SOURCES OF CHINESE DEMAND FOR RESOURCE COMMODITIES

Ivan Roberts and Anthony Rush

Abstract

Is China's demand for resources driven predominantly by domestic factors or by global demand for its exports? The answer to this question is important for many resource-exporting countries, such as Australia, Brazil, Canada and India. This paper provides evidence that China's (mainly manufacturing) exports have been a significant driver of its demand for resource commodities over recent decades. First, it employs input-output tables to demonstrate that, historically, manufacturing has been at least as important as construction as a driver of China's demand for resource-intensive metal products. Second, it shows that global trade in non-oil resource commodities can be described by the gravity model of trade. Using this model it is found that, controlling for domestic expenditure (including investment), exports are a sizeable and significant determinant of a country's resource imports, and that this has been true for China as well as for other countries.

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1.   Introduction

China's demand for resources is large. China accounts for around two-thirds of world iron ore demand, around one-third of aluminium ore demand and more than 45 per cent of global demand for coal.[1] Accordingly, Chinese demand for resources is of considerable importance to resource-exporting countries such as Australia, Brazil, Canada and India. Just as there is debate over the sources of Chinese growth – investment versus exports – there is a similar question as to the relative importance of investment and exports as drivers of resource demand.

Understanding the sources of Chinese demand for resources is important. On the one hand, if the demand for resources is driven by infrastructure and housing investment, then China's resource imports depend on the rate of urbanisation and the government's continued focus on improving public facilities.[2] On the other hand, if China's manufacturing export industry is an important driver of resource demand, then China's demand for resource commodities may be more vulnerable to external developments.

This paper attempts to shed some light on this issue in two main ways. First, we use input-output tables to trace through the direct and indirect effects that the construction and manufacturing sectors have on resource demand. We demonstrate that, over the past decade or so, manufacturing has been at least as important as construction as a driver of China's consumption of resources. Second, we show that global trade in non-oil resource commodities can be described by the gravity model of trade. Using this model we find that, controlling for domestic expenditure

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1   The sources for these shares are the US Geological Survey (USGS 2010b) and the United Nations COMTRADE database; USGS (2010a) and CEIC; and BP (2010), respectively. According to the US Energy Information Department, China is also the second-largest consumer of oil after the US, but we do not consider China's demand for oil in this paper.

2   The view that construction investment drives steel production and hence China's demand for iron ore appears to be common among commodity analysts. See, for example, Komesaroff (2008).

(including investment), total exports are, in general, a sizeable and significant determinant of a country's resource imports, and that this has also been true for China.

The approach taken by this paper differs from previous work on the drivers of China's demand for resources. A few papers consider the question for individual commodities using time-series econometric techniques: for example, demand for energy commodities such as oil and coal (Crompton and Wu 2005; Zhao and Wu 2007), or iron ore (Tcha and Wright 1999). By and large, these papers emphasise industrial production or GDP growth as the main determinant of resource demand; they do not focus on the extent to which exports or investment are important. Focusing on steel demand in particular, McKay, Sheng and Song (2010) report that a country's urbanisation rate, investment and automobile use are statistically significant determinants of its GDP per capita – which in turn displays a positive quadratic relationship with steel use (the 'Kuznets curve for steel') – while trade openness is insignificant. In contrast, Kahrl and Roland-Holst (2008) use input-output tables to demonstrate a clear link between China's export production and its demand for oil and coal. Garnaut and Song (2006, 2007) argue that three variables – the investment share of output, the export share of production, and the level of urbanisation – determine China's demand for metals and energy. This view is supported by Zhang and Zheng (2008) who argue that manufacturing production has a significant influence on resource demand. We do not dispute this general assessment, but instead use a gravity model of trade to demonstrate that China's (predominantly manufacturing) exports have been a significant determinant of its non-oil resource imports.

With the exception of Eita and Jordaan (2007), we are unaware of any previous efforts to model trade in *resource commodities* using this approach.[3] However, many recent studies have used the gravity framework to model China's role in international merchandise trade. Edmonds, La Croix and Li (2008) and Bussière and Schnatz (2009) find that China's aggregate bilateral trade can be explained by the gravity model. Eichengreen, Rhee and Tong (2007), Greenaway, Mahabir and Milner (2008) and Athukorala (2009) use the gravity model to examine whether China's growth has had an effect on Asian countries' exports to third countries.

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3 Eita and Jordaan analyse South African metal exports to 33 trading partners using a gravity model.

Eichengreen *et al* (2007) find that China's exports tend to displace the exports of less-developed Asian economies (but not those of high-income Asian economies). In contrast, Greenaway *et al* (2008) find that China's exports 'crowd out' the exports of most Asian economies (particularly the *more* developed economies), while Athukorala (2009) finds little evidence of crowding out.

Work that is more closely related to our paper is Sheng and Song (2008), who model bilateral trade between Australia and China at the industry level using a gravity model. They find that China's trade with Australia is negatively correlated with tariff rates and positively correlated with measures of each country's 'revealed comparative advantage'. They also report that China's revealed comparative advantage in downstream industries (such as manufacturing) tends to be positively correlated with China-Australia trade in upstream industries (such as resources). This supports the idea that, in recent decades, China's imports of resources have been heavily influenced by its manufacturing export sector.

This paper proceeds as follows. Section 2 discusses the debate on the key contributors to GDP growth in China, and presents some facts about Chinese investment and exports. Section 3 highlights construction and manufacturing as the primary end-use sectors for resources and metal products, and uses input-output tables to analyse these linkages. Section 4 uses a gravity model of resource trade to test the idea that manufacturing exports have influenced China's imports of resources. Section 5 concludes.

2. Sources of Chinese Growth

2.1 The Debate about the Sources of Growth

The question of what drives China's demand for resources is related to the more general debate about the sources of China's growth. The idea that global demand for low-cost Chinese manufacturing exports has been a major contributor to China's strong growth performance in the post-1978 reform era is taken for granted in many papers (for example, Eichengreen *et al* 2007; Haltmaier *et al* 2009; Blonigen and Ma 2010). Reports suggesting that China's growth has been 'export-led' have also regularly appeared in the media (for example, Stutchbury 2009).

But the view that China's growth has been driven by exports has recently been widely criticised. Keidel (2008) uses case studies of China's macroeconomic booms and slowdowns since 1978 to argue that domestic shifts in investment and consumption have been primarily responsible for China's growth. In a similar vein, Anderson (2007), He and Zhang (2010) and Sun (2009) all argue that exports divided by GDP (currently at about 30 per cent) overstates the export share of the economy. Anderson views this measure as especially flawed in China's case, as Chinese exports have a low value-added content due to the prevalence of high value-added imported intermediate inputs. He and Zhang use input-output tables (for 2002) developed by Koopman, Wang and Wei (2008) to show that, once processing trade is accounted for, China's ratio of export value-added to GDP is only about 15 per cent.

He and Zhang (2010) also employ a provincial-level panel dataset to test for leading relationships between export growth and growth in domestic expenditure. They find that export growth Granger causes investment growth and GDP growth in the coastal provinces (which have been the focus of the Chinese government's efforts to increase China's export orientation for many years), but that it does not Granger cause investment growth in China overall. Based on more disaggregated tests, they argue that the main channel through which export growth Granger causes GDP growth is its positive impact on productivity growth.

Recent research thus argues that exports have been a less significant contributor to GDP growth than investment and consumption in the reform era. But this does not mean that exports – and the manufacturing sector more generally – are unimportant for growth or the demand for resources. Attempts to calculate the contribution of exports to growth tell us little about how important the export sector really is in the Chinese economy because they do not account for the indirect effects of the manufacturing export sector on investment. The growth of the export sector, together with domestically oriented manufacturing operations, has undoubtedly fuelled substantial investment spending. This investment includes capital spending related directly to manufacturing, but also investment in infrastructure, services and housing (for urban workers) that are necessary to support a growing export sector.

2.2 Some Facts about Chinese Investment and Exports

One commonly used way to determine the sources of Chinese growth is to calculate the contributions of investment, consumption and net exports to GDP growth. However, comparing the contribution of net exports to growth with the contributions of other components tells us little about the fundamental drivers of growth in any given economy.[4] A country could have net exports of zero and yet exports could produce much of the income that supports consumption (including of imported consumer items) and drive growth in investment (which might also absorb a sizeable share of imports). And even if exports are small relative to total GDP, this may hide many indirect effects that an expanding export sector has on growth (and the demand for resources). These effects cannot be easily seen from the national accounts, but can be detected, at least partially, with input-output tables (as in Section 3) or with the aid of an econometric model (as in Section 4).

Nonetheless, such statistics provide useful background information, and build intuition for what the sources of resource demand in China might be. On an expenditure basis, the key contributor to Chinese growth in recent years has been investment. Since 2000, real GDP growth has averaged around 10 per cent per year. Gross fixed capital formation has accounted for more than half of this growth, with an average real growth rate of 12 per cent per year, and a share in GDP of over 40 per cent in 2009. Consumption has accounted for around two-fifths of GDP growth, with annual growth of roughly 8 per cent. Net exports have accounted for only one-twentieth of annual growth in GDP over this period. But as we have observed, calculating the contribution of net exports ignores the fact that exports may be an important driver of growth in national income. In fact, exports have contributed more than a third of annual real GDP growth since 2000. Owing to the apparent importance of investment and exports for growth, we proceed by examining the sectoral drivers of investment, before considering some facts about the Chinese export sector.

Much of the increase in Chinese investment in the past decade, and particularly in the past year or so, has been driven by strong growth in residential and non-

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4   As noted by He and Zhang (2010), the calculation of a GDP component's contribution to growth is 'purely an accounting relationship, suggesting no theoretical relationships or theoretical underpinning'.

residential construction. It is commonplace to think of this construction as being driven primarily by 'infrastructure' investment. To the extent that this is true, however, it says little about what might be driving that building in the first place. In particular, substantial investment in infrastructure is necessary to support commercial activities such as manufacturing and retail trade, and demand that arises from those sectors.

Manufacturing and infrastructure are now of roughly equal size as a share of total investment, at around 30 per cent (Figure 1).[5] The next largest category is real estate investment, with the primary, mining and service sectors accounting for the remainder. After rising in the mid 1990s, the share of infrastructure investment has declined while manufacturing has rapidly gained share in the current decade, overtaking infrastructure around 2007. This situation reversed in early 2009 (at least temporarily) as growth in infrastructure investment picked up sharply due to the fiscal stimulus measures introduced by the government.

