research paper series

Globalisation and Labour Markets

Research Paper 2002/28

Inequality, Trade and Defensive Innovation in the USA

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The Centre acknowledges financial support from The Leverhulme Trust under Programme Grant F114/BF

Leverhulme Centre
for Research on Globalisation and Economic Policy

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Acknowledgements

This research has been performed as part of the TSER project on "Globalisation and Social Exclusion". Financial support from the European Commission is gratefully acknowledged. Oscarsson has also been supported by the Swedish Foundation for International Cooperation in Research in Higher Education. All views expressed in this paper are the author's and do not necessarily reflect those held by the European Central Bank or the Swedish Ministry of Finance. Corresponding author: Robert Anderton, European Central Bank, Frankfurt am Main, Germany. Tel: 00 49 69 1344 6447; e-mail: robert.anderton@ecb.int

INEQUALITY, TRADE AND DEFENSIVE INNOVATION IN THE USA

By

Bob Anderton and Eva Oscarsson

Abstract

This paper investigates the reasons behind this rise in inequality in the United States during the early 80's by evaluating the impact of imports and technological change on the wage bill and employment shares of skilled workers in the USA. Using highly disaggregated data, which allow us to distinguish between imports from high- and low-wage countries at a highly detailed industry level, we find that an increase in US imports from low-wage countries seems to explain part of the rise in US inequality in low-skill-intensive sectors, while technological change (proxied by R&D expenditure) explains the rise in inequality in high-skill-intensive sectors. However, we also find that increased trade with high-wage countries had an indirect effect on inequality in the more high-skill-intensive sectors through its positive impact on investment in R&D. Accordingly, it seems that the technology-based explanation for rising inequality in the USA is actually partly a trade-based explanation via the mechanism of 'defensive innovation'.

Keywords: *Outsourcing, technological change, skilled and unskilled workers, inequality, defensive innovation*

JEL Classification Number: *F, J31, O33*

Outline:

Non-Technical Summary

The United States experienced a considerable increase in inequality during the 1980s, with the major increase in inequality occurring *within*, rather than *across*, industries.[1] Although several studies have investigated the possible causes of this decline in the relative economic fortunes of the less-skilled in the USA their conclusions differ quite considerably. For example: Feenstra and Hanson (1995 and 1996) claim that increased imports explain much of the rise in US inequality; Machin and Van Reenen (1998) find that the main cause is skill-biased technological change; and Haskel and Slaughter (1997) argue that it is the *sectoral* bias of skill-biased technological change that matters.

This paper contributes to this debate by focussing on the relationship between US labour market inequality, US imports and technological innovation, and also investigates whether trade also influences technological change via "defensive innovation". In contrast to most previous studies - which investigate the impact of US imports on inequality but do not distinguish between import suppliers - we examine whether the impact of imports from high-wage industrialised countries differs from that of imports from low-wage countries.

We find that an increase in US imports from low-wage countries, helped by the large appreciation of the dollar in the early 1980s, seems to explain some of the rise in US inequality in *low-skill-intensive* sectors. Rapid technological change does not seem to be an important determinant of labour market inequality in these sectors - which is not surprising given the low technological nature of these industries. By contrast, technological change - proxied by R&D expenditure - seems to be strongly positively correlated with the rise in US inequality in our sample of *high-skill-intensive* sectors.

We also tried to establish why skill-biased technological change was so rapid during the early 1980s in the USA. Given that the technological change seemed to be strongly positively correlated with rising imports - associated with the deterioration in US trade competitiveness due to the appreciation of the dollar over this period – we investigated whether the two were

[1] We define a rise in inequality as a deterioration in the relative wages and/or employment of the less-skilled.

connected by estimating some R&D expenditure equations. We found that growing import penetration from high-wage countries had a significant positive effect on R&D investments in the high-skill sectors over our sample period, while imports from low-wage countries had no impact. Meanwhile, our analysis of the wage and employment shares within US manufacturing sectors showed that trade had no impact on skill upgrading in the high-skill sectors, while technological change was important. Accordingly, it seems that trade may also have had an indirect effect on skill-upgrading in the high-skill sectors when we take into account its effects on R&D investments via 'defensive innovation'. Although it is not driven by import competition from low-wage countries but from high-wage countries, such defensive innovation will also reduce competition from low-wage as well as high-wage countries and therefore partly explains why imports from low-wage countries seem to have had no impact on US inequality in high-skill sectors. In summary, in comparison to other studies, our results place more weight on the trade-based explanation for skill-upgrading in the United States relative to the technology-based explanation. However, further work is needed before any strong conclusions can be drawn regarding the role of defensive innovation in the "trade and wages" debate.

Introduction

The United States experienced a considerable increase in inequality during the 1980s, with the major increase in inequality occurring *within*, rather than *across*, industries.[1] Although several studies have investigated the possible causes of this decline in the relative economic fortunes of the less-skilled in the USA their conclusions differ quite considerably. For example: Feenstra and Hanson (1995 and 1996) claim that increased imports explain much of the rise in US inequality; Machin and Van Reenen (1998) find that the main cause is skill-biased technological change; and Haskel and Slaughter (1997) argue that it is the *sectoral* bias of skill-biased technological change that matters.

