Republic, and Finland where recovery is more developed than in others like Germany, Italy, Brazil, and Spain.

[11] We use the Paasche formula rather than Laspeyres because the latter is not appropriate to deflate output at current prices (IMF, 2004).
[12] Recovery rates that are the share of total import value used to calculate the prices are available upon request.

The table in appendix 8.5 shows the average of the variables included in the econometric analysis over the period 2002-2008 for each country. China is by far the first importer of the sample with 40 billion current USD and 16 billion constant 1994 USD on average[13]. It is followed by Japan with 8 billion 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 72% of the countries included in the sample. The remaining 28% is countries like China, Sweden and Turkey with high endowment in virgin metallic raw materials. Trade protection does not vary much across countries. It is because 13 of the 20 countries are European Union member states sharing a common trade policy. However, it is worth to indicate that South Korea and China appear to be much more protected than the others[14]. Figure 2 plots the evolution of the total output of the three industries summed across ten European member states[15]. Output levels are measured in volume to phase out the impact of relative price evolution.

Figure 2 shows that the metal recovery industry grows at a swift rate between 1995 and 2007. In comparison, import in metallic raw material grows slowly while metal mining stays constant. The table in appendix 8.6 gives the average growth rate of the main economic variables for each country over the same period. With 15% 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 China and Finland and by 40% in Malaysia during that period. For 80% of the 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 6% in Hungary and by 2% in Portugal.

Figure 1: Output of the metal recovery industry and GDP in 2007, by country

[13] China is the world first importer of metallic raw materials with 159 billion current USD in 2012 far ahead before big importing economies absent from our sample. India imported 23 billion current USD and the United States imported 9 billion current USD in 2012.

[14] Descriptive data about weighted average tariff are available upon request.

[15] Output levels are in real USD are summed across available countries: Austria, Czech Republic, Finland, Hungary, Italy, Norway, Poland, Slovakia, Spain, and Sweden.

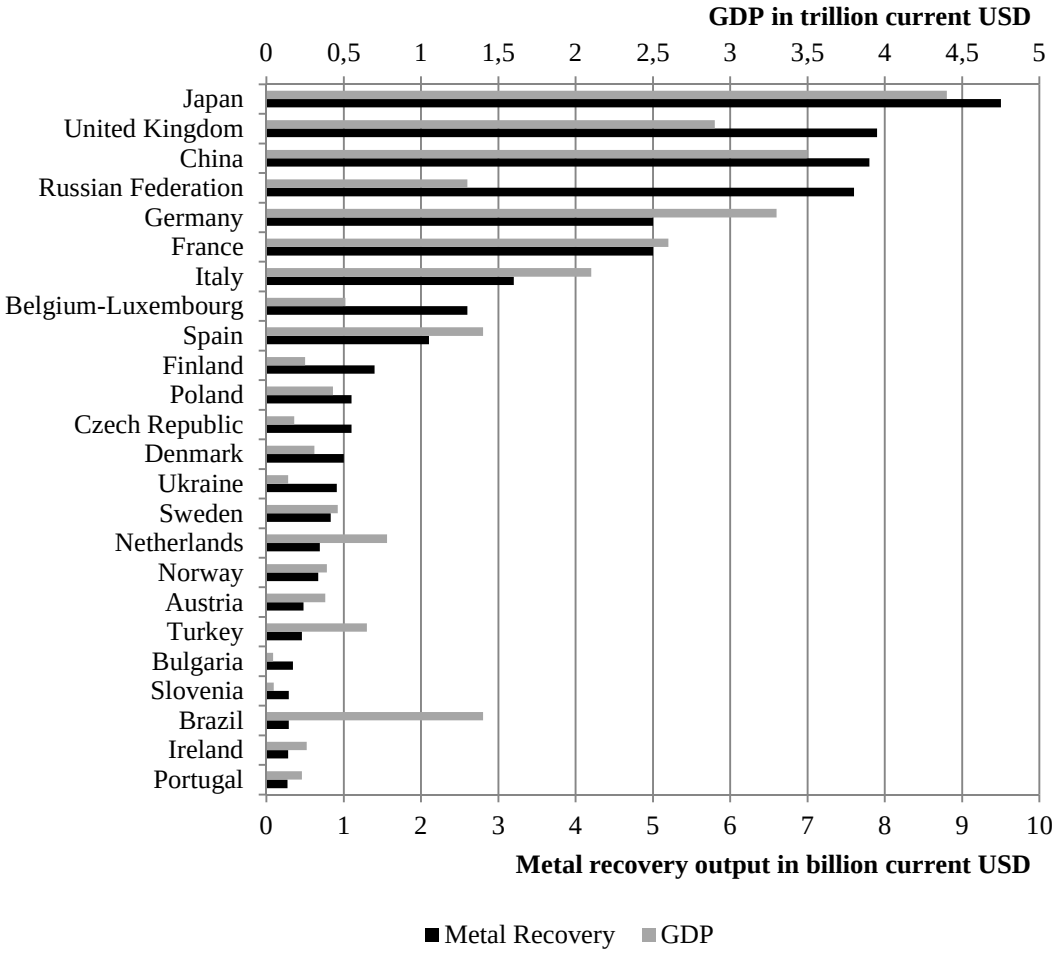
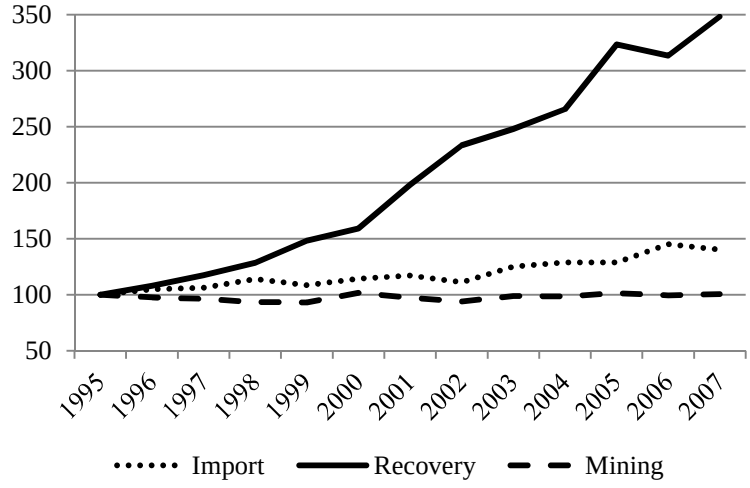


