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The Clean-up of Chinese Manufacturing: Examining the Role Played by Changing Techniques of Production

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Abstract

We document the recent reductions in the pollution intensity of Chinese manufacturing and utilise the methods developed and applied by Levinson (2009, 2015) and Brunel (2017) to explain the underlying causes of this pollution clean-up. We find that, unlike in the US, compositional changes to the Chinese manufacturing sector have actually increased pollution emissions. This implies that the observed reductions in pollution intensities have been caused by large improvements in techniques of production driven by technology and/or regulations. The dominance of the technique effect in driving down pollution intensities is found whether we measure an 'indirect' technique effect or a direct effect using Laspeyres and Paasche indices.

JEL: Q55, Q53, O44

Key words: Pollution intensity, composition effect, technique effect

Declarations of Interest: None

1. Introduction

The rapid growth of the Chinese economy over the last two decades has resulted in much discussion of the environmental impact of this significant industrial expansion. However, while pollution continues to be a problem, particularly in Chinese cities, it is less commonly recognised that the pollution intensity of Chinese production has declined significantly in recent years. Between 2003 and 2015 Chinese manufacturing output grew by 617% while the emission of waste gas increased by 299%, sulphur dioxide (SO_2) grew by 51% and soot actually fell by 18%.[1] This means that pollution per unit of output fell by 44% for waste gas, by 79% for SO_2 and by 89% for soot.

These reductions in pollution intensity are caused either by changes in the composition of Chinese manufacturing i.e. a shift away from pollution intensive industries towards cleaner industries (known as the composition effect) and/or changes in techniques of production as a result of technological advance or more stringent regulations (known as the technique effect).

Previous work for the US indicates that compositional changes were responsible for approximately 10% of the reduction in pollution intensity over the period 1990-2008 with the remaining 90% driven by changing techniques of production (Levinson 2009, 2015). For the EU, Brunel (2015) surprisingly finds that the composition of EU economies became more pollution intensive rather than less over the period 1995-2008, although changing techniques of production were sufficient to overcome this positive composition effect and to deliver significant reductions in emissions of many pollutants. To date, the methodology applied by Levinson (2009, 2015) and Brunel (2015) has yet to be applied to a developing economy. This note therefore identifies the extent to which compositional or technique effects explain the clean-up of Chinese manufacturing and, for the first time, estimates a direct technique effect for China.

2. Method

2.1 Scale, composition and indirect technique effects

Following Levinson (2009, 2015) and Brunel (2017), the total pollution from manufacturing *P* in a year can be defined as:

$$P_t = \sum_i p_{it} = \sum_i v_{it} z_{it} = V_t \sum_i \theta_{it} z_{it} \qquad (1)$$

where *i* and *t* index industry and year respectively, p_{it} is the pollution from industry *i* in year *t*, v_i is the output of industry *i*, *V* is the total manufacturing output, z_i is the emission intensity ($z_i = p_i / v_i$) of industry *i* and is θ is the share of industry *i* in total output ($\theta_{it} = v_{it}/V_t$) in year *t*.

[1] China Statistical Yearbook & China Statistical Yearbook on the Environment, various years.

The composition effect can be calculated as total pollution from manufacturing $\hat{P}$ holding the emission intensities $\bar{z}_i$constant:

$$\hat{P}_t = V_t \sum_i \theta_{it} \bar{z}_i \quad (2)$$

Changes in $\hat{P}$ over time are due to changes in the overall scale of manufacturing or its composition (θ) and the difference between $\hat{P}$ and P is due to changes in emissions intensities, i.e. the technique effect. Holding technique fixed over time, this method calculates pollution from changes in scale (V) and composition and therefore attributes the rest to the technique effect. Hence this approach calculates the technique effect in an indirect manner.

2.2 A direct estimate of the technique effect

Levinson (2015) proposes two indices for a direct estimate of the technique effect, i.e., the Laspeyres index (I_L) and the Paasche index (I_P):

$$I_L = \frac{\sum_i z_{it} * v_{i1}}{\sum_i z_{i1} * v_{i1}} \quad (3)$$

$$I_P = \frac{\sum_i z_{it} * v_{it}}{\sum_i z_{i1} * v_{it}} \quad (4)$$

where z_{it} and v_{it} are the pollution intensity and output value of industry *i* in year *t,* and z_{i1} and v_{i1} are the pollution intensity and output value of industry *i* in the initial year of the period of interest. Rather than holding fixed the technique effect as in the previous method, these two indices estimate the technique effect directly by holding fixed the composition of output.

3. Data

To estimate industry-level pollution intensities we exploit two sets of data. The first is the pollution data drawn from the China Statistical Yearbook on the Environment (CSYE). CSYEs are compiled by the National Bureau of Statistics and the Ministry of Environmental Protection (known as the State Environmental Protection Administration prior to 2008). In this paper, we use industry-level emissions data for industrial waste gas, SO_2 and industrial soot emission, for the period 2003-2015, for 31 industries.[2]

[2] Industrial soot emissions refer to the volume of soot (solid particles) in smoke emitted in the process of fuel burning in the premises of enterprises. Waste gas emissions refer to the volume of gases with pollutants emitted in the process of fuel burning and production in the premises of enterprises.