This paper contributes to this debate by focussing on the relationship between US labour market inequality, US imports and technological innovation, and also investigates whether trade also influences technological change via "defensive innovation". In contrast to most previous studies - which investigate the impact of US imports on inequality but do not distinguish between import suppliers - we examine whether the impact of imports from high-wage industrialised countries differs from that of imports from low-wage countries.

The first section of the paper looks at aggregate movements in US inequality. Section two describes developments in trade and technology indicators for three industry groups - representing high and low-tech sectors - while section three econometrically estimates the extent to which these factors explain the trends in US inequality. This is followed by a discussion of what drives technological innovation (proxied by R&D investment expenditure) and, in particular, empirically investigates whether import competition has any impact on innovation. Finally, the paper summarises our results and suggests issues for further work.

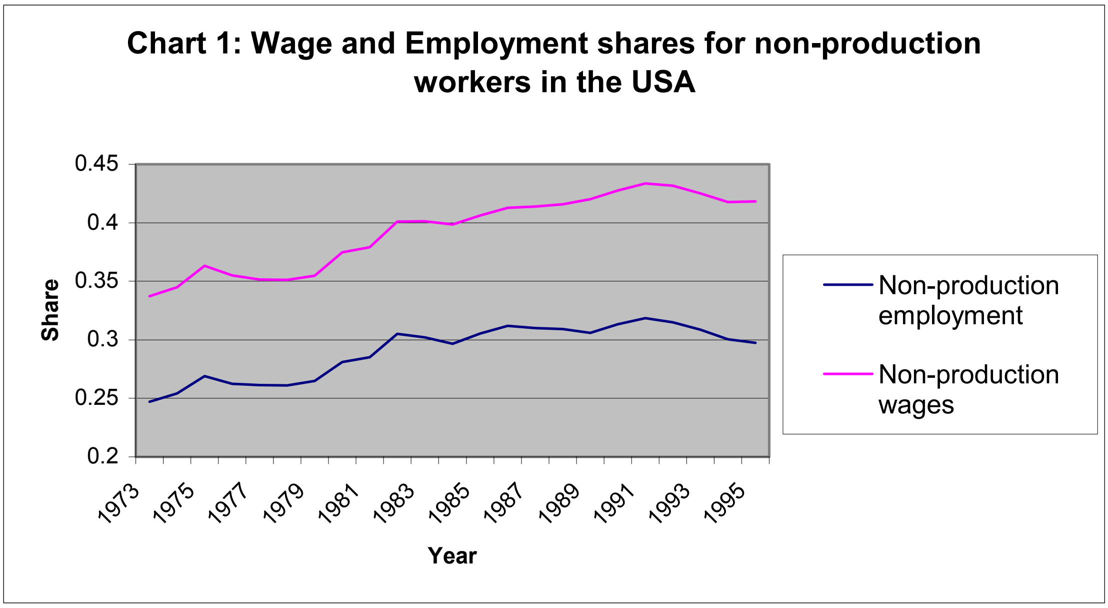
1. Movements in US inequality

[1] We define a rise in inequality as a deterioration in the relative wages and/or employment of the less-skilled.

It is now widely held that the main cause of the decline in the economic fortunes of the less-skilled seems to be a shift in demand towards higher skilled workers.[2] Two main explanations are frequently offered for such a demand shift: first, that labour-saving technical progress has reduced the relative demand for less-skilled workers; second, that increased international trade with Low-Wage Countries (LWCs) - ie, nations with an abundant supply of low-skill and low-wage labour - has decreased the demand for low-skilled workers in the advanced industrialised countries. These impacts from trade may come about via Stolper-Samuelson effects or by mechanisms such as 'outsourcing'.[3] Regarding the impact of innovation, there are various routes by which skill-biased technical progress may reduce the relative wages and employment of the less-skilled. For example, technical progress which is biased towards reducing the use of unskilled labour will tend to increase the share of skilled, relative to unskilled, labour in production. Such falls in the relative demand for unskilled workers – regardless of whether the cause is trade or technology - will tend to push down their wages and employment relative to the skilled. Using non-production workers as a proxy for higher-skilled labour, and production workers to represent the less-skilled, Chart 1 shows the wage and employment shares for skilled workers within US manufacturing from the early 1970s to the mid-1990s.

[2] For summaries and collections of papers on the causes of inequality see, for example: the Summer 1995 and Spring 1997 issues of the *Journal of Economic Perspectives; Oxford Review of Economic Policy*, vol. 16, No. 3 (Special Issue on "Globalisation and Labour Market Adjustment" edited by David Greenaway and Douglas Nelson); and the *Journal of International Economics,* Vol 50, No.1 and Vol 54, No.1

[3] Anderton and Brenton (1998a,b) describe both of these trade mechanisms in detail.



Source: US Census of Manufactures and Annual Surveys.
Notes: Wage bill of non-production workers divided by total wage bill for manufacturing sector. Employment of non-production workers divided by total employment.

As indicated by the Chart, the increase in US inequality has not occurred at a constant rate. This was highlighted by Feenstra and Hanson (1996) who pointed out that there was a particulary large increase in inequality in the United States in the *early* 1980s. Given that this period corresponds with a recession in the United States, the behaviour of the wage share is not surprising as the relative demand for non-production workers is generally countercyclical. However, two questions remain: why was the change in the wage share so abnormally large in the early 1980s; and why did it not return to its previous level after the recession?