Figure 2: Raw materials imports, metal recovery output, and metal extraction output for a group of European countries (index = 100 in 1995)



3.2 Measuring trade protection and country exogenous characteristics

The imports of an economy are influenced by time-invariant characteristic such as remoteness and distances from trade partners and by time-varying factors. The latter include trade policy. In our empirical analysis, we use two alternative way of capturing countries' level of protection towards import. The first is GDP per capita. The second is based on tariff data. As explained by Rodrik (1995), poor countries are generally more protectionist. Additionally, 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[16]. 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.

Data on the trade-weighted average tariff reveals that most countries saw their protection provided by tariffs phased out. South Korea and China still have the most stringent trade policy towards metallic raw materials imports although their weighted average tariff decreased significantly over 2002-2008.

In the next sections, we detail how we instrument metal recovery and metal mining output using country exogenous characteristics. One of the instrumental variables we employ is the country share of knowledge in environmental technologies. We calculate the ratio between the stock of environmental patents and the stock of all patents to proxy the share of knowledge available in each country in environmental technologies[17]. We expect this share to be positively correlated with the size of the recovery industry. The stock of patents filed in a country intends to capture the amount of knowledge available in each country[18]. We select

[16] For instance, Bordo, Eichengreen, and Irwin (1999).
[17] The latter stock excludes Human Necessities and ICT patents because these two categories are very patent intensive and may overestimate the knowledge of industries located upstream in the value chain.
[18] This includes patents filed by local and foreign inventors.

patents classified under the category "General Environment" defined in the classification adopted in the OECD Patent Database and summarized in appendix 8.7. We restrict our measure to triadic or high-value patents to avoid our measure to be flooded by the numerous low-value patents. As our aim is to evaluate the state of knowledge and not the effort of innovation in a given technology, we select only patents granted by patent offices. To reflect the ongoing obsolescence of new inventions, we discount every stock by an annual depreciation rate of 15%, a value used in most literature (see Keller, 2004). Data on patent filling come from Worldwide Patent Statistical Database (PATSTAT) database.

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.

3.3 Descriptive statistics

Table 3 gives the descriptive statistics. The final dataset is an incomplete panel of 229 observations mainly limited by the availability of the metal recovery industry output.

Table 1: descriptive statistics

Variables	Obs.	Mean	Between Std. Dev.	Within Std. Dev.	Min	Max
$\ln(Import)$	229	20.368	1.547	0.282	16.807	23.821
$\ln(Recovery)$	229	19.476	1.626	0.617	15.591	23.390
$\ln(Mining)$	229	17.946	2.382	0.469	11.460	24.020
$\ln(BasicMetal)$	229	22.931	1.608	0.183	19.497	26.606
$\ln(GDP\ per\ capita)$	229	10.191	0.506	0.117	8.434	11.081
$Tariff$	229	0.060	0.198	0.105	0	1.040
$\ln(PopDens)$	229	4.504	0.915	0.025	2.657	6.213
$\ln(PopDens)^2$	229	21.129	7.999	0.213	7.059	38.604
$ShareEnvironment$	229	1.548	0.407	0.102	0.724	2.784
$Tertiary$	229	52.5	18.148	9.022	14.97	97.51

4. 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, $Recovery$, and $Mining$ are endogenous in (2). To circumvent the problem, we employ a General Method of Moments (GMM) Instrumental Variable (IV) estimator to properly estimate α_1. We need at least as many instrumental variables as endogenous variables. In our base specification, we use the following instruments: log of population density ($\ln(PopDens)$), its square value ($\ln(PopDens)^2$), the share of knowledge available in each country in environmental technologies ($ShareEnvironment$), and percentage of tertiary enrollment ($Tertiary$). Figure 1 is a flow diagram that illustrates the identification strategy.