Figure 1: Fixed Asset Investment by Industry

Per cent of total urban fixed asset investment, current prices
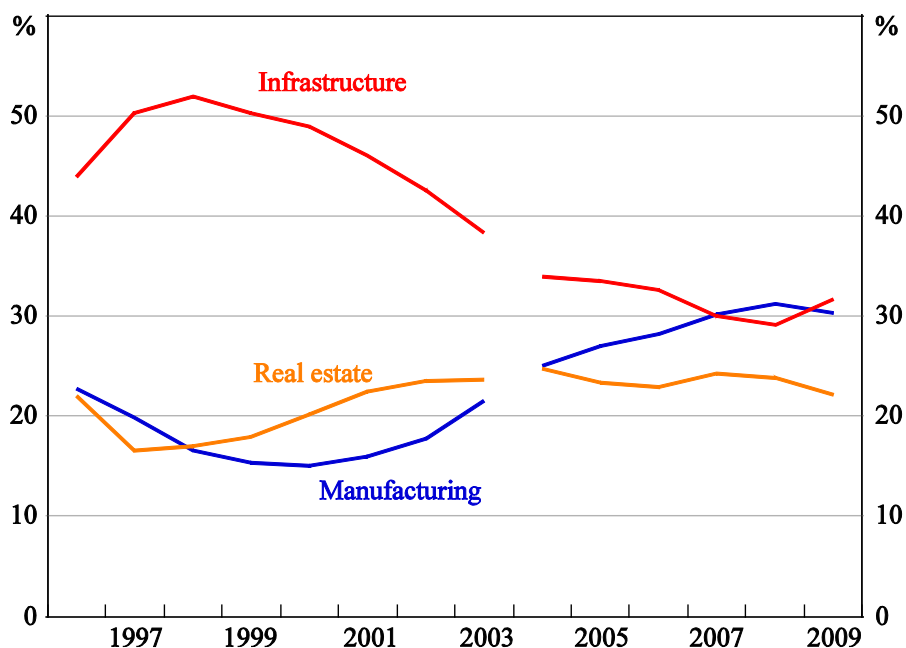
Sources: CEIC; RBA

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5 Since disaggregated data on gross fixed capital formation are not publicly available, we must use fixed asset investment (FAI) data. See Appendix A for details on how the sectoral FAI series are constructed from available sources.

The increased importance of manufacturing and real estate in total investment is related to another trend: the growing role of the private sector in investment (Figure 2). Although recent fiscal stimulus measures have at least temporarily boosted the role of the state in driving investment spending, for many years investment by government-owned or -controlled ('public') enterprises has been steadily declining as a share of urban investment. Over the past five years, the share of public investment has fallen from almost 60 per cent to around 45 per cent. The falling share of public investment and the rising share of private investment reflect both the legal transformation of state-owned firms into joint-stock corporations and a change in the industrial composition of investment: infrastructure investment continues to be mainly conducted by firms under government ownership or control, while the rapid growth in manufacturing and real estate investment has been driven mainly by the private sector.

Figure 2: Fixed Asset Investment by Industry and by Ownership

Per cent of total urban fixed asset investment
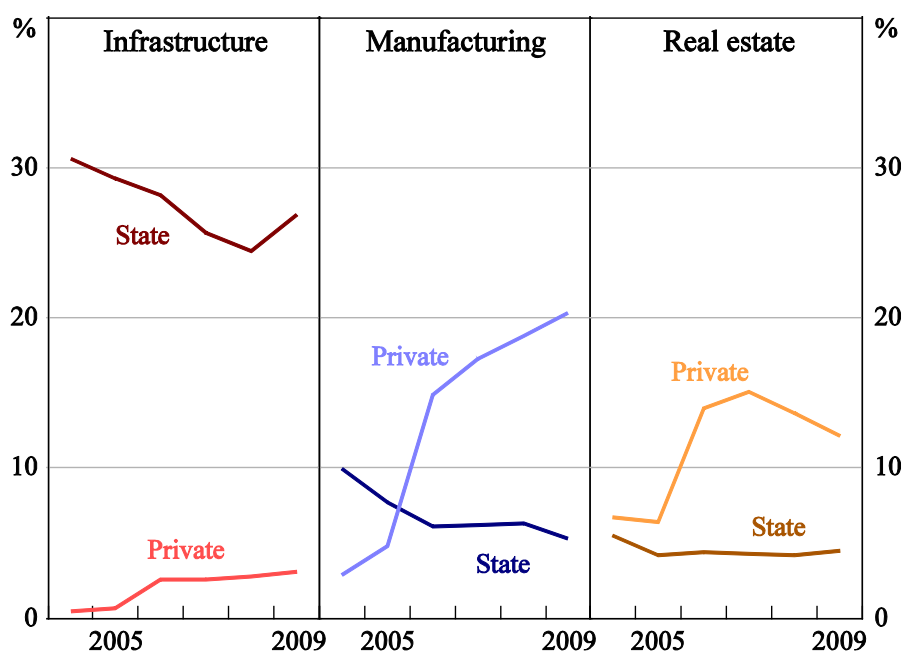
Notes: 'State' denotes investment undertaken by enterprises in which the state is the largest shareholder. 'Private' denotes investment undertaken by enterprises in which private entities have the primary holding.

Source: National Bureau of Statistics of China

Growth in (predominantly private) manufacturing investment has partly reflected the rise of the Chinese manufacturing export sector. China's manufactured exports have risen significantly since the early 1990s, in line with the increasing

integration of China into the global economy, and bolstered by China's accession to the World Trade Organization in 2001.

The vast bulk of Chinese goods exports (around 95 per cent) are manufactured items. Since the beginning of the economic reform period in 1978, Chinese merchandise exports have risen steadily from less than 1 per cent of global exports to around 10 per cent currently. From an initial specialisation in relatively low-tech items such as textiles, clothing and agricultural products, Chinese exports have become increasingly sophisticated, with growing market shares in machinery and equipment, electronics, white goods, motor vehicles and other consumer durables.

Moreover, China has rapidly risen in significance as a centre of assembly and processing operations, whereby intermediate inputs are imported from overseas, processed or assembled into final goods and then exported to third markets. Since the early 1990s, processing and assembly exports (the sum of 'processing and assembly' and 'processing with imported materials' exports) have averaged more than half of total exports (Table 1).[6]

Table 1: Chinese Exports by Customs Classification
Per cent of total merchandise exports

	Average	
	1993–2005	2006–2009
Processing	55	50
Processing and assembly	14	9
Processing with imported materials	41	41
Ordinary trade	42	45
Other	3	6
Sources: CEIC; RBA		

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6 Haltmaier *et al* (2009) show that advanced Asian economies have been supplying China with intermediate goods that are subsequently exported as final goods. According to Dean, Fung and Wang (2008), in 2002, east and south east Asian suppliers accounted for 80 per cent of China's processing intermediate imports. Zhang (2008) uses Chinese firm-level data to show that in 2006, up to one-half of high-income Asian economies' exports to China were processed and exported to developed economies.

The integration of China into global manufacturing networks means that fluctuations in foreign orders can rapidly lead to changes in domestic production. So, to the extent that growth in resource-intensive investment reflects developments in the manufacturing export sector, over the past couple of decades this investment has probably become more sensitive to developments overseas.

3.   Industrial Uses of China's Resource Imports

3.1   Overview

Although the question of what drives resource demand is related to the question of what drives Chinese growth overall, it is helpful to see how the resource commodities that China imports are actually used across industries. This can shed light on the direct sources of demand for resources. With the aid of input-output tables we can also say something about the direct and indirect effects that the manufacturing export sector has on resource consumption, in terms of inter-industry linkages. This section of the paper explores these approaches, bearing in mind that they only provide a snapshot of inter-industry linkages, and cannot properly control for international factors driving the demand for resources.

Iron ore, aluminium ores, base metal ores and coal account for more than half of China's non-oil resource imports. Chinese consumption of imported iron ore and coking coal is driven by steel production in China. China's existing deposits of iron ore have low iron content by international standards,[7] and the majority of iron ore reserves are located inland in the north and west of China, which makes transportation to the steel mills in the more industrialised coastal areas costly. In addition, in 2008, more than 90 per cent of China' crude steel was produced using blast furnaces and basic oxygen converters (the highest proportion in the world), which tend to rely on coking coal and iron ore, while comparatively little use was made of electric arc furnaces utilising a mix of steel scrap and other iron inputs. Thus the steel industry depends heavily on imported raw materials, with around half of China's total iron ore supply (adjusted for differences in iron content) sourced from overseas.

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7   According to the US Geological Survey (Jorgenson 2010), China reports that its iron ore has an iron content of about 33 per cent, compared with a little over 60 per cent in Australia, Brazil and India.

Data from various sources suggest that Chinese steel production in the 2000s is used in the construction (50–60 per cent), machinery (12–18 per cent), automobile (5–6 per cent) and home appliance (2 per cent) industries, with at least a quarter of domestic consumption being broadly 'manufacturing' (Table 2).

Table 2: Chinese Steel Consumption by Industry
Per cent of total steel consumption, selected years

	2001	2005	2008
Construction	57	55	54
Machinery	15	12	18
Automobile	6	5	6
Home appliance	3	2	2
Rail, shipping and fuel[a]	5	5	5
Other	15	21	15

Note: (a) We define 'rail, shipping and fuel' as the sum of the 'container', 'railway', 'shipbuilding' and 'petroleum' categories.

Sources: OECD (2006) (estimates for 2001 are sourced to the China Iron and Steel Association and estimates for 2005 are sourced to World Steel Dynamics); data for 2008 are obtained from Wu (2009).

While these estimates suggest that the bulk of steel consumption is accounted for by construction, it is unclear how the various sources define end-use sectors and their accuracy is uncertain. Earlier sectoral estimates of steel consumption provided by Wu (1998, 2000) suggest substantially higher shares for manufacturing and lower shares for construction.

Even so, the mix of steel items produced in China underscores the importance of construction as an end use. China's steel industry has traditionally been weighted towards production of 'long' products and low-grade 'flat' products, both of which have important uses in residential and non-residential construction. But in addition to being used in construction, flat steel products – which account for a rising share of production – are used extensively in manufacturing, especially in appliances such as air conditioners and refrigerators, and in steel casing for vehicles. China's automotive manufacturing sector is now the largest in the world, and (in gross output terms) accounted for about 7 per cent of Chinese GDP in 2009; this share has almost doubled over the past 12 years.