The trade-based explanation of inequality may offer some explanation. For example, the hysteresis-type behaviour of the wage and employment shares of non-production workers corresponds to a period when the US dollar temporarily appreciated by around forty per cent which, in turn, corresponds to a period of possible hysteresis in trade performance.[4] Baldwin (1988) and others argue that the high level of the dollar during the early 1980s caused a surge in US imports, and a fall in US import prices

[4] 'Hysteresis' denotes the situation where a *temporary* shock results in *permanent* effects.

(in dollars), neither of which were reversed when the dollar depreciated back to its previous level from 1986 onwards.

Table 1 shows values at key points in time for the wage and employment shares of US non-production workers, total import penetration and R&D expenditure as a percentage of GDP.[5] The latter variable is shown as R&D is frequently used in inequality analysis as a proxy for technological change and its behaviour over time lies behind many of the claims that technology has caused an increase in inequality in a number of countries.[6] The table clearly shows that the *major* rise in US inequality - proxied by the wage and employment share of non-production workers - occurred between 1978 to 1986 and roughly corresponds with the period of the appreciation of the dollar. Similarly, US import penetration rose at a more rapid rate during this period, but carried on rising - albeit at a much slower pace - even though the dollar depreciated by around forty per cent from 1986 onwards (which is consistent with hysteresis-type behaviour).

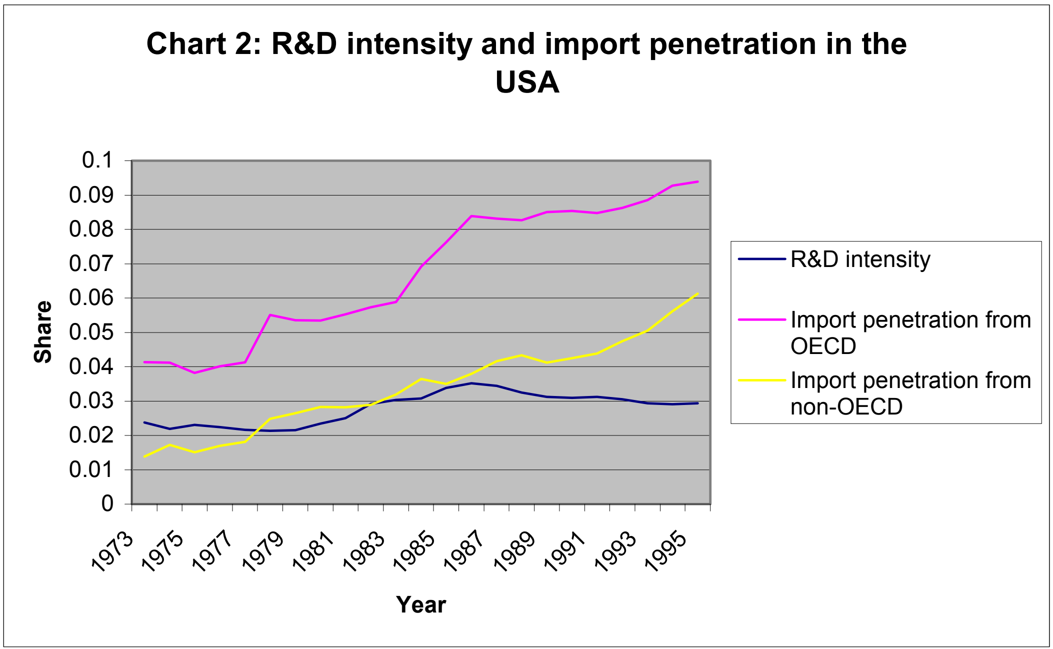
Table 1: US Non-production worker's wage and employment shares, import penetration and R&D[1]

Year	Non-production wage share[2]	Non-production employment share[3]	Import penetration[4]	R&D/Output ratio[5]
1974	34.5	25.4	5.8	2.19
1978	35.1	26.1	8.0	2.13
1986	41.3	31.2	12.2	3.51
1993	42.5	30.9	13.9	2.94

Notes: [1]All figures are in percentages. [2] Wage bill of non-production workers divided by total wage bill for manufacturing sector. [3] Employment of non-production workers divided by total employment [4] Imports divided by US imports plus domestic production of manufactures. [5]R&D expenditure in manufacturing divided by manufacturing output.

[5] The years 1974 and 1993 correspond to the beginning and end of our sample period, whereas 1978 and 1986 roughly correspond to dates before and after the dollar appreciation.

[6] However, some papers use different proxies for technology (eg, Haskel, 1996a,b find that increased computer usage can explain the rise in UK inequality).



Source: OECD ANBERD database and OECD trade database. *Notes:* Imports divided by US imports plus domestic production of manufactures. R&D expenditure in manufacturing divided by manufacturing output.

However, R&D expenditure (as a percentage of GDP) also follows a similar profile. It seems that technological change accelerated extremely rapidly during the early 1980s and then slowed down somewhat from the mid-1980s onwards, but R&D expenditure then remained at a significantly higher level relative to the previous decade (which is again consistent with hysteresis-type behaviour). The increase in both R&D expenditure and import penetration ratios in the early 1980s are shown in Chart 2 above. US Imports are also broken down into imports from high-wage countries (OECD) and low-wage countries (non-OECD).