Let us now explain in detail why we believe these instruments to be relevant and valid. To start with $\ln(PopDens)$, we expect population density to have a significant positive effect on the metal recovery output (a). Densely populated countries are more inclined to engage in waste recovery activities for two main reasons. First, waste collection is less costly in densely populated area because short distances between numerous waste producers allow economies of scale and economies of density. Several studies have actually found a negative relationship between waste collection cost and population density (Hirsch, 1965; Stevens, 1978; Antonioli and Filipini, 2002; Koushki et al., 2004; Beuve et al., 2013)[19]. Lower collection costs imply more waste available for recovery. Second, waste recovery is favored over waste disposal and incineration in densely populated area. This is because the higher the density, the higher the land price and the cost of performing land intensive activities such as disposal. Moreover, waste disposal and incineration generates more environmental damages than the alternative waste recovery when there are numerous inhabitants living in a small area. These local considerations seem to be also valid at the country level. Berglund and Söderholm (2003) find that population density has a positive and significant impact on waste recovery.

Turning to the second endogenous variable, we expect mining to be facilitated in country with high population density at a given level of domestic metallic raw materials consumption (b). The intuition behind is that mining requires high logistic means and in particular labor force at an acceptable distance from the mines. Mining is still moderately labor intensive compared to other industries in developed countries and it should be even more labor intensive in emerging and developing economies[20].

The square value of the log of population density ($\ln(PopDens)^2$) is the second instrument we employ. We expect the instrument to have a negative effect on both mining and recovery. Stevens (1978) finds there are economies of scale up to a population threshold in the United States. Abranta et al. (2012) find that high population density can be associated with higher waste collection cost because of likely frequent traffic congestion. Higher collection cost results in shorter waste supply for recovery. Furthermore, large areas with few inhabitants are easier places to perform metal ores extraction. Finally, recovery and at a further extent mining remain pollution intensive activities. They generate bigger environmental external costs in densely populated countries so they tend to be deterred at high level of density.

[19] Beuve et al. (2013) do not find a significant effect of population density on the waste collection cost in France. However, the effect of density is likely captured by the dummies characterizing the habitat: urban, dense urban, touristic they include as regressors.

[20] Whithin the OECD, the mining industry ranks 8th over 14 industries in terms of ratio between total employment and output. Authors calculations based on 2000 data provided by OECD STAN database and exclude services.