China is dependent on imports for around one-third of its aluminium ore needs. Unlike iron ore, the bulk of aluminium ore demand is driven by the machinery, electronics and transport (particularly automobile) sectors, which together have accounted for around half of total consumption (Hunt 2004). Turning to other base metals, these have a range of industrial uses in both the construction and manufacturing sectors. The chief industrial uses of copper are for electrical/electronic products, engineering, construction and automobiles (Tse 2009). According to the World Bank (IBRD/World Bank 2009), 44 per cent of China's copper demand in 2007 was used in construction and infrastructure (compared to a global average of one-third). Zinc and lead have important uses in manufacturing – especially the automotive industry.

3.2   Input-output Tables

Although the assorted estimates shown above give a rough sense of the relative importance of manufacturing and construction as direct consumers of metal ores, they come from various sources and from different time periods. To avoid some of the problems of comparing data from inconsistent sources, we consider direct *and indirect* effects of manufacturing and construction activities on the consumption of resources using the official input-output tables for China. Overall, we find that manufacturing is a greater direct consumer of resources than construction. This is not surprising, as manufacturing accounts for about 40 per cent of China's GDP while construction accounts for only 6 per cent.[8] At the same time, taking indirect effects into account shows that *changes* in manufacturing and construction may be equally important for resource demand.

To compute the direct effects, we calculate the share of the 'output' from resource-related industries used as intermediate inputs in the construction and manufacturing (excluding metal products) sectors. Metal products are excluded

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8   This low share for construction could partly reflect measurement error, particularly with regard to the overlap of classifications. A feature of the Chinese national accounts is that data are often collected for each enterprise as a whole. For example, the OECD (Lequiller and Blades 2006) reports that large state-owned enterprises may extract mineral ores, produce metal products, construct their own buildings and generate their own electricity. Since the total output and value-added of each enterprise can only be assigned to one of its activities, the sectoral classification is chosen on the basis of which activity accounts for the greatest part of the enterprise's gross output. Given the ubiquity of construction in industry, it is likely that classification overlap is an issue for construction.

from 'manufacturing' to enable a better understanding of the relationship between resource imports and manufacturing production.[9] We define 'output' as domestic supply – that is, an industry's gross output plus imports less exports, so as to reflect the value of resource-related output that is available for use in the economy. To gauge the importance of manufacturing *exports* as a driver of resource demand, we combine these estimates with export data. We use input-output tables published by the National Bureau of Statistics of China (NBS) from 1995 to 2005, with each table containing 17 industries, and update the analysis using the 42 sector table for 2007 (see Appendix B for details).

Figure 3 provides our estimate of the extent to which domestic 'mining and quarrying' (hereafter 'mining') inputs are directly used in manufacturing and construction, over the period 1995–2007. Mining includes coal, iron ore, other metal ores and other mining, while manufacturing (less metal products) is aggregated from individual industries.

Figure 3: Mining – Direct Use by Industry
Share of mining and quarrying domestic supply
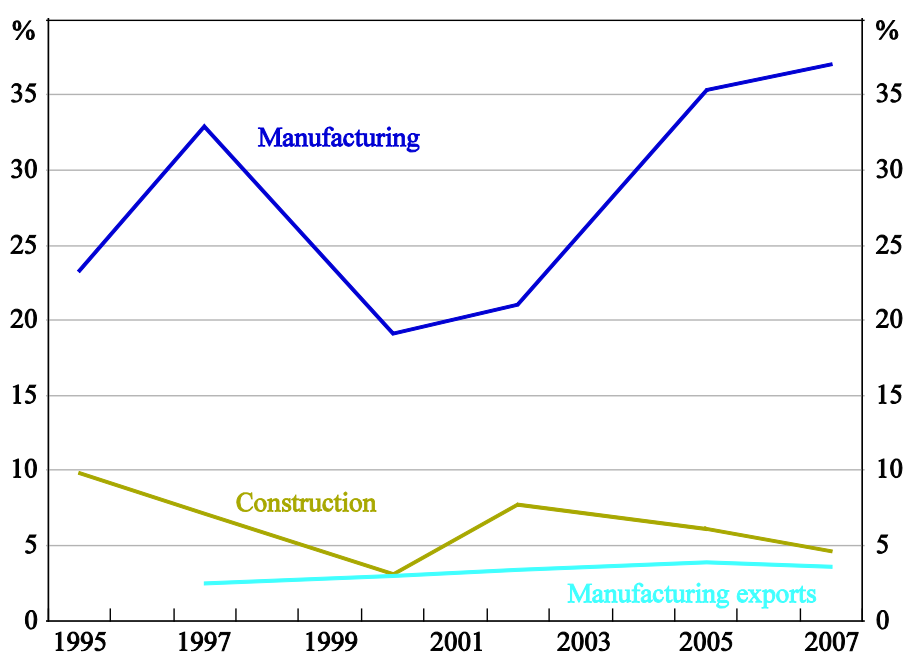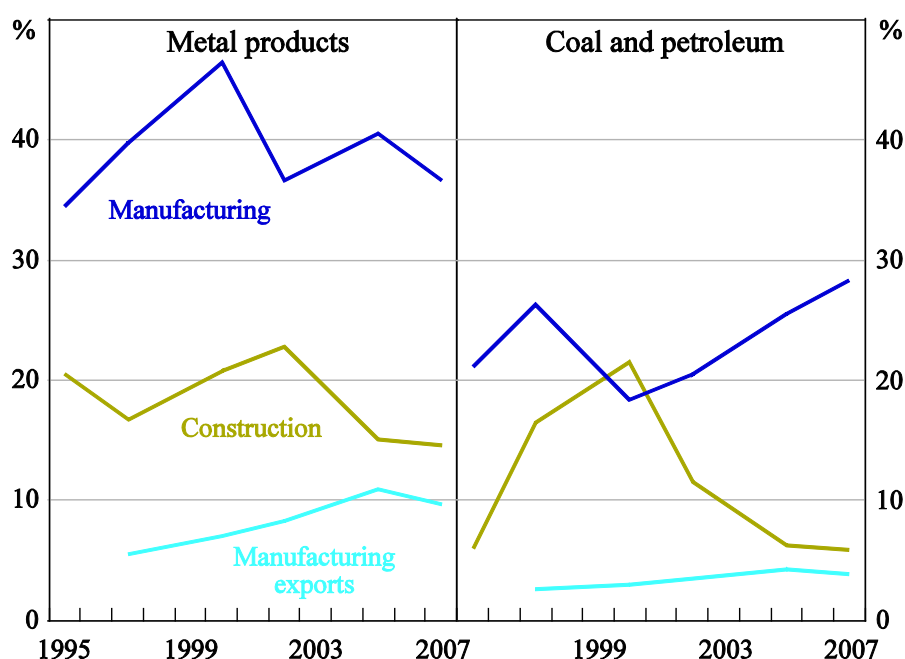

Sources: National Bureau of Statistics of China; RBA

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9 Metal products manufacturing includes both finished and unfinished metal products (including raw steel), and is thus closely related to mining production and resource imports.

Clearly, a larger share of the domestic supply of mining products is used *directly* in manufacturing than is used in construction, although much more manufacturing output is consumed domestically than is exported. The share of mining directly embodied in manufacturing *exports* is much lower, since a low share of mining output is used in manufacturing sectors with high export ratios (such as textiles, and machinery and transport). The construction sector and the manufacturing export sector each directly consumed around 5 per cent of the supply of mining products in 2007. However, the majority of mining output was used as intermediate inputs to 'metal products' and 'coal and petroleum' (not shown in Figure 3). For example, iron ore – a key mining product – is not used directly in construction, but *is* used to manufacture metal products such as steel, which are in turn used intensively by the construction sector (consistent with Table 2).

Indeed, a substantial proportion of metal products are *themselves* used as direct inputs to construction and manufacturing (Figure 4). The share of the domestic supply of metal products used in *total* manufacturing was almost three times higher than construction in 2007, though the construction sector consumed a higher proportion of metal products than manufacturing *exports*. The high share for total manufacturing is influenced by the use of non-ferrous metal products: the construction and manufacturing industries directly consumed roughly equal shares of the domestic steel supply in 2007. Our estimate of the share of metal products supply directly embodied in manufacturing exports rose strongly over the period 1997–2005, before easing in 2007 to around 10 per cent of metal products output. The share of the domestic supply of coal and petroleum used in manufacturing exports and construction is lower than the share of metal products inputs used in these sectors.

Figure 4: Metal Products, Coal and Petroleum – Direct Use by Industry
Share of domestic supply

Sources: National Bureau of Statistics of China; RBA

The above calculations only consider the *direct* shares of resource-related products used in other sectors. For example, it might be the case that a significant proportion of metal products are used as inputs to produce manufacturing equipment that is ultimately used by the construction sector. To get a rough idea of the role of indirect linkages in driving resource demand, we can compute the 'Leontief inverse' of the NBS input-output tables to gauge the effect of a one unit rise in construction and manufacturing final demand on different resource-related inputs.[10]

Figure 5 presents the results of the calculation for metal products. It suggests that accounting for indirect linkages between industries makes a big difference (compare the left-hand panel of Figure 4). Over 1995–2007, a one unit increase in the final demand of the construction sector typically resulted in a larger increase in metal products output than a one unit increase in manufacturing final demand.

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10 For further details, please refer to Appendix B. We do not compute a separate effect for a rise in manufacturing export demand, since the NBS input-output tables do not distinguish between a change in final demand for manufactures that are exported and a change in final demand for manufactures that are consumed domestically.

However, the effect of a rise in manufacturing demand on metal products output increased strongly over this period, and by 2005 was equal to the effect of an increase in construction demand. The effects of higher demand for manufacturing and construction had both increased further by 2007. These results suggest that while a unit of manufacturing requires a higher *direct* input of metal products than a unit of construction, construction requires a substantial input of manufactured items that themselves use metal product inputs intensively. Moreover, the total (direct plus indirect) effect of higher final demand in construction and manufacturing has risen since the mid 1990s, suggesting a rise in the intensity with which metal products were used over this period.