What can we conclude from the above table and charts? If our choice of explanations for the rise in US inequality is only between trade or technology then the above evidence seems to suggest that there is more support for the trade-based explanation than suggsted by previous studies. This is not only because import penetration increased when inequality increased but also because the rise in the dollar, and the associated deterioration in the trade competitiveness of US industry, may explain the rapid rise in R&D expenditure via various mechanisms. For example, less-competitive firms - most likely comprising low-tech companies offering low quality products, perhaps associated with minimal R&D spending and a high proportion of low-skilled workers in their labour force - would be squeezed out of business (as the dollar appreciation made US imports much cheaper). These possible *compositional* effects imply that, after a considerable 'shake-out' brought about by the dollar appreciation, US industry would subsequently consist of a higher proportion of high-tech firms and the average R&D/output ratio would therefore rise (and be associated with a higher proportion of high-skilled workers if the technology is skill-biased). In addition, the deterioration in competitiveness may have encouraged US manufacturers to '*innovate defensively'*, ie, faced with strong competition from low-cost imports, firms may attempt to escape fierce import price competition by upgrading the quality of their manufactures via 'product innovation' which, in turn, is achieved by spending more on R&D.[7]

2. Trade, technology and inequality within high and low-skill-intensive sectors

Traditional trade theories can help explain movements in relative wages *across* industries, whereas what needs to be explained is the dramatic fall in the economic fortunes of less-skilled workers *within* US sectors. One possible mechanism which may explain how trade with low-wage countries may have caused increased inequality within US sectors is '*outsourcing*'. 'Outsourcing' is where firms take advantage of both the low-wage costs of the LWCs and modern production techniques - where the process of manufacturing a product can be broken-down into numerous discrete activities - by moving the low-skill-intensive parts of production abroad to the LWCs but continue to carry out the high-skill-intensive activities themselves. Once the low-skill activities have been performed the goods are then imported back from the LWCs and either used as intermediate inputs or sold as finished goods. Hence, trade with the LWCs via this route will shift demand away from less-skilled towards skilled workers in countries such as the USA, and put downward pressure on the relative wages and employment of low-skilled workers *within* industries.

[7] The experience of the UK during this period is very similar to that of the US. Between 1979-'81, sterling temporarily appreciated by around thirty per cent and was associated with a rise in the UK manufacturing R&D/output ratio from around 1.5 per cent to 2 per cent which remained higher even when the appreciation was subsequently reversed.

'Outsourcing' is claimed to be an important activity in industries such as footwear (Yoffie and Gomes-Casseres, 1994, case 7) and textiles (Waldinger, 1986; Gereffi, 1993), etc. The above articles also illustrate that outsourcing applies to *finished* goods as well as *intermediate* inputs.

Orcutt (1950) may provide one explanation for a possible link between exchange rate movements and 'outsourcing'. Orcutt argues that the *costs of switching* from domestic to foreign suppliers may cause the price elasticity of imports to be bigger for large price changes than for small changes and a similar argument can be made for disproportionately large increases in 'outsourcing'. For example, when considering whether or not to 'outsource', US producers have to take into account the costs incurred when switching from in-house, or other domestic, supplies to foreign suppliers. For instance, when switching to foreign suppliers US producers may have to modify production techniques to be compatible with the newly-imported products and spend time ensuring that the new supplier is both reliable and makes a product of the required specifications and quality. Consequently, small changes in the price of foreign goods will not be acted upon as the change in price differential will not cover switching costs. In contrast, a large appreciation of the dollar could result in a substantial differential between the costs of producing 'in-house' (or domestic) goods and imports - which may be at least sufficient to cover the costs of switching. In summary, *switching costs* may cause a *disproportionate* increase in 'outsourcing' during *large* exchange rate appreciations, which may partially explain the 'lumpiness' of changes in the economic circumstances of the less-skilled in the USA. Furthermore, such increases in 'outsourcing' may be difficult to reverse, even if the large appreciation of the dollar is fully reversed, since US manufacturers now have a greater understanding of the benefits of 'outsourcing' and are now familiar with the quality of goods not previously imported. Consequently, the substantial *temporary* appreciation of the dollar may have encouraged US purchasers to *permanently* switch from domestic to foreign goods (which may suggest a disproportionate increase in 'outsourcing' at a time when the economic fortunes of the less-skilled in the US deteriorated very rapidly).

Our method for investigating the causes of US inequality is to econometrically estimate the impact of trade with LWCs on the wages and employment of the less-skilled by using a proxy variable for 'outsourcing' similar to Feenstra and Hanson (1996). Feenstra and Hanson (1996) proxy 'outsourcing' by US imports from *all* countries, which implicitly captures 'outsourcing' of US production to advanced industrialised countries as well as LWC's. However, there is no obvious reason why firms would 'outsource' *low-skill-intensive* activities - which is the mechanism by which 'outsourcing' affects the demand for the less-skilled - to advanced industrialised countries which are relatively abundant in skilled labour. Consequently, a major objective of this paper is to investigate whether the *source* of imports matters by disaggregating US imports according to individual supplier countries and constructing US import share terms for both high and low-wage countries. Therefore, by explicitly identifying imports solely from *low-wage countries* and using this as a variable to explain changes in the wage share of the less-skilled in the USA, we are more likely to accurately capture 'outsourcing' to low-wage countries.