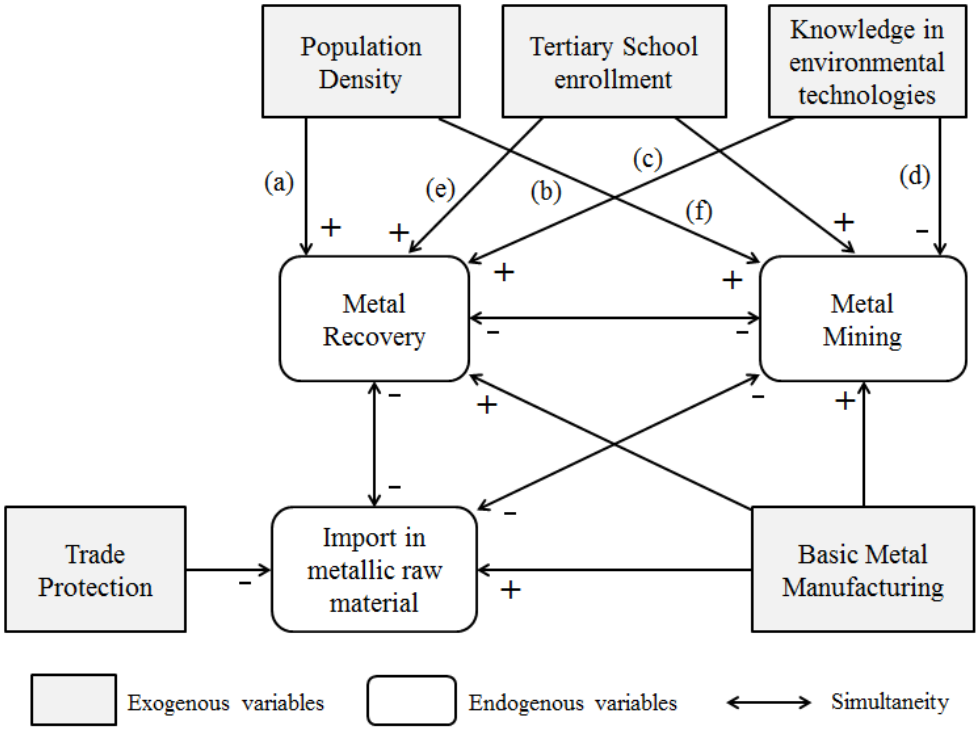


Figure 3: identification strategy involving exogenous country characteristics

We use the share of knowledge available in each country in environmental technologies ($ShareEnvironment$) as our third instrumental variable. It aims to proxy country capacity to perform activities that prevent environmental damages and recovery can be seen as one of them. As mining is more pollution intensive than recovery, countries with high share of knowledge in environmental technologies should favor metal recovery (c) and deter metal mining (d) other things equal. Our last instrumental variable is the percentage of tertiary enrollment ($Tertiary$) which is the percentage of high school graduates that successfully enroll into university. Tertiary enrollment aims to proxy overall productivity. We believe tertiary enrollment is a good indicator of the average skill of labor in an economy. More skilled labor results in more productive industries and more output in both metal recovery (e) and metal mining (f). Human capital as a determinant of growth is at the core of the growing and large literature on endogenous growth theories and neoclassical growth theories[21]. There are also empirical evidences that education is associated with higher productivity. Moretti (2004) finds that an increase in U.S. city share of college graduates is associated with a significant increase in productivity of manufacturing firms. Other studies find a positive relationship between education and total factor productivity (de la Fuente and Ciccone, 2003; Nicoletti et al., 2003; Vandenbussche et al., 2006). As the tests for under identification in the next section suggest, the instruments we employ are strong. The strength of the instrumental variables used is a necessary but insufficient property to identify equation (2).

We think that population density, share of environmental knowledge, and tertiary enrollment are valid instrument in the sense that they are not correlated with unobserved factors contained in the error term u_{it}. Population density should not impact import in

[21] See Psacharopoulos and Patrinos (2004) for a review of the literature.

metallic raw material once total demand for metallic raw material is controlled for. Moreover, we do not identify any unobserved factor in equation (2) that is correlated with population density. The share of knowledge in environmental technologies should not directly impact import of metallic raw material. It may have an indirect effect on import through its impact on the metal recovery industry which is controlled for in equation (2). As population density, we do not identify any unobserved factor in equation (2) that is correlated with the share of knowledge in environmental technologies. Eventually, productivity that we proxy with tertiary enrollment can have an indirect impact on import. Higher productivity is associated with a decline of production cost and a rise in output in the three industries of interest: metal mining, metal recovery, and metal manufacturing. Additionally, tertiary enrollment should not be correlated with unobserved characteristics in the main equation. Therefore, it should be a valid instrument.

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. We find that the metal mining series are stationary only when we do not subtract cross-sectional averages from the series. 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.

5. Results

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 and $\ln(GDPpercapita)$ to control for trade protection. Including $Tariff$ instead of $\ln(GDPpercapita)$ leads to lose 13% of the observations. Column 3 includes the share of environmental knowledge and the logarithm of population density along with its squared value as instruments. Column 4 includes tertiary enrollment and the logarithm of population density along with its squared value. Column 5 comprises two instruments: the logarithm of population density along with its squared value. Column 6 is identical to column 2 except that

we use $Tariff$ instead of $\ln(GDPpercapita)$. Finally, column 6 is the same as column 2 where we include both $Tariff$ and $\ln(GDPpercapita)$ [22].

Estimations in column 2, 3, 4, 5, 6 and 7 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. 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 column 2, 3, 4, and 5 in table 4. The results are line with our expectations. 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. Countries with high share of environmental knowledge tend to do less mining but not more recovery as we expected. Countries that have strict environmental policy tend to have a high share of environmental knowledge. There it is not surprising that the latter has a negative effect on the size of a pollution intensive industry like mining. Finally, countries with higher productivity levels consistently produce more everything else equal. Eventually, the results of the first stage regressions of the excluded instruments on the endogenous variables are jointly and individually significant.

[22] This still makes sense because we expect that once tariff have been controlled for, GDP per capita capture other countries characteristics such that the fact that richer countries tend to trade more.

Table 2: 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	7
	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error
ln (Recovery)	-0.060	-0.210***	-0.211***	-0.210***	-0.211**	-0.239***	-0.258***
	(0.047)	(0.074)	(0.080)	(0.078)	(0.082)	(0.085)	(0.091)
ln (Mining)	-0.013	-0.037	-0.039	-0.036	-0.038	0.019	-0.062
	(0.047)	(0.118)	(0.127)	(0.123)	(0.130)	(0.125)	(0.110)
ln (BasicMetal)	0.488	0.580***	0.582***	0.578***	0.580***	0.591***	0.691***
	(0.115)	(0.194)	(0.205)	(0.201)	(0.208)	(0.214)	(0.201)
ln (GDP/capita)	0.408	0.510	0.515	0.506	0.512		0.982**
	(0.580)	(0.351)	(0.376)	(0.363)	(0.381)		(0.422)
Tariff						-0.145	0.012
						(0.129)	(0.155)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instruments		ln (PopDens) ln (PopDens)² Share Environment Tertiary	ln (PopDens) ln (PopDens)² Share Environment	ln (PopDens) ln (PopDens)² Tertiary	ln (PopDens) ln (PopDens)²	ln (PopDens) ln (PopDens)² Share Environment Tertiary	ln (PopDens) ln (PopDens)² Share Environment Tertiary
Hansen J-statistic		< 0.01	< 0.01	< 0.01	Just identified	0.48	0.62
Kleibergen-Paap rk LM statistic		14.79***	11.65***	12.65***	10.43***	10.24**	10.08**
R^2	0.82	0.38	0.38	0.38	0.37	0.37	0.38
No. obs.	229	229	229	229	229	200	200

Standard errors robust to heteroskedasticity and autocorrelation in parentheses

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

Import of metallic raw materials, metal recovery, metal mining, and basic metals manufacturing are expressed in constant 1994 USD. Nominal values are deflated using appropriate price indices (see section 2.1). 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. Date on GDP per capita (constant 2011 USD PPP) come from the World Bank. Data on tariff come from the TRAINS database and data on trade flows come from UN Comtrade.