Industry-level annual sales revenue data are drawn from the China Statistical Yearbook.[3] We use industry-specific ex-factory price indices (i.e. producer price indices, PPI) which are also available from the China Statistical Yearbooks to deflate the nominal values of sales revenue. We then divide pollution emissions by the value of sales for each industry to obtain industry-specific pollution intensities for each year.

4. Results

Figure 1 presents the decomposition of the scale, composition and technique effects for SO_2 emissions for Chinese manufacturing 2003-2015. Line (2) provides the value of the total output of the manufacturing sector, adjusted for inflation and indexed so that 2003 = 100. Output increased by 617% over this period. If the output of each industry had grown by the same amount and if techniques of production remained unchanged then we would expect total emissions to have also increased by 617%. However, line (4) illustrates that actual emissions of SO_2 grew by only 51.3%. Table 1 provides some of the raw data underlying lines (2) and (4) and also shows that waste gas emissions increased by 299.4% while soot fell by 18.2% over the period. In terms of pollution intensities, waste gas fell by 44.3%, SO_2 by 78.9% and soot by 88.6%.

Table 1: Scale, composition and (indirect) technique effects for Chinese manufacturing, 2003-2015

	P_{2003} (1)	P_{2015} (2)	$\hat{P}_{2015}$ (3)	% change in P (4)	% change in output (scale) (5)	% change in poll'n intensity (6)	% change in $\hat{P}$ (scale + composition) (7)	Technique share of the clean-up (8)
SO_2	5744	8693	42969	51.3	616.6	-78.9	648.5	105.1
Waste gas	11696	46713	94678	299.4	616.6	-44.3	709.0	129.5
Soot	10223	8364	84984	-18.2	616.6	-88.6	731.2	118.0

Notes: P_{2003} and P_{2015} are actual pollution emissions in 2003 and 2015, respectively while $\hat{P}_{2015}$ in (3) is obtained from Equation (2); (4) = [(2)-(1)]/(1); (7) = [(3)-(1)]/(1) and (8) = [(7)-(5)]/[(7)-(4)]. SO_2 and soot in columns (1), (2) and (3) are expressed in thousand tonnes, waste gas is expressed in billion cubic metres.

Line 1 in Figure 1 stems from equation (2) and shows predicted SO_2 emissions holding constant pollution intensities (i.e. techniques of production). This predicted pollution, which results from scale and compositional changes alone, increased by 648%. Since this is greater than the 617% increase in output, it is clear that compositional changes to Chinese manufacturing *increased* SO_2 emissions by 31% over the period 2003-15. This is a notable contrast to the findings for the US by Levinson (2015) who found that compositional changes to the US economy reduced SO_2 emissions by 12% between 1990 and 2008.

Since we have ascertained that actual SO_2 emissions (line 4) increased by far less than output (line 2) and we now know that compositional changes actually increased emissions (line 1) then we know that the indirect technique effect must be large and negative and in fact is shown in Figure 1 by the distance between lines 1 and 4.

[3] We use sales revenue rather than output due to output data being missing for 2004. For the years in which both variables are reported they have a correlation of 0.999. For convenience we refer to sales revenue as output for the remainder of the paper.