In previous work on the UK, Anderton and Brenton (1998b) find that the impact of trade with LWCs differs considerably between high and low-skill-intensive sectors. Hence in the following analysis we distinguish between groups of industries which we classify as intrinsically high- or low-skill. In Table 2 below we look at two groups of industries which can be classed as low-skill-intensive (abbreviated as LSA and LSB) and one group of high-skill-intensive sectors (HS). The first part of Table 2 shows that the largest rise in US inequality occurred in all three sectors during the period of substantial dollar appreciation, but that inequality continued to increase, albeit more gradually, through the rest of the 1980s and early 1990s.[8]

The last three columns of Table 2 show that R&D expenditure expressed as a proportion of output is extremely small in the low-skill sectors (less than one per cent

[8] The higher wage bill share for non-production workers in the HS sectors relative to the other sectors is consistent with our claim that the former sectors are relatively high-skill-intensive. Also note that the sum of the sectors do not add up to the aggregate wage share in Table 1 as not all sectors are included in Table 2.

in LSA and LSB). Given that the R&D ratios in the low-skill sectors are very small (seemingly confirming that these are indeed low-technology-intensive industries), it becomes doubtful as to whether it is feasible that movements in R&D expenditure/technology can explain the change in the wage share of non-production workers in these sectors. On the other hand, the technology explanation corresponds to movements in R&D expenditure in the high-skill sectors, particularly the large rise in R&D during the period of the dollar appreciation in the early1980s. In addition, unlike the low-skill sectors, it seems feasible that the large absolute size of R&D expenditure in the high-skill sectors, combined with the significant changes in R&D over time, could have a strong impact on labour-skill requirements in these sectors.

Table 2 also shows US imports from LWCs as a proportion of total sectoral imports. Although the relationship between the import share of LWCs in the low-skill sectors and the wage and employment shares of non-production workers is unclear in the early 1970s, there is a large increase in US imports from LWCs during the period when inequality rose more rapidly and the dollar appreciated. Conversely, imports from LWCs for the high-skill sector group remained nearly static between 1978 to 1986 - perhaps indicating that defensive innovation succeeded in reducing import competition from LWCs in this sector (the relatively high import share of LWCs in this high-skill sector also suggests that the degree of low-wage country competition may be sufficient to be a plausible cause of defensive innovation).

Table 2: USA wage bill share and employment share of non-production workers, import share of low-wage countries (LWCs) and R&D in low and high-skill-intensive sectors[1]

	Wage bill share			Employment share		
Year	**LSA[2]**	**LSB[2]**	**HS[2]**	**LSA[2]**	**LSB[2]**	**HS[2]**
1974	24.8	25.8	41.2	14.6	20.3	30.9
1978	25.1	26.3	42.2	14.9	20.3	32.3
1986	27.3	30.3	49.6	17.1	23.4	38.4
1993	28.6	31.7	51.1	17.5	23.7	37.6

	Import share of LWCs[3]			R&D/Output ratio		
Year	**LSA[2]**	**LSB[2]**	**HS[2]**	**LSA[2]**	**LSB[2]**	**HS[2]**

1974	37.7	26.1	34.9	0.45	0.48	4.24
1978	46.1	26.0	36.6	0.46	0.49	3.85
1986	58.0	30.2	35.8	0.57	0.86	5.79
1993	61.2	33.7	42.8	0.80	0.62	5.42

Notes: [1]All figures are in percentages. [2]**LSA**= low-skill sector group 'A' comprising ISIC sectors 3200, 3300 and 3400 (ie, Textiles, Apparel and Leather; Wood Products and Furniture; Paper, Paper Products and Printing). **LSB**= low-skill sector group 'B' comprising ISIC sectors 3600, 3700 and 3810 (ie, Non-Metallic Mineral Products; Basic Metal Industries; Metal Products); **HS**= High-skill sectors comprising ISIC sectors 3500, 3820, 3830, 3850 (Chemical Products; Non-electrical Machinery; Electrical Machinery; Professional Goods). [3] Sectoral imports from low-wage countries (LWCs) expressed as a percentage of total sectoral imports.

3. Econometric results for the 'inequality' equations (ie, wage and employment share equations)

In this section, we econometrically estimate the impact of both trade with LWCs and R&D spending on the wage and employment shares of non-production workers in the USA. We use highly disaggregated US wage and production data - converted from US SIC to ISIC REV2 - and define non-production workers as skilled and production workers as less-skilled (Source: US Census of Manufactures and Annual Surveys). Technological change is proxied by R&D expenditure as a proportion of GDP (source: OECD ANBERD database). The capital stock data are from the OECD's International Sectoral Database (ISDB). The bilateral US imports data were supplied by the OECD on an SITC basis and converted to the ISIC REV2 classification. Trade, production and wage bill and employment share data are all disaggregated to the 4-digit ISIC level (hence all variables are on an ISIC basis - further details of the 4-digit sectors used in the analysis are given in the data appendix). In order to provide enough observations for separate 'panel estimation' of our three sectoral groupings, we pool the data across the 4-digit ISIC sectors within the LSA, LSB and HS broad groupings using annual data for the sample period 1973-1993 (imposing, in effect, the same parameters across the different 4-digit sectors).