Table 3: 1st stage regression results

Excluded instruments	1st stage dependent variable							
	2		3		4		5	
	ln (Recovery)	ln (Mining)	ln (Recovery)	ln (Mining)	ln (Recovery)	ln (Mining)	ln (Recovery)	ln (Mining)
	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error
ln (PopDens)	23.025** (9.142)	22.200** (10.717)	26.717*** (9.445)	25.890** (11.999)	24.819*** (8.500)	31.108*** (11.655)	27.502*** (8.610)	33.570*** (12.764)
ln (PopDens)²	-1.196 (1.069)	-2.714** (1.217)	-1.815 (1.109)	-3.332** (1.376)	-1.408 (0.982)	-3.765*** (1.341)	-1.906*** (0.998)	-4.221*** (1.477)
Share Environment	-0.185 (0.389)	-0.916*** (0.349)	-0.083 (0.431)	-0.815** (0.339)				
Tertiary	0.021*** (0.007)	0.021*** (0.007)			0.020*** (0.007)	0.019** (0.007)		
ln (BasicMetal)	0.251 (0.230)	1.055*** (0.341)	0.363 (0.234)	1.168*** (0.365)	0.269 (0.219)	1.148*** (0.362)	0.371* (0.222)	1.241*** (0.379)
ln (GDP/capita)	0.428 (0.789)	-0.557 (0.761)	1.085 (0.702)	0.100 (0.736)	0.464 (0.788)	-0.376 (0.763)	1.096 (0.711)	0.203 (0.744)
F-test on excluded instruments	6.02***	4.58***	7..23***	4.37***	7.95***	4.98***	10.83***	5.18***
No. obs.	229	229	229	229	229	229	229	229

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) come from the World Bank and gross enrollment ratio in tertiary education comes from the UNESCO Institute for Statistics. Share Environment is the ratio between the stock of knowledge in environmental technologies and total stock of knowledge. The stock of knowledge is a discounted stock of triadic patent. Date on patent comes from PATSTAT.

6. Robustness checks

Table 6 shows there is no particular country in the sample that drives the results presented in the previous section. In column 8, we replicate our base estimation but we drop China because it is the biggest importer, metal miner, and basic metal produce. It also has the lowest percentage of tertiary enrollment in the sample. In column 9, we drop France because it has the largest metal recovery industries. In column 10, we drop the Republic of Korea because it is significantly more densely populated than the other countries. In column 11, we drop Japan for three reasons. It has the second largest metal recovery industry and is the second largest importer far ahead from other countries in the sample. Japan is also one of the most densely populated countries included in our analysis. In column 12, 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 perform two placebo tests. In column 13, we first replace total import value of metallic raw materials by the total import value of fuels as dependent variable. In column 14, we replace total import value of metallic raw materials by the total import value of agricultural commodities. In both regressions, the joint null hypothesis of the Hansen J-statistic 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 and not any kind of raw materials import.

To provide additional support to the validity of our instrumental variable approach, we replicate our base estimation in table 7 using an additional instrument: the country average minimum temperature ($MinTemperature$). The exogenous nature of this weather variable makes sure it is a valid instrument. This means we can rely on the Hansen J-statistic. We expect low temperatures to slow down economic activities resulting in a lower level of output. More precisely we calculate the yearly average of monthly minimum temperatures previously averaged across countries' recording stations. Data comes from the Global Historical Climatology Network-Monthly (GHCN-M) version 3 dataset provided by the National Climatic Data Center. The over-identification test reported in table 7 states that we cannot accept the joint null hypothesis of the Hansen J-statistic. As we find a coefficient similar to the one obtained in our base specification, this suggests that our overall identification strategy is valid.

Eventually, appendix 8.8 indicates that our results are not sensitive to the price index used to deflate nominal metal recovery output into real terms. Appendix 8.8 shows our base estimation with three versions of the variable of interest. In column 15, the production of the metal recovery industry is deflated using an arithmetic Paasche index. Column 15 is identical to column 2. In column 16, metal recovery output is deflated using a Tornqvist index. In column 17, a geometric Paasche index is used to obtain the real output of the metal recovery industry. All estimations provide coefficients of similar size.