Figure 5: Metal Products – Use by Sector

Effect of a one unit increase in final demand
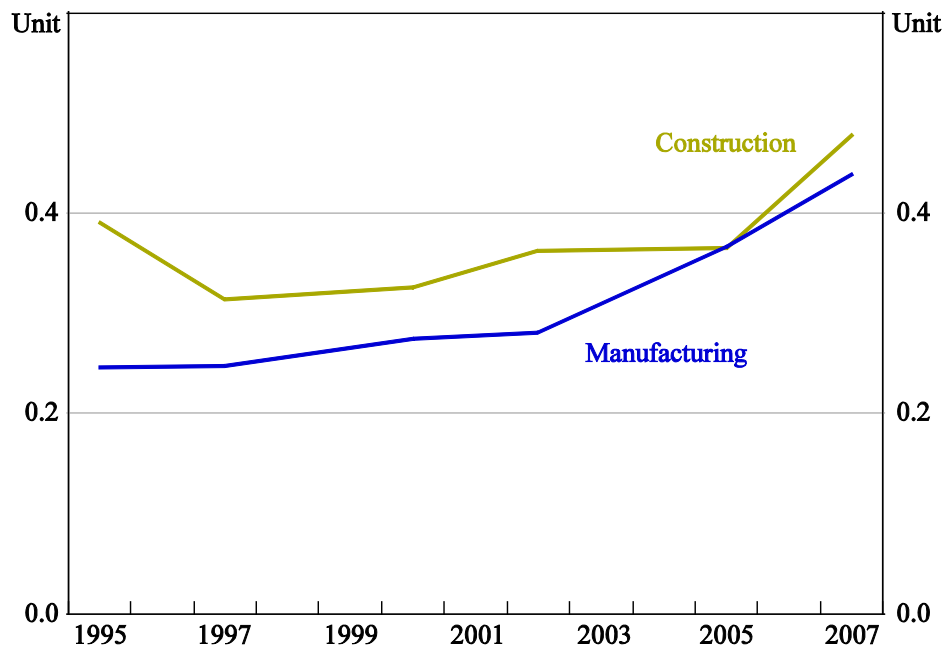
Sources: National Bureau of Statistics of China; RBA

To summarise, our analysis of input-output tables indicates that the share of resource/metal product inputs *directly* used in manufacturing exports has risen, while the share of these inputs used in construction has trended downwards slightly over the 1995–2007 period. Accounting for *indirect* effects via inter-industry linkages, metal products are used more intensively in construction than their direct input-output shares would suggest. This exercise also indicates that the impact of a one unit increase in final demand, in either construction or manufacturing, on

metal products production has been increasing over time. However, when we consider the much larger scale of the manufacturing sector, it seems clear that manufacturing has been at least as important, if not more important, than construction as a source of Chinese resource demand. In the next section we estimate a model of trade in resources in order to test the importance of manufacturing *exports* as a driver of China's resource imports.

4. Explaining Chinese Resource Imports

To examine global trade in non-oil resource commodities[11] we use the gravity model, which predicts that trade between two countries is positively related to their economic size and negatively related to the cost of transportation (typically proxied by the distance between the two countries' capital cities). We proceed in three stages. First, we estimate a baseline equation explaining bilateral resource imports using an unbalanced panel of 180 economies over the period 1980 to 2008. Second, we adjust the equation to separate out the effects of importing country domestic expenditure, domestic investment and exports on resource imports. We then use a dummy variable to test if – controlling for other determinants of commodity trade – China's imports of resources depend on its (mainly manufacturing) exports, and whether this relationship is different for China than for other resource importers.

4.1 Modelling Trade in Resources – Estimation Strategy

Our data consist of an unbalanced panel of real bilateral non-oil resource imports, real GDP, real expenditure components of GDP and population for 180 economies over 1980–2008 (see Appendix E for details). We start by estimating a baseline gravity model for resource imports. This includes both country-pair fixed effects and time-fixed effects, and is estimated using ordinary least squares. The real level

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11 Our focus on non-oil resources (metal ores and coal) reflects our interest in the effect of China's resource demand in countries such as Australia, Brazil, Canada and India. It also recognises that the market for crude oil and petroleum may be sufficiently different to constitute a separate object of study. The decision to include coal could be questioned on the grounds that it is qualitatively different from metal ores, and is used for energy generation as well as, for example, the production of metal products. However, additional analysis (not reported here) indicates that the results of this paper are robust to redefining 'non-oil resource commodities' as metal ores alone.

of resource imports (M_{ijt}^{R}), by country i from country j, in year t is expressed as follows:

$$M_{ijt}^{R} = GDP_{jt}^{\beta_1} GDP_{it}^{\beta_2} pop_{jt}^{\beta_3} pop_{it}^{\beta_4} e^{\alpha_t + \alpha_{ij} + \varepsilon_{ijt}}$$

where *GDP* refers to real gross domestic product, and *pop* refers to population. Although some authors enter real GDP per capita as a dependent variable rather than including GDP and population separately, it is also common to leave the coefficients on population unconstrained. The time-fixed effect (α_t) is a dummy variable for each time period, capturing common global trends, such as macroeconomic shocks and commodity prices. The country-pair fixed effect (α_{ij}) captures all factors without time variation that affect the volume of trade between two countries; for example, relative differences in resource endowments and the distance between two countries. Country-pair fixed effects are included because they can eliminate substantial bias in gravity models (Cheng and Wall 2005).[12] To estimate this equation using least squares, we take the log of both sides, resulting in the following specification:

$$\ln M_{ijt}^{R} = \alpha_{ij} + \beta_1 \ln GDP_{jt} + \beta_2 \ln GDP_{it} + \beta_3 \ln pop_{jt} + \beta_4 \ln pop_{it} + \alpha_t + \varepsilon_{ijt} \quad (1)$$

To examine the extent to which – controlling for other factors – commodity imports are correlated with individual components of importing country GDP, such as domestic expenditure on consumption and investment, and exports, we need to include these components in the specification.

We know from the accounting identity that:

$$GDP = C + I + G + X - M = (GNE - M) + X$$

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12 Cheng and Wall argue that one could estimate the effect of distance on trade indirectly by conducting a second stage regression of the country-pair fixed effects obtained from the first stage regression on the distance between countries i and j and a variety of other time-invariant explanators of bilateral trade. This approach is problematic, however, because if the inclusion of these time-invariant explanators in the first stage regression would lead to omitted variables bias, there is also reason to believe that the same problem would be present in the second stage regression. Notwithstanding this criticism, if we follow the two-stage approach, a significant negative coefficient for distance is found for all gravity equations estimated in this paper.

where: *C*, *I*, *G*, *X* and *M* refer to household consumption, gross capital formation, government consumption, total exports and total imports, and *GNE* refers to gross national expenditure. Our hypothesis is that a country's resource imports are correlated with a combination of gross national expenditure less imports (hereafter *GNE−M*) and exports.[13] GDP is an unweighted linear combination (the sum) of these components; however, *a priori*, the nature of their relationship with resource imports is unknown. While it would be convenient to assume that resource imports were a function of a weighted arithmetic average of *GNE–M* and *X* in the importing country, identifying the weights of this average would be problematic in least squares estimation.[14] Assuming that resource imports are correlated with a geometric average of these two variables at least allows the weights to be identified, and allows for the possibility of a nonlinear relationship. Therefore, we also propose the following gravity equation:

$$M_{ijt}^R = GDP_{jt}^{\beta_1} \left(GNE - M\right)_{it}^{\delta_1} X_{it}^{\delta_2} pop_{jt}^{\beta_3} pop_{it}^{\beta_4} e^{\alpha_{ij}+\alpha_t+\xi_{ijt}}$$

We estimate this equation in the log form:

$$\ln M_{ijt}^R = \alpha_{ij} + \beta_1 \ln GDP_{jt} + \delta_1 \ln\left(GNE - M\right)_{it} + \delta_2 \ln X_{it}$$
$$+ \beta_3 \ln pop_{jt} + \beta_4 \ln pop_{it} + \alpha_t + \xi_{ijt} \tag{2}$$

It may seem unusual to include a trade variable on both the right- and left-hand-sides of the estimated equations. But the fact that we are regressing *resource*

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13 The decision to subtract imports from GNE could be criticised on the grounds that imports are used in the production of goods for export as well as being absorbed by household consumption and investment. Ideally, one would want to subtract imports from the expenditure components corresponding to their actual use. This criticism may be relevant in the case of China, where a large proportion of imports are processed and then exported to other countries. But it is likely to be less relevant for countries where processing trade is not pervasive and exports mainly rely on domestic intermediate inputs. Owing to the difficulty of separating processing from non-processing imports across such a large sample, we leave testing the empirical importance of this issue to future work.

14 In this case, the equation could take the form:

$$M_{ijt}^R = GDP_{jt}^{\beta_1} \left(\pi_1(GNE - M)_{it} + \pi_2 X_{it}\right)^{\delta} pop_{jt}^{\beta_3} pop_{it}^{\beta_4} e^{\alpha_{ij}+\alpha_t+\xi_{ijt}}$$

While the coefficient of δ may be identified by taking logs of both sides, yielding the separate term $\delta \ln\left(\pi_1(GNE - M)_{it} + \pi_2 X_{it}\right)$, the relative weights of expenditure less imports and exports (π_1 and π_2) cannot be directly estimated.

imports by country *i* from country *j* on country *i*'s *total exports* to the rest of the world means that endogeneity is unlikely to be a serious problem. As an additional precaution, for each economy we also subtract its imports of resources from total imports. This ensures that the dependent variable is not appearing on both sides of the equation, though for most economies the share of resources in total imports is small. For China, this share was a little more than 2 per cent until 2004, but even today, resources still account for only around 10 per cent of total imports.

We can perform a similar exercise to consider the effect that investment, on its own, has on resource imports, by including GDP less investment (hereafter *GDP−I*) and investment (*I*) separately on the right-hand-side of the equation:

$$
\begin{aligned}
\ln M_{ijt}^{R} = \alpha_{ij} &+ \beta_1 \ln GDP_{jt} + \tau_1 \ln\left(GDP - I\right)_{it} + \tau_2 \ln I_{it} \\
&+ \beta_3 \ln pop_{jt} + \beta_4 \ln pop_{it} + \alpha_t + \varsigma_{ijt}
\end{aligned}
\tag{3}
$$

As we are particularly interested in the determinants of China's resources imports, we adjust Equation (1) to examine whether China's imports of commodities are more responsive to its GDP compared to other economies, as follows:

$$
\begin{aligned}
\ln M_{ijt}^{R} = \alpha_{ij} &+ \beta_1 \ln GDP_{jt} + \beta_2 \ln GDP_{it} + \gamma \ln GDP_{it} \times China_i \\
&+ \beta_3 \ln pop_{jt} + \beta_4 \ln pop_{it} + \alpha_t + \eta_{ijt}
\end{aligned}
\tag{1A}
$$

where the variable *China_i* is a dummy variable that is equal to one if the importing country is China. Hence, $\beta_2 + \gamma$ is the total marginal effect of an increase in China's GDP on its resource imports.