Following Feenstra and Hanson (1995 and 1996), we seek to assess whether industry import shares have contributed significantly to the determination of the within-sector wage bill and employment shares of low-skilled workers in the United States. Following the approach of Berman *et al* (1993, 1994), and assuming capital to be a fixed factor of production, we start from a variable cost function in translog form:

$$\ln C_i = \alpha_0 + \alpha_y \ln Y_i + \frac{1}{2}\alpha_{YY} \ln(Y_i)^2 + \beta_K \ln K_i + \frac{1}{2}\beta_{KK} \ln(K_i)^2$$

$$+ \sum_j \gamma_j \ln W_{ij} + \frac{1}{2}\sum_j \sum_k \gamma_{jk} \ln W_{ij} \ln W_{ik} + \sum_j \delta_{Yj} \ln Y_i \ln W_{ij}$$
$$+ \sum_j \delta_{Kj} \ln K_i \ln W_{ij} + \rho \ln Y_i \ln K_i +$$
$$\lambda_T T_i + \frac{1}{2}\lambda_{TT}(T_i)^2 + \lambda_{YT} T_i \ln Y_i + \lambda_{KT} T_i \ln K_i \quad + \sum_j \varnothing_{TW_j} T_i \ln W_{ij} \qquad (1)$$

where C_i is variable costs in industry i,

Y_i is output in industry i,

K_i is the capital stock in industry i,

W_{ij} is the price of variable factor j and

T_i represents technology in industry i.

Cost minimisation generates the following linear equations for the factor shares (S):

$$S_{ij} = \gamma_j + \delta_{Yj} \ln Y_i + \delta_{Kj} \ln K_i + \sum_k \gamma_{jk} \ln W_{ik} + \varnothing_{TW_j} T_i \qquad (2)$$

whilst differencing (denoted by d) generates

$$dS_{ij} = \varnothing_{TW_j} dT_i + \delta_{Yj} d\ln Y_i + \delta_{Kj} d\ln K_i + \sum_k \gamma_{jk} d\ln W_{ik} \qquad (3)$$

assuming homogeneity of degree one in prices imposes

$$\sum_k \gamma_{jk} = \sum_j \gamma_{jk} = \sum_j \delta_{Kj} = \sum_j \delta_{Yj} = 0 \qquad (4)$$

which generates with two variable factors, j and k

$$dS_{ij} = \varnothing_{Tw_j} d\,T_i + \delta_{Kj} d\ln K_i + \delta_{Yj} d\ln Y_i + \gamma d\ln\left(\frac{W_j}{W_k}\right) \qquad (5)$$

In our empirical application of the above model we have two variable factors of production, low-skilled (production) workers and higher-skilled (non-production) workers, and adopt a similar approach to Machin *et al* (1996) and estimate the following US wage bill and employment share equations:

$$dSW_{it} = \alpha d\ln K_{it} + \beta d\ln Y_{it} + \rho TECH_{it} + \lambda d\ln MS_{it} + \gamma D_t + U_{it} \quad (6)$$

$$dSE_{it} = \alpha d\ln K_{it} + \beta d\ln Y_{it} + \rho TECH_{it} + \lambda d\ln MS_{it} + \ell d\ln(W^{hs} / W^{ls})_{it} + \gamma D_t + U_{it} \quad (7)$$

Where: SW_{it} is the share of the wage bill of the high skilled $\left(\frac{WBit^{hs}}{\left(WBit^{hs} + WBit^{ls} \right)} \right)$

SE_{it} is the employment share of the high skilled (similarly derived as SW_{it}).

$WBit^{hs}$ is the wage bill of the higher skilled (i.e. non-production workers).

$WBit^{ls}$ is the wage bill of the lower skilled (i.e. production workers).

W^{hs} / W^{ls} is the relative wage rate of high and low-skilled workers.

K_{it} is the capital stock.

Y_{it} is real output.

$TECH_{it}$ is a proxy variable for technological change (proxied by R&D).

MS_{it} is the share of the value of domestic demand for the output of industry i accounted for by imports from low-wage countries.

D_t is a set of time dummies included to capture any company preferences for non-manual or manual workers common across industries for a given year.

U_{it} is an error term.

Subscript i represents industry i.

First differences are denoted by d.

The time dummies capture any changes in firm-level preferences for non-production or production workers common across industries in each year. The MS term represents US imports and can be interpreted as a proxy for outsourcing. In this paper, we follow the approach of Feenstra and Hanson (1995, 1996) and justify the inclusion of the MS term in the wage bill share equation by arguing that merely including the factors derived from a traditional translog production function will not capture other factors – such as outsourcing – which may influence a firm's demand for skilled labour. Given that outsourcing to low-wage countries is claimed to push the range of activities performed by domestic industry away from low-skill towards high-skill tasks, the MS term can be interpreted as representing a reduced-form relationship between outsourcing and a firm's unit input requirement for skilled labour. As we want to distinguish between the impacts of high and low-wage country import suppliers, we experiment with two different versions of MS:

1. MSO = US imports from high-wage countries (which we define as OECD countries).[9]
2. MSNO = US imports from LWCs (which we define as Non-OECD countries).