Table 4: 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 fuels)	Dependent variable: ln (Import of agricultural commodities)
	China dropped	France dropped	Republic of Korea dropped	Japan dropped	Norway dropped	All countries	All countries
	8	9	10	11	12	13	14
	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error
ln (Recovery)	-0.209*** (0.073)	-0.230*** (0.077)	-0.210*** (0.074)	-0.229*** (0.081)	-0.237*** (0.081)	0.170** (0.070)	-0.032 (0.040)
ln (Mining)	-0.016 (0.120)	-0.132 (0.135)	-0.046 (0.118)	-0.040 (0.118)	0.041 (0.097)	-0.186*** (0.066)	0.133* (0.072)
ln (BasicMetal)	0.535*** (0.197)	0.645*** (0.216)	0.598*** (0.195)	0.584*** (0.203)	0.483*** (0.167)	-0.063 (0.097)	-0.033 (0.047)
ln (GDP/capita)	0.381 (0.402)	0.416 (0.358)	0.526 (0.353)	421 (0.390)	0.424 (0.381)	1.022*** (0.215)	1.086*** (0.291)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instruments	ln (PopDens) ln (PopDens)² Share Environment Tertiary	ln (PopDens) ln (PopDens)² Share Environment Tertiary	ln (PopDens) ln (PopDens)² Share Environment Tertiary	ln (PopDens) ln (PopDens)² Share Environment Tertiary	ln (PopDens) ln (PopDens)² Share Environment Tertiary	ln (PopDens) ln (PopDens)² Share Environment Tertiary	ln (PopDens) ln (PopDens)² Share Environment Tertiary
Hansen J-statistic	0.01	0.51	0.02	0.03	0.58	14.42***	7.96**
Kleibergen-Paap rk LM statistic	14.9***	9.78**	14.84***	16.26***	14.95***	14.79***	14.79***
R^2	0.37	0.38	0.38	0.37	0.38	0.46	0.71
No. obs.	223	216	223	217	214	229	229

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

Import of metallic raw materials, metal mining, and basic metals manufacturing are expressed in constant 1994 USD. Nominal values are deflated using appropriate price indices (see section 2.1). 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. Date on GDP per capita (constant 2011 USD PPP) come from the World Bank. Data on tariff come from the TRAINS database and data on trade flows come from UN Comtrade.

Table 5: GMM-IV estimates with additional instrument

	Main equation		First-stage	
	ln (Import)		ln (Recovery)	ln (Mining)
	Coefficient Std. Error		Coefficient Std. Error	Coefficient Std. Error
ln (Recovery)	-0.270*** (0.078)	ln (PopDens)	9.066 (12.783)	30.803** (12.614)
ln (Mining)	-0.054 (0.120)	ln (PopDens)²	0.521 (1.451)	-3.551** (1.425)
ln (BasicMetal)	0.601*** (0.194)	Share Environment	-0.906** (0.384)	-1.003*** (0.367)
ln (GDP/capita)	0.760* (0.417)	Tertiary	0.017** (0.007)	0.019*** (0.007)
Year dummies	Yes	Min Temperature	0.112*** (0.042	0.018 (0.033)
Country fixed-effect	Yes	ln (BasicMetal)	0.103 (0.209)	1.009*** (0.377)
Instruments	ln (PopDens) ln (PopDens)² Share Environment Tertiary MinTemperature	ln (GDP/capita)	0.964 (0.887)	-0.957 (0.876)
Year dummies	Yes	Year dummies	Yes	Yes
Country fixed-effect	Yes	Country fixed-effect	Yes	Yes
Hansen J-statistic	2.8			
Kleibergen-Paap rk LM statistic	14.5***			
R^2	0.38	F-test on excluded instruments	5.13***	3.97***
No. obs.	211	No. obs.	211	211
Standard errors robust to heteroskedasticity and autocorrelation in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Import of metallic raw materials, metal mining, and basic metals manufacturing are expressed in constant 1994 USD. Nominal values are deflated using appropriate price indices (see section 2.1). 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. Date on GDP per capita (constant 2011 USD PPP) come from the World Bank. Data on tariff come from the TRAINS database and data on trade flows come from UN Comtrade. Nominal recovery is deflated using a different price index for each column.

7. Discussion

Our results indicate that the development of the metal recovery industry has an important economic impact on the import of metallic raw materials. The following examples give practical illustrations of this effect. Between 2007 and 2008, Chinese metal recovery increase by 81% and its metallic raw material imports increase by 10%. If the metal recovery industry remained constant, the increase of imports would have been 27%. The import saving equals to 3.4 billion constant 1994 USD is substantial for China. Between 2004 and 2005, Japan metallic raw material imports felt by 4.6%. At the same period, the metal recovery industry grew by 5.1%. This increase was responsible for 1.1% of the total decrease in import which corresponds to 85 million constant 1994 USD. While these yearly savings may seem small at first glance, the cumulated value of yearly savings over a decade can reach billion of USD. A country can, other things equal, cut metallic raw material imports by 15% in 5 years if the annual growth rate of the recovery industry is 15%.