Using this framework we can also ask whether China's commodity imports are more responsive to the 'domestic' components of GDP or exports than are the resource imports of other economies:

$$
\begin{aligned}
\ln M_{ijt}^{R} = \alpha_{ij} &+ \beta_1 \ln GDP_{jt} \\
&+ \delta_1 \ln\left(GNE - M\right)_{it} + \phi_1 \ln\left(GNE - M\right)_{it} \times China_i \\
&+ \delta_2 \ln X_{it} + \phi_2 \ln X_{it} \times China_i + \beta_3 \ln pop_{jt} + \beta_4 \ln pop_{it} + \alpha_t + \upsilon_{ijt}
\end{aligned}
\tag{2A}
$$

Finally, we also augment Equation (3) with *China* dummies, to consider the responsiveness of China's resource imports to investment on its own:

$$\ln M_{ijt}^{R} = \alpha_{ij} + \beta_1 \ln GDP_{jt} + \tau_1 \ln(GDP - I)_{it} + \psi_1 \ln(GDP - I)_{it} \times China_i$$
$$+ \tau_2 \ln I_{it} + \psi_2 \ln I_{it} \times China_i + \beta_3 \ln pop_{jt} + \beta_4 \ln pop_{it} + \alpha_t + \omega_{ijt} \quad \text{(3A)}$$

As the gravity model is estimated in log form, the model cannot be estimated for observations with zero trade flows. Thus, all observations without trade are excluded from the regressions.[15] To prevent economies with very little resource trade having an undue influence on the results, we also exclude all observations where real resource imports were particularly small.

4.2   Results

Table 3 presents regression results for resource imports. The three 'Baseline' columns present the results for Equations (1) to (3) without *China* dummies, while the three 'China effect' columns report results including *China* dummies (Equations (1A) to (3A)). While all regressions were estimated with time and country-pair fixed effects, for the sake of brevity these coefficients are not reported.[16]

---

15 It is standard to exclude zero trade flows (that is, observations for which imports by country *i* from country *j* are zero) from the gravity model. However, this may bias our estimates if zero flows in resource trade do not occur randomly – that is, if countries that have lower GDP, or are further apart, are less likely to trade. Rauch (1999) argues that excluding zero trade flows may underestimate the magnitudes of these coefficients. To deal with zero flows, a number of papers estimate the gravity model in its non-linear form with an additive error term (for example, Westerlund and Wilhelmsson 2006). Helpman, Melitz and Rubinstein (2008) derive a two stage estimation procedure, by first estimating a probit model on the probability of trade between two countries, and then using these estimates to estimate a gravity equation in log-linear form.

16 For all equations, we correct for heteroskedasticity using an Eicker-Huber-White robust standard errors estimator that clusters standard errors at the country-pair level. As discussed by Klein and Shambaugh (2006, p 369), this allows for different variances across the country pairs and for serial correlation within country pairs. In general, this is the approach advocated by Stock and Watson (2006).

Table 3: Gravity Model Results for Resource Imports

	Baseline			China effect		
	(1)	(2)	(3)	(1A)	(2A)	(3A)
GDP_{jt}	0.71***	0.78***	0.72***	0.72***	0.78***	0.73***
GDP_{it}	1.67***			1.40***		
$GDP_{it} \times China_i$				0.88***		
X_{it}		0.98***			0.83***	
$X_{it} \times China_i$					0.12	
$(GNE-M)_{it}$		0.13***			0.08**	
$(GNE-M)_{it} \times China_i$					0.99	
I_{it}			0.52***			0.46***
$I_{it} \times China_i$						0.51
$(GDP-I)_{it}$			0.98***			0.76***
$(GDP-I)_{it} \times China_i$						0.48
pop_{jt}	0.00	−0.08	0.02	−0.02	−0.10	−0.01
pop_{it}	0.08	0.88***	0.24	0.26	0.95***	0.43**
Adjusted R^2	0.75	0.76	0.75	0.75	0.76	0.75
Observations	85 025	79 867	85 006	85 025	79 867	85 006

Notes: Model estimated with robust standard errors. *, **, *** represent statistical significance at the 10, 5 and 1 per cent levels respectively. Data cover bilateral trade between 180 economies over the period 1980–2008. Country-pair fixed effects and time-fixed effects are included in all regressions, but omitted from this table. Resource imports are excluded from aggregate imports (*M*).

Overall, Table 3 suggests that the estimated equations display a reasonable fit to the data. The adjusted R-squared values of around 0.75 are comparable to other gravity studies, although it is likely that the R-squared will be inflated by excluding zero observations on trade from the regressions.

As an aside, before discussing the results it is worth considering the issue of nonstationarity, which is potentially a concern for the panel data used in our estimation. Spurious correlation is less of a problem in panel data models than in time series analysis, as the fixed effects estimator for non-stationary data is asymptotically normal, although the results may still be biased (Kao and Chiang 2000; Fidrmuc 2009). Fidrmuc finds that gravity models estimated with fixed effects perform relatively well compared with models estimated using panel cointegration techniques that explicitly account for non-stationary variables and the long-run relationship between trade and output.

In our case, the highly unbalanced nature of the panel makes testing for unit roots and cointegration in the data problematic. Nonetheless, for the variables entering Equations (1) and (2), we can still construct a balanced sub-sample and test for panel unit roots and cointegration.[17] We performed three separate panel unit root tests: the Levin, Lin and Chu (2002), Breitung (2000), and Im, Pesaran and Shin (2003) tests. While the results for each variable vary somewhat depending on the test used, they suggest that all of the variables entering Equations (1) and (2) potentially contain panel unit roots (see Appendix D). The Breitung test, in particular, indicates that all variables are non-stationary. To test whether the relationships specified by Equations (1) and (2) are cointegrating, we tested for panel cointegration using two approaches: the Pedroni (1999, 2004) tests, and the Kao (1999) test. For both equations, the results strongly reject the null hypothesis of no cointegration. Given that the power of these tests might be limited, as a further check we estimated Equations (1) and (2) with all variables entered in (log) first differences. The results of this exercise are qualitatively similar to those presented in Table 3, suggesting that even if the variables contained unit roots but were not cointegrated, our findings would not change substantially (see Appendix D).

Turning to the results, Equation (1) implies that a 1 per cent increase in importing country GDP increases the volume of resource imports by 1.7 per cent, and that this effect is statistically significant. Exporter country GDP has a smaller, and also highly significant, effect on resource trade in all equations.

The results for Equation (2) imply that a country's resource imports are highly correlated with its aggregate exports, controlling for fixed effects and GDP in the resource exporting country. Somewhat surprisingly, while statistically significant, the effect of domestic expenditure (GNE less imports) is small. Similar results are obtained when the gravity equation is estimated in first differences (see Appendix D).

The finding that a country's imports of resources are *in general* highly correlated with its total exports is striking. But it is certainly true that resources are used intensively in the production of many traded goods. A strong correlation between

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17 Our sub-sample contains more than 750 country-pairs, over the period 1987–2008 (we truncate the time period to include data for China).

resource imports and total exports is also consistent with the empirical observation of Garnaut and Song (2006, 2007) that resource demand is often related to the size of a country's export sector. They find that this has particularly been the case in north east Asian economies with poor resource endowments.

One possibility is that our results are biased in favour of a strong export effect (and a weak expenditure effect) because the sample includes many developing economies with poor resource endowments that have pursued an export-oriented development strategy. But this explanation can be easily ruled out. As we show below, the marginal effect of exports on resource imports is actually stronger than average in the case of developed countries such as the United States, Canada and Germany. Moreover, if we interact a 'development' dummy variable – set equal to one if an economy is 'developing' and zero otherwise – with the variables *GNE–M* and *X*, we find that the coefficient on exports is no different for a developing economy than for a developed economy (the estimated difference is –0.05, and it is statistically insignificant; see Table C2). In contrast, the coefficient on *GNE–M* is higher for developing economies (the estimated difference is 0.33, with a *p*-value of 0.00). One possible explanation for this pattern might run as follows. For countries that rely on consumption rather than investment to propel growth (such as the United States), one might expect resource imports to have a relatively low correlation with domestic expenditure, as consumption is presumably less resource-intensive than investment. For countries with high investment shares of GDP (such as China or India), the opposite could be expected. While resource imports are in general likely to rise as a country boosts its manufacturing exports, one would also expect developing economies with policies favouring capital formation to import relatively more resources than consumption-focused developed economies.

However, if resource trade is correlated with aggregate trade, one could also question whether there is anything to be gained by including total exports, rather than total imports, on the right-hand-side of the estimated equation. To check this, we separately estimate the following equation:

$$\ln M_{ijt}^{R} = \alpha_{ij} + \beta_1 \ln GDP_{jt} + \pi_1 \ln (GNE + X)_{it} + \pi_2 \ln M_{it}$$
$$+ \beta_3 \ln pop_{jt} + \beta_4 \ln pop_{it} + \alpha_t + \chi_{ijt}$$

This equation is comparable to Equation (2), except that we split GDP into GNE plus exports, and imports. Once again we remove resource imports from total imports for each economy. The results for this equation, and for the analogue of Equation (2A) are reported in Table C3. Briefly, we find that an economy's aggregate imports have a (borderline) significant and *positive* effect on its resource imports. However, this effect is about a fifth of the size of the effect reported for exports in the second column of Table 3. Furthermore, GNE plus exports has a much larger and more significant effect on resource imports than aggregate imports. In other words, an economy's resource imports are generally more highly correlated with its aggregate exports than with its aggregate imports (less resource imports), controlling for other determinants of trade. This supports our choice to split resource-importer GDP into exports and GNE less imports, and our emphasis on the results in Table 3.

Turning to our alternative decomposition of GDP, Equation (3) shows that investment on its own also has a significant and positive effect on an economy's resource imports, although the effect is smaller than that of GDP less investment. A positive effect for investment is hardly surprising since much capital investment is resource-intensive. What is interesting is that the effect is quantitatively smaller than it is for the other expenditure components of GDP. It is likely that this reflects the strong relationship between resource trade and aggregate total exports (now included in *GDP–I*) revealed by the estimation results for Equation (2).

Focusing on determinants of China's resources imports, the effect of China's GDP on its imports of resources is larger than the effect of other economies' GDP on their imports of resources, on average. This effect is large and highly significant. A 1 per cent increase in China's GDP results in a 2.3 per cent increase in its resource imports, compared with an average effect of 1.4 per cent for the rest of the world. The high coefficient on GDP may reflect a particularly resource-intensive pattern of development in China, and is consistent with the rapid rise in China's steel intensity in the past decade or so (documented by, for example, McKay *et al* 2010).