Our final wage-bill share specifications based upon (6) above are shown in Table 3 below. Note that we do not include the relative wage rates for the two types of labour in our final estimated wage bill share equations mainly because relative wages are unlikely to be exogenous. However, the equation includes a set of macro time dummies, which will capture any firm-level changes in preferences for higher-skilled workers due to absent variables such as relative wages. We estimate two equations for each industry group - the first equation uses US imports from low-wage countries (ie, OECD countries: 'MSO') and the second uses imports from low-wage countries (ie, non-OECD countries: 'MSNO'). The results show that the change in output is negatively signed and statistically significant (with the exception of industry group LSA) which conforms with our prior that a short-run decline in output tends to reduce the demand for the less-skilled relative to the skilled. The capital stock term is not statistically significant in any of the equations, which may not be surprising for the low-skill-intensive sectors as they are extremely low-capital-intensive industries. Although the capital stock term has the correct positive sign for the high-skill sector grouping - as we expect complementarities between capital and skill - it is not statistically significant (perhaps because it is dominated by the R&D term). One striking result is that R&D is not statistically significant for the low-skill sectors, but is strongly significant for the high-skill sectors.

[9] The OECD countries are defined as those members up to and including 1993 (ie, excluding later members such as the Czech Republic, Hungary, Poland, South Korea and, probably most importantly, Mexico).

Table 3: US wagebill share equations (dSW_{it})

Equation	LSA (1)	LSA (2)	LSB(1)	LSB (2)	HS (1)	HS (2)
C	0.016	0.0149	0.003	0.0032	0.0006	0.0007
	(2.500)	(2.427)	(0.720)	(0.669)	(0.217)	(0.252)
$dlnY_{it}$	-0.013	-0.014	-0.042	-0.043	-0.026	-0.025
	(-0.970)	(-1.001)	(-3.205)	(-3.362)	(-2.580)	(-2.516)
$dlnK_{it}$	-0.045	-0.041	0.005	-0.007	0.059	0.058
	(-0.977)	(-0.869)	(0.074)	(-0.103)	(1.423)	(1.392)
$(R\&D/Y)_{it-1}$	0.118	0.129	0.008	-0.014	0.043	0.042
	(0.131)	(0.142)	(0.030)	(-0.056)	(3.118)	(3.084)
$dlnMSO_{it}$	0.004		0.0009		-0.003	
	(1.831)		(0.222)		(-0.924)	
$dlnMSNO_{it}$		0.003		0.0058		-0,0006
		(2.116)		(2.226)		(-0.480)
N	340	340	200	200	440	440
R^2	0.254	0.248	0.551	0.559	0.358	0.356
SEE	0.011030	0.011075	0.008620	0.008543	0.011043	0.011056

Notes: (i) OLS estimation for annual data sample period of 1974-1993 (full set of time dummies included) using White's heteroskedasticity consistent SEs; (ii) 't' statistics are in parentheses; (iii) MSO=US imports from OECD countries for sector group are expressed as a proportion of total US demand for goods produced in that sector ; MSNO=US imports from non-OECD countries for sector group are expressed as a proportion of total US demand for goods produced in that sector.

The statistical significance of the MSNO terms in the LSA and LSB sectors suggest that increased trade with LWCs tends to increase the wage share of non-production workers in the low-skill sectors, but that technological change rather than trade partly explains the rise in US inequality in the high-skill sectors. For the LSA sector grouping, there is also some limited - but less-convincing - evidence that any increase in inequality from increased trade may also be partly due to increased imports from the higher-wage OECD countries, whereas only imports from LWCs increase inequality in the LSB sectors.[10]

Table 4 shows the results arising from the estimation of the employment share equation (ie, equation (7)). The results support the conclusions drawn in the wage share analysis that imports from low-wage countries seem to explain part of the rise in US inequality in low-skill-intensive sectors, while technological change (proxied by R&D expenditure) explains the rise in inequality in high-skill-intensive sectors. The relative wage term is strongly significant and, as expected, negatively signed. Finally, the explanatory power of the variables in the employment equations is generally better than the wage equations, and the increase in the R^2 is especially large for the LSA sectors.

Table 4: US employment share equations (dSE_{it})

Equation	LSA (1)	LSA (2)	LSB(1)	LSB (2)	HS (1)	HS (2)
C	0.010 (2.809)	0.0097 (2.714)	0.0044 (1.152)	0.0042 (1.106)	0.0004 (0.149)	0.0004 (0.155)
$dlnY_{it}$	-0.007 (-0.727)	-0.008 (-0.748)	-0.035 (-3.132)	-0.037 (-3.298)	-0.023 (-2.705)	-0.023 (-2.725)
$dlnK_{it}$	-0.036 (-1.113)	-0.033 (-1.005)	-0.0004 (-0.009)	-0.011 (-0.230)	0.051 (1.466)	0.051 (1.469)
$(R\&D/Y)_{it-1}$	0.212 (0.334)	0.217 (0.340)	-0.004 (-0.021)	-0.025 (-0.134)	0.041 (3.305)	0.041 (3.304)
$dlnMSO_{it}$	0.0024 (1.897)		0.0014 (0.461)		0.0001 (0.055)	
$dlnMSNO_{it}$		0.002 (2.159)		0.005 (2.350)		0.00005 (-0.046)
dln(NP wage/P wage)	-0.107 (-8.264)	-0.106 (-8.080)	-0.100 (-5.807)	-0.099 (-6.060)	-0.115 (-6.528)	-0.115 (-6.543)
N	340	340	200	200	440	440
R^2	0.529	0.526	0.699	0.706	0.527	0.527
SEE	0.007400	0.007426	0.006554	0.006472	0.009252	0.009252