Our results show that increasing the size of the metal recovery industry by 10% allows decreasing import in metallic raw materials by 2%. This is effect is not economically small when we consider the size of the metal recovery industry relative to the size of import. According to appendix 8.5, gross imports are four times metal recovery industry on average. This means that an increase of metal recovery by 10 USD reduce import by 8 USD. They are two plausible explanations why the relation is not 1 to 1. 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 our baseline 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. Third, it is important to note that employing the density of population is central to our identification strategy. An alternative

instrument could be country endowment in metallic ores because it clearly impacts decision of economic agents when it comes to extraction. Unfortunately, data comparable across countries are not available. Lastly, although our sample contains 7 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 India. 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.

8. 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, share of knowledge in environmental technologies, and percentage enrollment in tertiary education. We also find that the metal recovery industry doubled its size every five years on average between 2002 and 2008.

At the same time, 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 an environmental policy, especially for countries with low natural resources endowment.

9. References

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10. Appendices

10.1. Import of metallic raw materials and its weight in different countries average over 2002-2008

Country	Import of metallic raw materials in million current USD	Share of total raw materials import[23]	Annual growth rate of this share
China	39,821	28%	7%
Japan	16,453	9%	4%
Germany	11,454	9%	3%
Korea, Rep.	10,121	11%	3%
Spain	5,247	9%	2%
Turkey	4,604	21%	10%
Italy	4,469	7%	5%
France	2,946	4%	0%
United Kingdom	2,921	5%	-1%
Finland	2,748	23%	6%
Austria	1,531	11%	18%
Malaysia	1,300	10%	5%
Sweden	1,226	7%	-2%
Poland	971	6%	10%
Czech Republic	826	9%	16%
Norway	581	14%	2%
Slovak Republic	538	9%	2%
Portugal	243	2%	30%
Hungary	173	3%	8%
Ireland	163	3%	-13%
Average	**5,417**	**10%**	**6%**

[23] Total raw material regroup SIC0 – Agricultural, Foresty, and Fishery products and SIC1 – Mineral commodities.

10.2. 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

10.3. 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.

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

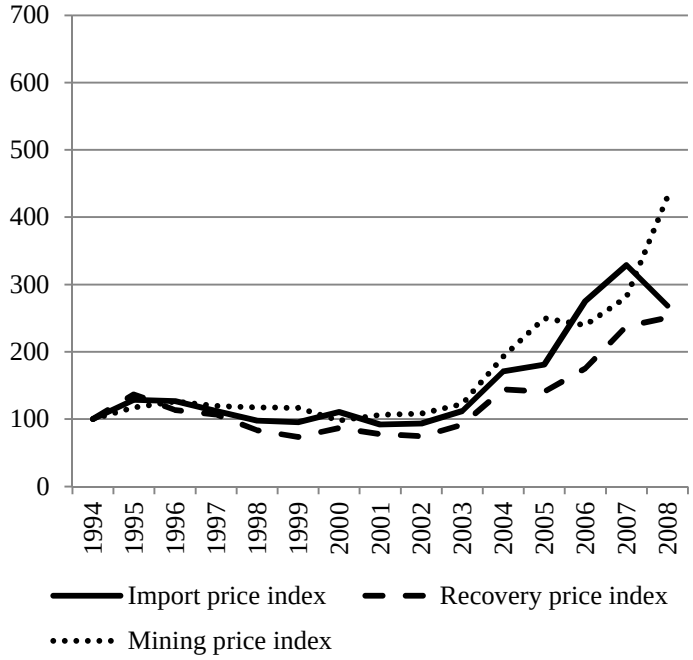

Figure 4: Calculated Price indices for Sweden

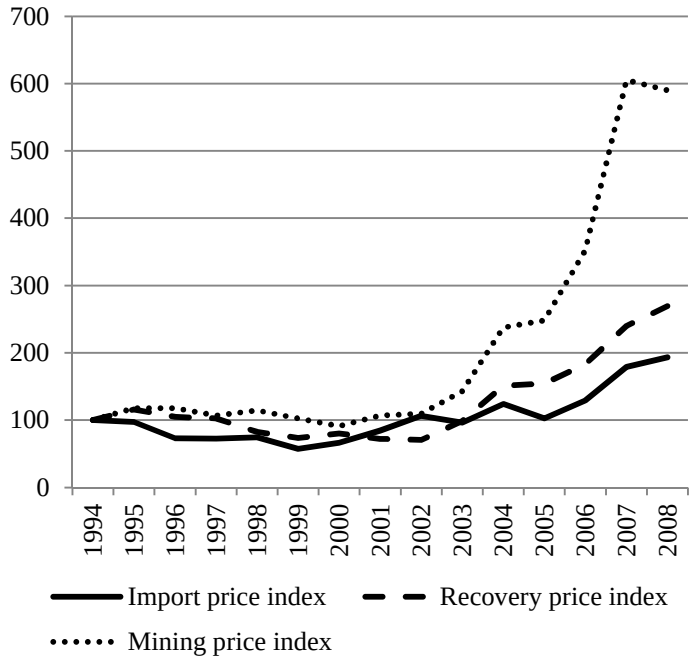

Figure 5: Calculated Price indices for the United Kingdom

10.5. : Main economic variables average over 2002-2008 (output and import are expressed in constant thousand USD)[24]