Equation (2A) suggests that China's exports have a slightly larger effect on its resource imports relative to the average effect observed for other countries. The additional marginal effect of Chinese exports (that is, the coefficient on $X_{it} \times China_i$) is not statistically significant, but a Wald test finds that the *total* marginal effect of Chinese exports on Chinese imports of resources (the sum of coefficients on X_{it}

and $X_{it} \times China_i$) is statistically significant. While the effect of China's domestic expenditure (*GNE–M*) on its resource imports is larger than it is for the rest of the world, it is not statistically significant, and is not substantially larger than the effect of China's aggregate exports on Chinese imports of resources.

Finally, when we decompose GDP into investment and GDP less investment (Equation (3A)), it is clear that the additional marginal effect of Chinese investment (the coefficient on $I_{it} \times China_i$) is not statistically significant, and that the same is true of the additional effect of Chinese GDP less investment. A Wald test finds that the total marginal effect of Chinese investment on resource imports is weakly significant (at the 10 per cent level), and that the same is true of the total marginal effect of Chinese GDP less investment. This suggests that, as for other economies in the sample, investment is a significant driver of resource imports by China; however, as we have seen from Equation (2A), Chinese exports are also a significant source of demand for resource commodities.

Overall, the results indicate that Chinese GDP exerts a larger influence on its resource imports than is the case for other economies, on average, in our sample. To confirm that this is the case, we conduct separate regressions of Equations (1A) and (2A), replacing the *China* dummy with dummies for other major resource importers:

$$
\begin{aligned}
\ln M_{ijt}^{R} = {}& \alpha_{ij} + \beta_1 \ln GDP_{jt} + \beta_2 \ln GDP_{it} + \gamma \ln GDP_{it} \times country_i \\
& + \beta_3 \ln pop_{jt} + \beta_4 \ln pop_{it} + \alpha_t + \eta_{ijt}
\end{aligned}
\tag{1A*}
$$

$$
\begin{aligned}
\ln M_{ijt}^{R} = {}& \alpha_{ij} + \beta_1 \ln GDP_{jt} \\
& + \delta_1 \ln\left(GNE - M\right)_{it} + \phi_1 \ln\left(GNE - M\right)_{it} \times country_i \\
& + \delta_2 \ln X_{it} + \phi_2 \ln X_{it} \times country_i + \beta_3 \ln pop_{jt} + \beta_4 \ln pop_{it} + \alpha_t + \upsilon_{ijt}
\end{aligned}
\tag{2A*}
$$

The results are shown in Table 4, with only the additional marginal effects reported (that is, the coefficients of γ, ϕ_1 and ϕ_2 from the above equations).

Table 4: Gravity Model Results for Resource Imports by Country

	Equation (1A*)	Equation (2A*)	
	$GDP_{it} \times country_i$	$(GNE-M)_{it} \times country_i$	$X_{it} \times country_i$
China	0.88***	0.99	0.12
Japan	−0.49	1.68**	−0.85***
South Korea	−0.03	0.10	−0.05
Germany	2.74***	0.25	0.22
US	0.20	−2.09**	0.95**
UK	−0.14	0.73	−0.15
Italy	0.76	1.56	−0.03
France	−0.16	−1.00	0.06
Canada	−0.82	−2.70***	0.42
Spain	0.05	−0.39	0.10
India	0.81***	1.26*	−0.30

Notes: Model estimated with robust standard errors. *, **, *** represent statistical significance at the 10, 5 and 1 per cent levels respectively. Data cover bilateral trade between 180 economies over the period 1980–2008. Country-pair fixed effects and time-fixed effects are included in all regressions, but omitted from this table. Resource imports are excluded from aggregate imports (*M*). Countries other than China are listed in order of their total resource imports over 1980–2008, from largest to smallest. China would be second on this list.

Table 4 shows that, controlling for other determinants of trade, resource imports are more highly correlated with GDP in the case of China than for several other major resource importers, including Japan, South Korea and the United States. At the same time, the effect for China is not so large compared with these other countries as to seem implausible. The effect of GDP on resource imports reflects different factors in different countries. For example, the resource imports of Japan and, to a lesser extent, India are more strongly correlated with their domestic expenditure and less correlated with their exports than is the case for the rest of the world. In contrast, the resource imports of the US appear to be more strongly correlated with aggregate exports than is the case for other major resource importers, while they are much less correlated with domestic expenditure. Looking at the specific effect of exports on resource trade across countries, China's coefficient on exports is larger than is the case for countries such as Japan, India and the UK, but smaller than it is for the US, Germany and Canada. Thus, the additional marginal effect of exports for China lies well within the range observed for other major resource importers.

5.   Conclusion

This paper provides evidence that China's manufacturing exports have been a significant driver of its demand for resource commodities. Data on Chinese investment indicate that manufacturing was the strongest driver of growth in Chinese investment prior to the recent global financial crisis. Analysis of input-output tables shows that, over the past decade or so, the manufacturing sector (which accounts for most of China's exports) has been more important than construction as a direct consumer of resources and intermediate metal products. Accounting for indirect linkages between industries, it is found that manufacturing has been at least as important as construction as a source of demand for metal products.

Econometric results based on a gravity model of resource trade show that, controlling for domestic expenditure (including investment), exports are in general a significant determinant of a country's non-oil resource imports, and that this has been true for China as well as for other countries. This implies that China's resource demand is influenced by developments in the rest of the world. Consistent with the resource-intensive nature of much investment, the results also indicate – in China and elsewhere – a significant role for investment as a source of resource demand. This is in line with previous literature highlighting a dual role for investment and exports as drivers of demand for resource commodities. However, it appears that, over recent decades, a sizeable proportion of China's investment can be traced to the growth of its domestic and export-oriented manufacturing operations. Thus, while much of China's demand for resource commodities over this period has been driven by investment, it appears that this investment has in turn been sensitive to global influences.

Appendix A: Fixed Asset Investment Data by Sector

Obtaining estimates of investment by sector for China is not straightforward. We use fixed asset investment (FAI) data, as disaggregated data on gross fixed capital formation are unavailable. FAI includes purchases of land, and existing structures and equipment (which should be excluded from GDP); this means these data are generally biased from a national accounting perspective. We proceed on the assumption that industry shares of gross fixed capital formation are similar to those for FAI. More seriously, a major change in classifications and in the scope of measured expenditure and output in 2004–2005, following the 2004 economic census, means that internally consistent series of investment by industry are not available over the longer term. From 1996 onwards, monthly data on total urban FAI by industry is available. Prior to that, there is only incomplete industry detail on investment in capital construction and innovation by industry, which is defined as FAI less investment in real estate development, urban private housing projects and rural FAI (NBS 2004).[18] Owing to large differences between the FAI and the capital construction and innovation data, and the lack of industry detail for real estate and 'other' investment, we focus on developments since the mid 1990s.

While the changes in classifications around 2004 mean that long-term series for individual industries cannot be reliably constructed, we can aggregate industries into broader classifications to get a rough idea of the relative roles of large sectoral groupings. Barnett and Brooks (2006) decompose urban FAI since 2004 into *manufacturing*, *infrastructure* and *real estate* (which together account for 85 per cent of FAI according to their classification). Owing to the break in the data, and in the interests of obtaining a longer time series, we do not exactly replicate the decomposition of Barnett and Brooks for manufacturing and infrastructure investment, although our results for the post-2004 period are similar to theirs.

Our definition of *manufacturing* is the same as that of Barnett and Brooks from 2004 onwards, since it is given as a complete category in the FAI by industry data. Prior to 2004, we define manufacturing as 'secondary industry' less 'energy' and 'construction'. Barnett and Brooks define 'infrastructure' investment as the sum of

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18 Capital construction investment refers to new or 'extension' construction projects with a total investment of CNY500 000 or greater. Innovation investment refers to technological improvements of existing facilities or renewal of fixed assets.

FAI in electricity, gas & water; transport, storage & post; water conservancy & environmental management; education; health, social security & welfare; and public administration & social organisations. From 2004, we follow the definition of Barnett and Brooks, except that we omit public administration & social organisations and include culture, sport & entertainment. Given the higher level of aggregation in the pre-2004 data, before 2004 we define *infrastructure* as the sum of 'industry: energy', transport, storage & telecommunications; culture, education & health care; and 'other' (since infrastructure-related categories that did not exist prior to 2004 such as water conservancy & environmental management were included in this category). Including investment in the 'construction' industry itself would make little difference to the calculation as it is small (around 1 per cent of total FAI), but we omit it as it is not clear that it constitutes 'infrastructure' investment as such. Since a (discontinued) urban real estate investment category is available prior to the 2004 reclassification, we use this series to extend the *real estate* FAI series back to 1996.[19]

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[19] Barnett and Brooks (2006, p 29) use a 'wider definition of real estate investment than in the FAI survey and estimated … to include investment in residential buildings beyond that undertaken by real estate developers'. We do not adopt this strategy owing to uncertainty regarding how residential building investment is allocated across industries.

Appendix B: Input-output Analysis

To compare the relative roles of manufacturing and construction as consumers of resources over time, we employ the 17 industry input-output (I-O) tables published by the NBS for the years 1995, 1997, 2000, 2002 and 2005, and collapse a 42 sector table published by the NBS (a version of the 135 sector table) for 2007 into a comparable 17 industry table. Table B1 shows how we have reclassified industries to contract the 42 sector I-O table.

These I-O tables do not distinguish between imported and domestically produced intermediate goods. To estimate the share of resources used as inputs to construction and manufacturing, we assume that the intensity in the use of imported inputs is the same for production for exports and production for domestic sales. This assumption has been used in the literature to construct separate intermediate use tables for imports and domestic production (see Dean *et al* 2008 for a discussion).

Construction is defined as a separate industry in the I-O tables, and we define manufacturing as 'machinery and equipment', 'chemicals', 'building materials and non-metal mineral products', 'textile, sewing, leather and fur products', and 'other manufacturing' industries. Metal products manufacturing includes both finished and unfinished metal products (including raw steel), and is thus closely related to mining production and resource imports. Consequently, we exclude this sector from 'manufacturing' to obtain a better understanding of the relationship between resource imports and manufacturing production.

We look at the *direct* uses of products from three resource-related industries: 'mining and quarrying', 'metal products', and 'coal and petroleum'. For these three industries, their direct use is defined as the share of domestic supply used as intermediate inputs in the construction and manufacturing sectors. We define the share of domestic supply of (resource-related) industry j used by industry i as α_{ij}:

$$\alpha_{ij} = \frac{y_{ij}}{(Y + M - X)_j}$$

where: *Y*, *M*, and X and are gross output, imports and exports (of industry *j*); (*Y* +*M* –*X*) is domestic supply; and y_{ij} is the gross output of industry *j* consumed by industry *i*.