Figure 1: Sulphur dioxide emissions from Chinese manufacturing

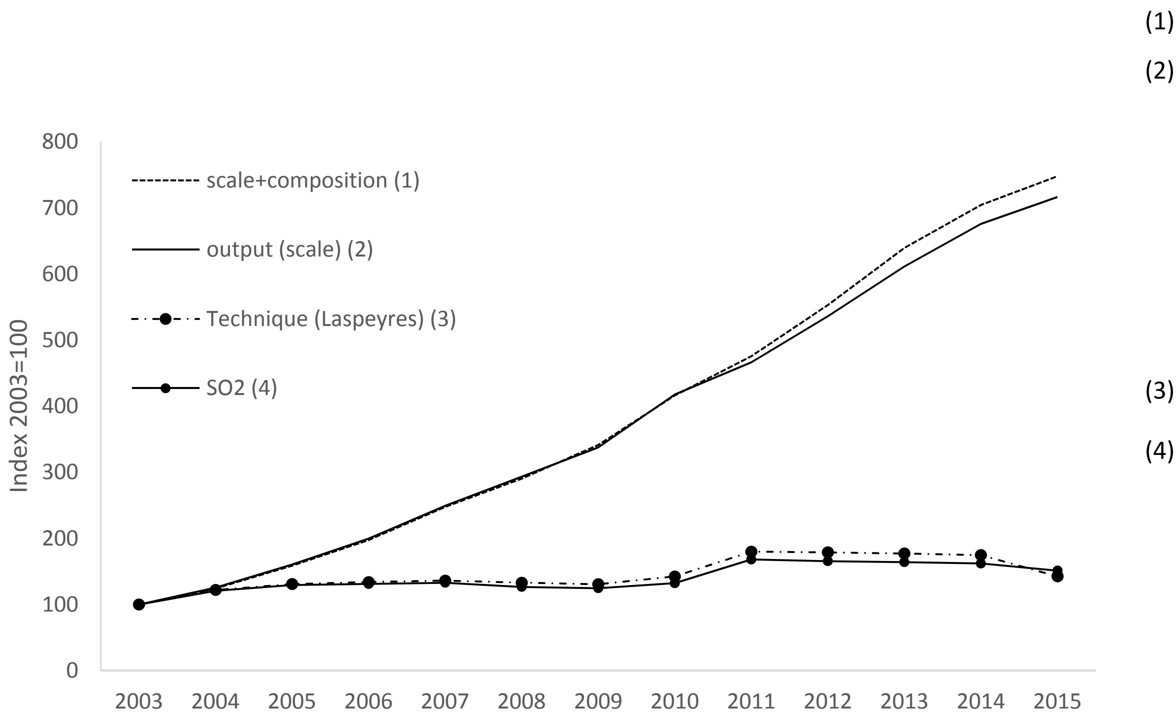

Table 1 allows us to see the magnitudes of the effects described above for all three pollutants. Columns 1 and 2 provide actual emissions in 2003 and 2015, respectively, while column 3 provides predicted emissions from equation (2) holding constant techniques of production. Column 4 provides the change in actual pollution over the period while column 5 provides the change in output. Column 6 provides the change in pollution intensity over the period. Column 7 relates to line 1 and shows the increase in pollution from scale and compositional effects alone. Holding constant techniques of production, SO_2 increased by 648%, waste gas by 709% and soot by 731%. Since output grew by 617% over the period then changes to the composition of Chinese manufacturing increased emissions by 31% for SO_2, by 92% for waste gas and by 114% for soot. Column 8 provides the indirect estimates of the technique effect which form the residual having removed compositional and scale effects. The indirect technique effect contributed 129% to the clean-up of waste gas, 118% to the clean-up of soot and 105% to the clean-up of SO_2. These figures exceed 100% because the technique effect has offset the positive composition effect.

Finally, we turn to the direct estimates of the technique effect as calculated using equations (3) and (4). Table 2 reports the Laspeyres and Paasche indices for each of our pollutants for the period 2003-2015 and indicates, for instance, that waste gas intensity fell 41.2% to 58.8% according to the Laspeyres index while, according to both indices, SO_2 fell approximately 80% and soot fell approximately 90%. These are direct estimates of the technique effect i.e. changes in the pollution intensity of manufacturing holding constant its composition.

Table 2: Indices of pollution intensity of Chinese manufacturing (%), 2003-2015

Pollutant	Laspeyres	Paasche
Waste gas	58.8	49.3
SO_2	19.9	20.2
Soot dust	10.5	9.8

From equations (3) and (4), multiplied by 100.

Line 3 in Figure 1 plots the direct technique effect from the Laspeyres index for SO_2 by multiplying the index value each year by total real manufacturing output (indexed so that 2003=100). This provides us with predicted pollution from scale and technique effects alone, holding constant the composition of production. The fact that line 3 is so similar to line 4, which provides actual SO_2 emissions, shows the extent to which the clean-up of SO_2 stems from the technique effect.

Table 3 shows the technique shares of the clean-up of manufacturing using these two direct estimates. The technique effect accounts for 93.0% and 114.4% of the clean-up of waste gas according to the Laspeyres index and the Paasche index, respectively. For SO_2 and soot the technique shares of the clean-up are between 101.1% and 102.8%.

Table 3: Direct estimates of the technique effect within Chinese manufacturing 2003-2015

		Laspeyres		Paasche		
pollutant	Clean-up of manufacturing (%) (1)	Technique (%) (2)	Technique share (%) (3)	Technique (%) (4)	Technique share (%) (5)	Indirect technique Share (%)
Waste gas	-44.3	-41.2	93.0	-50.7	114.4	129.5
SO_2	-78.9	-80.1	102.5	-79.8	101.1	105.1
Soot	-88.6	-89.5	101.1	-90.2	102.8	118.0

Notes: (1) from Column (6) of Table 1; (3) = (2)/(1) and (5) = (4)/(1).

Table 3 also includes the share of the indirect technique effect (from Table 1) for comparison. For each pollutant the direct technique share is smaller than the indirect share suggesting that the latter method overestimates the true technique effect.

5. Conclusion

This note documents the recent reductions in the pollution intensity of Chinese manufacturing and utilises the methods developed and applied by Levinson (2009, 2015) and Brunel (2017) to explain the underlying causes of this pollution clean-up. We find that, unlike in the US, compositional changes to the Chinese manufacturing sector have actually increased pollution emissions. This implies that the observed reductions in pollution intensities have been caused by large improvements in techniques of production driven by technology and/or regulations. The dominance of the technique effect in driving down pollution intensities is found whether we measure an 'indirect' technique effect or a direct effect using Laspeyres and Paasche indices.

The important role played by the technique effect is positive news for China and demonstrates the benefits of regulatory and technological responses to pollution. However, we should not lose sight of the fact that while pollution intensities are falling (for our 3 pollutants at least), total emissions are still increasing, indicating the size of the challenge China faces if it is to reduce the overall environmental impact of its industrial output.

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