Country	Import of metallic raw materials	Metal recovery output	Metal mining output	Basic metal manufacturing output	GDP
Austria	866,000	194,429	28,200	9,271,429	331,428,571
China	15,786,667	2,051,167	18,266,667	256,333,333	7,866,666,667
Finland	970,857	301,614	95,629	6,181,429	194,285,714
France	1,405,714	9,791,429	14,100	29,214,286	2,271,428,571
Hungary	107,657	48,029	34,329	1,975,714	217,142,857
Ireland	141,400	100,260	307,200	356,600	192,000,000
Italy	2,250,000	1,758,571	141,286	42,700,000	2,085,714,286
Japan	8,056,667	3,658,333	136,833	128,833,333	4,300,000,000
Korea, Rep.	4,616,000	1,015,800	7,636	56,320,000	1,120,000,000
Malaysia	709,429	75,671	48,714	6,310,000	464,285,714
Norway	360,429	307,429	131,286	5,462,857	290,000,000
Poland	365,429	396,857	350,143	5,618,571	650,000,000
Portugal	125,917	108,233	53,550	2,503,333	270,000,000
Slovak Republic	164,833	21,217	26,833	1,890,000	105,166,667
Spain	2,678,571	1,373,000	181,714	22,185,714	1,414,285,714
Sweden	585,571	349,143	757,571	10,042,857	352,857,143
Turkey	2,301,429	93,886	203,143	14,228,571	1,021,428,571
United Kingdom	2,077,143	3,324,286	153	16,385,714	2,128,571,429
Median	**918,429**	**328,286**	**113,457**	**9,657,143**	**557,142,857**

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

10.6. 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
Austria	27%	10%	2%	3%	3%
China	19%	56%	20%	16%	11%
Finland	5%	50%	-5%	-1%	3%
France	-1%	-1%	-2%	-3%	2%
Hungary	15%	-6%	5%	0%	2%
Ireland	0%	18%	5%	9%	4%
Italy	2%	8%	4%	1%	1%
Japan	2%	1%	-4%	-1%	2%
Korea, Rep.	3%	13%	4%	6%	5%
Malaysia	4%	40%	-1%	1%	6%
Norway	0%	5%	3%	1%	2%
Poland	13%	10%	-3%	1%	5%
Portugal	22%	-2%	2%	4%	1%
Slovak Republic	2%	13%	2%	8%	8%
Spain	1%	22%	2%	0%	2%
Sweden	3%	3%	3%	3%	3%
Turkey	9%	38%	13%	10%	6%
United Kingdom	13%	0%	-13%	-7%	3%
Median	**8%**	**15%**	**2%**	**3%**	**4%**

10.7. General Environmental Management technology fields classification of the OECD[25]

A.1.	Air Pollution Abatement
A.2.	Water Pollution Abatement
A.3.	Waste Management
A.3.1.	Solid Waste collection
A.3.2.	Material recovery, recycling and re-use
A.3.3.	Fertilizers from waste
A.3.4.	Incineration and energy recovery
A.3.5.	Landfilling
A.3.6.	Waste Management – Not Elsewhere Classified
A.4.	Soil Remediation
A.5.	Environmental Monitoring

[25] The detailed classification is available on : http://www.oecd.org/env/consumption-innovation/ENV-tech%20search%20strategies%20for%20OECDstat%20(2013).pdf

10.8. 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
	8	9	10
	Coefficient Std. Error	Coefficient Std. Error	Coefficient Std. Error
ln (Recovery)	-0.210*** (0.074)	-0.202*** (0.069)	-0.209*** (0.072)
ln (Mining)	-0.037 (0.118)	-0.038 (0.117)	-0.039 (0.118)
ln (BasicMetal)	0.580*** (0.194)	0.575*** (0.192)	0.578*** (0.193)
ln (GDP/capita)	0.510 (0.351)	0486 (0.343)	0.483 (0.347)
Year dummies	Yes	Yes	Yes
Country fixed-effect	Yes	Yes	Yes
Instruments	ln (PopDens) ln (PopDens)² Share Environment Tertiary	ln (PopDens) ln (PopDens)² Share Environment Tertiary	ln (PopDens) ln (PopDens)² Share Environment Tertiary
Hansen J-statistic	< 0.01	0.01	0.01
Kleibergen-Paap rk LM statistic	14.79***	14.68***	14.82***
R^2	0.38	0.39	0.38
No. obs.	229	229	229

Standard errors robust to heteroskedasticity and autocorrelation in parentheses

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

Import of metallic raw materials, metal mining, and basic metals manufacturing are expressed in constant 1994 USD. Nominal values are deflated using appropriate price indices (see section 2.1). 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. Date on GDP per capita (constant 2011 USD PPP) come from the World Bank. Data on tariff come from the TRAINS database and data on trade flows come from UN Comtrade. Nominal recovery is deflated using a different price index for each column.