To estimate the direct use of resource-related industries' products by the manufacturing export sector, we multiply the ratio of exports to gross output for each manufacturing industry *k* (where *k* = *1...5*) by its share of resource-related industry *j*'s domestic supply. We then sum over *k* to obtain the total direct use of resource-related products by the manufacturing export sector. Denoting the direct use of products supplied by resource-related industry *j* to the manufacturing export sector as α_{manj}^{X}, and the export-to-gross output ratio for manufacturing industry *k* as xr_k we have:

$$\alpha_{manj}^{X} = \sum_{k=1}^{5} \frac{y_{kj}}{\left(Y + M - X\right)_{j}} \times xr_{k}$$

To look at *indirect* effects of manufacturing and construction demand on the output of 'metal products', we calculate the effect of a one unit increase in manufacturing and construction final demand on 'metal products' gross output. This is done by computing the Leontief inverse of the direct input coefficient matrix from China's I-O tables over the 1995–2007 period.

First, denote the final demand of industry *j* as c_j. Second, denote the share of the gross output of industry *j* used by industry *i* as δ_{ij}. An industry *j*'s gross output (that is, intermediate use plus final demand) can be written as:

$$Y_{j} = \left(\sum_{i=1}^{n} \delta_{ij} Y_{j}\right) + c_{j}$$

Denoting the direct input coefficient matrix as *A*, and the vectors of final demand and gross output as *C* and $\hat{Y}$:

$$D = \begin{bmatrix} \delta_{11} & \delta_{12} & \dots & \delta_{1n} \\ \delta_{21} & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ \delta_{n1} & \dots & \dots & \delta_{nn} \end{bmatrix} \qquad C = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{bmatrix} \qquad \hat{Y} = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix}$$

we can summarise the input-output table as follows:

$$\hat{Y} = D\hat{Y} + C$$
$$= (I - D)^{-1} C$$

where $(I - D)^{-1}$ is the Leontief inverse. Element ij of $(I - D)^{-1}$, say T_{ij}, is the impact of a one unit increase in c_i (the final demand of industry i) on Y_j (the gross output of industry j). T_{ij} is the total effect coefficient of an increase in final demand in industry i on the gross output of industry j. In effect, the coefficient T_{ij} estimates the output of 'metal products' required both directly and indirectly to produce an extra unit of 'manufacturing' or 'construction' final demand. See Miller and Blair (2009, Chapter 2) for further discussion of this exercise.

To calculate the effect of a one unit increase in manufacturing final demand, we weight each of the five manufacturing sub-industries' total effect coefficients by the manufacturing sub-industries' respective shares of total manufacturing final demand. We do not compute a separate effect for a rise in manufacturing export demand, since the NBS I-O tables do not allow us to distinguish between a change in final demand for manufactures that are exported and a change in final demand for manufactures that are consumed domestically.

Table B1: Industry Reclassification for the 2007 17 Sector I-O Table

(continued next page)

42 sector industry	17 sector industry
Agriculture, forestry, animal husbandry and fishery	Agriculture
Mining and washing of coal	Mining and quarrying
Extraction of petroleum and natural gas	Mining and quarrying
Mining of metal ores	Mining and quarrying
Mining and processing of non-metal ores and other ores	Mining and quarrying
Manufacture of foods and tobacco	Foodstuffs
Manufacture of textiles	Textile, sewing, leather and fur products
Manufacture of textile wearing apparel, footwear, caps, leather, fur, feather (down) and its products	Textile, sewing, leather and fur products
Processing of timbers and manufacture of furniture	Other manufacturing
Papermaking, printing and manufacture of articles for culture, education and sports activities	Other manufacturing
Processing of petroleum, coking, processing of nuclear fuel	Coking, gas and petroleum refining
Chemical industry	Chemical industry
Manufacture of non-metallic mineral products	Building materials and non-metal mineral products
Smelting and rolling of metals	Metal products
Manufacture of metal products	Metal products
Manufacture of general purpose and special purpose machinery	Machinery and equipment
Manufacture of transport equipment	Machinery and equipment
Manufacture of electrical machinery and equipment	Machinery and equipment
Manufacture of communication equipment, computer and other electronic equipment	Machinery and equipment
Manufacture of measuring instrument and machinery for cultural activity and office work	Machinery and equipment
Manufacture of artwork, other manufacture	Other manufacturing
Scrap and waste	Other manufacturing
Production and supply of electric power and heat power	Production and supply of electric power, heat power and water

Table B1: Industry Reclassification for the 2007 17 Sector I-O Table

(continued)

42 sector industry	17 sector industry
Production and distribution of gas	Coking, gas and petroleum refining
Production and distribution of water	Production and supply of electric power, heat power and water
Construction	Construction
Traffic, transport and storage	Transportation, postal and telecommunication services
Post	Transportation, postal and telecommunication services
Information transmission, computer services and software	Real estate[a]
Wholesale and retail trade	Wholesale and retail trade, hotels and catering services
Hotels and catering services	Wholesale and retail trade, hotels and catering services
Financial intermediation	Banking and insurance
Real estate	Real estate
Leasing and business services	Real estate
Research and experimental development	Other services
Comprehensive technical services	Other services
Management of water conservancy, environment and public facilities	Other services
Services to households and other services	Other services
Education	Other services
Health, social security and social welfare	Other services
Culture, sports and entertainment	Other services
Public management and social organisation	Other services

Notes: (a) It appears that 'information transmission, computer services and software' was classified as part of 'real estate' in the 2002 17 sector I-O table. Although we have reservations about the decision to classify this item in this way, for consistency with the 17 sector I-O tables we retain the classification.

Appendix C: Gravity Model Variables and Supplementary Results

Table C1: List of Variables Used in Regressions	
Coefficient	Description
M_{ijt}^{R}	volume of bilateral resource imports by country i from country j
α_t	time dummy intercept, specific to year t and common to all trading partners
α_{ij}	country-pair fixed effect, a dummy variable for each pair of trading partners in all years (note that $\alpha_{ij} \neq \alpha_{ji}$)
GDP_{it}	real GDP of country i at time t
pop_{it}	population of country i at time t
X_{it}	real exports of country i at time t
$(GNE{-}M)_{it}$	real gross national expenditure less imports of country i at time t
M_{it}	total real imports of country i at time t
$(GNE{+}X)_{it}$	real gross national expenditure plus exports of country i at time t
I_{it}	real gross capital formation of country i at time t
$(GDP{-}I)_{it}$	real GDP less gross capital formation of country i at time t

Table C2: Gravity Model Results for Resource Imports

	Baseline			Developing country effect		
	(1)	(2)	(3)	(1A)	(2A)	(3A)
GDP_{jt}	0.71***	0.78***	0.72***	0.71***	0.78***	0.72***
GDP_{it}	1.67***			1.48***		
GDP_{it} $\times Developing_i$ [(a)]				0.24**		
X_{it}		0.98***			0.96***	
$X_{it} \times Developing_i$ [(a)]					−0.05	
$(GNE-M)_{it}$		0.13***			0.01	
$(GNE-M)_{it}$ $\times Developing_i$ [(a)]					0.33***	
I_{it}			0.52***			0.28***
$I_{it} \times Developing_i$ [(a)]						0.39***
$(GDP-I)_{it}$			0.98***			1.07***
$(GDP-I)_{it}$ $\times Developing_i$ [(a)]						−0.22*
pop_{jt}	0.00	−0.08	0.02	0.02	−0.09	0.03
pop_{it}	0.08	0.88***	0.24	0.00	0.79***	0.20
Adjusted R^2	0.75	0.76	0.75	0.75	0.76	0.75
Observations	85 025	79 867	85 006	85 025	79 867	85 006

Notes: Model estimated with robust standard errors. *, **, *** represent statistical significance at the 10, 5 and 1 per cent levels respectively. Data cover bilateral trade between 180 economies over the period 1980–2008. Country-pair fixed effects and time-fixed effects are included in all regressions, but omitted from this table. Resource imports are excluded from aggregate imports (M).

(a) An economy is classified as developing if it does not appear on the World Bank's list of 'high-income economies'. Note that the list of developed and developing economies does not change over the sample.

Table C3: Gravity Model Results for Resource Imports

Alternative decomposition of GDP into *GNE+X* and *M*

	Baseline		China effect	
	(1)	(2)	(1A)	(2A)
GDP_{jt}	0.71***	0.71***	0.72***	0.72***
GDP_{it}	1.67***		1.40***	
$GDP_{it} \times China_i$			0.88***	
M_{it}		0.18*		0.20**
$M_{it} \times China_i$				0.34
$(GNE+X)_{it}$		1.24***		1.00***
$(GNE+X)_{it} \times China_i$				0.43
pop_{jt}	0.00	0.01	−0.01	−0.02
pop_{it}	0.08	0.57***	0.86***	0.70***
Adjusted R^2	0.75	0.75	0.75	0.75
Observations	85 025	85 025	85 025	85 025

Notes: Model estimated with robust standard errors. *, **, *** represent statistical significance at the 10, 5 and 1 per cent levels respectively. Data cover bilateral trade between 180 economies over the period 1980–2008. Country-pair fixed effects and time-fixed effects are included in all regressions, but omitted from this table. Resource imports are excluded from aggregate imports (*M*).

Appendix D: Panel Unit Root and Cointegration Tests

The Levin, Lin and Chu (2002) and Breitung (2000) panel unit root tests specify a null hypothesis of a unit root against the alternative of no unit root (across all cross-sections). The Im, Pesaran and Shin (2003) test employs the null hypothesis of a unit root against the alternative that *some* cross-sections do not contain a unit root. Table D1 shows the results of these tests with fixed effects, time trends and two lags.

Table D1: Panel Unit Root Tests			
	LLC	Breitung	IPS
M_{ijt}^R	8.23	0.93	–4.73***
GDP_{jt}	–3.04***	13.53	–11.03***
GDP_{it}	–1.97**	15.31	–12.95***
X_{it}	13.82	10.17	10.12
$(GNE–M)_{it}$	–5.80***	22.66	–0.08
pop_{jt}	34.63	31.63	15.10
pop_{it}	29.32	36.24	22.66

Notes: *, **, *** represent statistical significance at the 10, 5 and 1 per cent levels respectively. Data cover bilateral trade between 777 country-pairs for the period 1987–2008, with all variables in logs.

Pedroni (1999, 2004) proposes several panel cointegration tests that extend the Engle-Granger (Engle and Granger 1987) cointegration framework. Table D2 reports the panel Augmented Dickey-Fuller (Dickey and Fuller 1979) test statistics for two of these tests: first, the null hypothesis of no cointegration against the alternative of cointegration with common autoregressive coefficients for all country-pairs; and second, the null hypothesis of no cointegration against the alternative of cointegration with individual autoregressive coefficients for all country-pairs. The Pedroni tests are implemented with fixed effects and two lags. The Kao (1999) test also extends the Engle-Granger two-stage cointegration framework, testing the null hypothesis of no cointegration against the alternative of cointegration with common autoregressive coefficients for all country-pairs.

Table D2: Panel Cointegration Tests

	Pedroni Common autoregressive coefficients	Pedroni Individual autoregressive coefficients	Kao Common autoregressive coefficients
Equation (1)	–5.59***	–10.08***	–0.56
Equation (2)	–3.91***	–8.24***	–4.33***

Notes: *** represents statistical significance at the 1 per cent level. Data cover bilateral trade between 777 country-pairs for the period 1987–2008, with all variables in logs.

Table D3: Gravity Model Results for Resource Imports
Equation (1) in log differenced form

	Baseline		China effect	
	No fixed or time effects	Time effects only	No fixed or time effects	Time effects only
GDP_{jt}	0.16	0.21	0.16	0.21
GDP_{it}	1.66***	1.80***	1.60***	1.75***
$GDP_{it} \times China_i$			–0.03	–0.05
pop_{jt}	1.80***	1.79***	1.79***	1.78***
pop_{it}	0.23	0.20	0.27	0.23
Adjusted R^2	0.002	0.004	0.002	0.004
Observations	66 782	66 782	66 782	66 782

Notes: Model estimated with robust standard errors. *, **, *** represent statistical significance at the 10, 5 and 1 per cent levels respectively. Data cover bilateral trade between 180 economies for the period 1980–2008. Resource imports are excluded from aggregate imports (M). For regressions with *China* dummy interactions, the *China* dummy was also included on its own (because country-pair fixed effects are not employed), but was found to be insignificant (not reported).

Table D4: Gravity Model Results for Resource Imports
Equation (2) in log differenced form

	Baseline		China effect	
	No fixed or time effects	Time effects only	No fixed or time effects	Time effects only
GDP_{jt}	0.25*	0.25*	0.26*	0.25*
X_{it}	0.32***	0.38***	0.27***	0.33***
$X_{it} \times China_i$			–0.13	–0.13
$(GNE{-}M)_{it}$	0.08**	0.07*	0.06	0.06
$(GNE{-}M)_{it} \times China_i$			0.26	0.22
pop_{jt}	1.60***	1.71***	1.57***	1.67***
pop_{it}	0.91*	1.04*	0.98*	1.10**
Adjusted R^2	0.001	0.003	0.001	0.003
Observations	62 545	62 545	62 545	62 545

Notes: Model estimated with robust standard errors. *, **, *** represent statistical significance at the 10, 5 and 1 per cent levels respectively. Data cover bilateral trade between 180 economies for the period 1980–2008. Resource imports are excluded from aggregate imports (*M*). For regressions with *China* dummy interactions, the *China* dummy was also included on its own (because country-pair fixed effects are not employed), but was found to be insignificant (not reported).

Appendix E: Data Used in Regressions

Table E1: Additional Data Descriptions and Sources

(continued next page)

Variable	Description and source
Value of bilateral non-oil resource imports	The sum of annual bilateral imports of 'metal ores' (SITC code 28) and 'coke and coal' (SITC code 32) in US dollars. As both 'metal ores' and 'coke and coal' SITC codes are consistent across SITC revision 2 and SITC revision 3 classifications, the dataset comprises all bilateral import observations reported under either SITC revision over the period 1980–2008. *Source*: United Nations COMTRADE database
Resource prices	*Source*: IMF Primary Commodity Prices database
Volume of non-oil resource imports	The value of bilateral non-oil resource imports by country i from country j in year t divided by resource prices. Metal ore sub-components are deflated by a comparable IMF commodity price index where one is available, with 2005 chosen as a base year. For metal ores that lack a corresponding price index (such as manganese), we deflate their nominal trade value by the IMF metal price index. Coke and coal imports are deflated by the IMF coal price index. The sub-components are then weighted together to create 'real' volumes of bilateral resource imports.
Real GDP	Annual real GDP in 1990 prices. *Source*: United Nations National Accounts Main Aggregates Database, 'GDP and its Breakdown at Constant 1990 Prices in US Dollars, All countries for all years – sorted alphabetically' excel file. Available at <http://unstats.un.org/unsd/snaama/dnltransfer.asp?fID=6>. October 2009 vintage data accessed. The UN real GDP data are reported differently to the COMTRADE trade data for a few economies. Specifically, UN COMTRADE aggregates trade data for Belgium and Luxembourg into the one region over 1980–1998 (but record trade data for the two countries separately thereafter), whereas GDP data are recorded separately for the two countries in all years. Similarly, trade data for Botswana, Lesotho, Namibia, South Africa and Swaziland are aggregated into the South African Customs Union region over 1980–1999, but real GDP data are reported for each country individually. From 2000, both trade and GDP data are reported separately for each of the five countries. As Belgium is a sizeable importer and South Africa a major exporter of resources, in years where the trade data has been aggregated we also aggregate GDP across the two regions. We then identify the two regions as distinct economies in all regressions.

Table E1: Additional Data Descriptions and Sources

(continued)

Variable	Description and source
	While trade data are reported for the former USSR, former Yugoslavia and former Czechoslovakia as aggregated regions over 1980–1991, comparable real GDP data for these regions could not be obtained. Similarly, trade data are reported for East and West Germany separately in the years 1980–1990, but consistent real GDP data were not available. Thus, trade data for these economies have been omitted from the regressions.
Population	Adjustments were made for Belgium and Luxembourg, and the South African Customs Union to ensure consistency with the real GDP data.
	Source: Angus Maddison's 'Statistics on World Population, GDP and Per Capita GDP, 1–2008 AD'. Data available at <http://www.ggdc.net/maddison/>. Site accessed December 2009.
Real exports	Real exports in 1990 prices, with adjustments made for Belgium and Luxembourg, and the South African Customs Union to ensure consistency with the real GDP data.
	Source: see Real GDP
Real imports	Real imports in 1990 prices, with adjustments made for Belgium and Luxembourg, and the South African Customs Union to ensure consistency with the real GDP data.
	Source: see Real GDP
Real investment	Real investment in 1990 prices, with adjustments made for Belgium and Luxembourg, and the South African Customs Union to ensure consistency with the real GDP data.
	Source: see Real GDP

Table E2: List of Countries [a]
(continued next page)

Afghanistan[b]	Central African Republic	Ghana	Liberia
Albania	Chad[b]	Greece	Libya
Algeria	Chile	Grenada	Lithuania
Angola[b]	China	Guatemala	Luxembourg[c]
Antigua and Barbuda	Colombia	Guinea	Macedonia
Argentina	Comoros[b]	Guinea-Bissau[b]	Madagascar
Armenia	Congo (Brazzaville)	Guyana	Malawi
Australia	Costa Rica	Haiti[b]	Malaysia
Austria	Côte d'Ivoire	Honduras	Maldives
Azerbaijan	Croatia	Hong Kong	Mali
Bahamas, The	Cuba	Hungary	Malta
Bahrain	Cyprus	Iceland	Mauritania
Bangladesh	Czech Republic	India	Mauritius
Barbados	Denmark	Indonesia	Mexico
Belarus	Djibouti	Iran	Moldova
Belgium[c]	Dominica	Iraq[b]	Mongolia
Belgium and Luxembourg[c]	Dominican Republic	Ireland	Montenegro[b],[h]
Belize	Ecuador	Israel	Morocco
Benin	Egypt	Italy	Mozambique
Bermuda	El Salvador	Jamaica	Namibia[g]
Bolivia	Equatorial Guinea[b]	Japan	Nepal
Bosnia and Herzegovina	Eritrea[d]	Jordan	Netherlands
Brazil	Estonia	Kazakhstan	New Zealand
Brunei	Ethiopia[d]	Kenya	Nicaragua
Bulgaria	Fiji	Kiribati	Niger
Burkina Faso	Finland	Kuwait	Nigeria
Burundi	France	Kyrgyzstan	Norway
Cambodia	Gabon	Laos[b]	Oman
Cameroon	Gambia, The	Latvia	Pakistan
Canada	Georgia	Lebanon	Palau[b],[i]
Cape Verde	Germany[e]	Lesotho[f],[g]	Panama

Table E2: List of Countries [a]
(continued)

Papua New Guinea	Sao Tome and Principe	Spain	Turkey
Paraguay	Saudi Arabia	Sri Lanka	Turkmenistan
Peru	Senegal	Sudan	Uganda
Philippines	Serbia[h]	Swaziland[g]	Ukraine
Poland	Seychelles	Sweden	United Arab Emirates
Portugal	Sierra Leone[b]	Switzerland	United Kingdom
Qatar	Singapore	Syria	United States
Romania	Slovakia	Tajikistan[b]	Uruguay
Russia	Slovenia	Tanzania	Uzbekistan[b]
Rwanda	Solomon Islands	Thailand	Venezuela
Saint Kitts and Nevis [j]	Somalia[b]	Togo	Vietnam
Saint Lucia	South Africa[g]	Tonga	Yemen[e]
Saint Vincent and the Grenadines	South African Customs Union[g]	Trinidad and Tobago	Zambia
Samoa	South Korea	Tunisia	Zimbabwe

Notes: (a) Data span 1980–2008. While data were available for Bhutan, Botswana, Suriname, Timor-Leste, and Vanuatu, because residuals for these countries were particularly large they were treated as outliers and therefore excluded from the regressions. However, the results for all equations remain robust to their inclusion.

(b) Resource importer only.

(c) Data for 'Belgium' and 'Luxembourg' span 1999–2008, while 'Belgium and Luxembourg' span 1980–1998.

(d) Data span 1993–2008.

(e) Data span 1991–2008.

(f) Resource exporter only.

(g) 'South African Customs Union' data span 1980–1999. Data for Lesotho, Namibia, South Africa and Swaziland span 2000–2008.

(h) Data span 2006–2008.

(i) Data span 1992–2008.

(j) Data span 1981–2008.

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