Notes: (i) OLS estimation for annual data sample period of 1974-1993 (full set of time dummies included) using White's heteroskedasticity consistent SEs; (ii) 't' statistics are in parentheses; (iii) MSO=US imports from OECD countries for sector group are expressed as a proportion of total US demand for goods produced in that sector ; MSNO=US imports from non-OECD countries for sector group are expressed as a proportion of total US demand for goods produced in that sector.

It is important to note that the above results may underestimate the impact of trade with low-wage countries on US inequality as we do not include the import *price* in our specifications (due to the lack of reliable trade price data for the USA at this level of disaggregation). Relative import price terms may capture other effects in addition to those captured by the import penetration terms such as the *threat* of increased competition from LWCs (eg, the fall in the import price of LWC products as the dollar appreciated may have made it easier for firms to obtain agreement from their workforce to restrain the wages, or terminate the employment, of less-skilled workers, etc).[11]

[10] However, note that only imports from the LWCs are actually statistically significant at the five per cent level of significance for the LSA sector grouping.

[11] A relative import price term may also capture the increased opportunities for decreasing labour costs via outsourcing.

As mentioned before, previous studies such as Machin *et al* (1996) do not find a significant impact of trade on the relative wages and employment of the less-skilled in the USA. However, unlike our analysis, they do not use trade data which separately identifies imports from low-wage countries - which is important as mechanisms such as 'outsourcing' only influence inequality via trade with low-wage countries - and their empirical work is at a more aggregate level. Although Feenstra and Hanson (1995) do find that imports have increased US inequality, they too do not distinguish between import suppliers. In contrast, we have shown that when assessing the impact of trade on inequality the source of imports matters, which is consistent with economic theory. For the USA, it seems that using aggregate imports to capture mechanisms such as outsourcing may be misleading and that disaggregation of imports in order to identify low-wage countries is necessary, particularly as the impact of trade on inequality may vary across sectors of different skill intensities.

4. What drives technological innovation?

Given that R&D seems to explain a large part of the rise in inequality in the high-skill sectors, we now turn our attention to investigating the factors behind the rapid rise in technological innovation, particularly as to whether trade influences technological change. Adrian Wood (1994, 1995) launched the term 'defensive innovation' meaning that some innovation may be driven by the need to stay competitive against increased low-wage competition. He argues that some firms in advanced industrialised countries may have to look for new methods of production that are unskilled labour-saving (ie, 'process innovation' driven by import competition). As we have argued above, 'defensive innovation' may also mean that firms upgrade the quality of their products in order to stay competitive (ie, 'product innovation' driven by import competition). Another relationship between trade and innovation is hypothesised by Glass and Saggi (2001). These authors argue that an increase in outsourcing to a low wage country lowers the the marginal cost of production and thus increases profits, thereby creating greater incentives and/or opportunities for innovation.

Considerable empirical research has been carried out regarding the R&D investment decision of the firm (see Cohen, 1989). In the standard Schumpeterian framework, firm size and market concentration are the two major explanatory variables explaining

R&D at the firm level. Firm size is thought to be important as bigger firms have scale economies in the R&D function, greater access to risky financing on the capital market as well as a larger volume of sales over which they can spread the fixed costs of innovation, etc. Meanwhile, monopoly power (or market concentration) enables firms to reap profits from R&D investments and also provides a more stable environment for the firm's investment decision.

Using data at the industry level, with the objective of investigating whether trade influences technological change, we estimate a simple R&D function for the US loosely based on the specification used by Hirsch (1992) which includes a mixture of industry and firm-level variables. As optimal investment is a function of output (and thus product prices) and relative factor prices, Hirsch includes firm level data on both the physical capital stock and the R&D stock as well as firm-level profitability to take into account firm-specific differences. At the industry level, Hirsch includes the annualised growth rate in industry output, labour costs per employee, the concentration ratio and the share of imports in domestic sales.[12]

Our industry-data approximation of Hirsch's R&D function is as follows:

$$
\begin{aligned}
& d\ln\left(\frac{I_{it}}{PROD_{it}}\right) = \alpha_i + \beta_C d\ln\left(\frac{CAP_{it-1}}{RPRDV_{it-1}}\right) \\
& + \beta_W d\ln RWAGE_{it-1} + \beta_{RP} d\ln RPRDV_{it-2} + \beta_R d\ln RR_{it-1} + \beta_M d\ln MS_{it-1} \\
& + \Sigma\delta_m YEAR_{mt} + e_{it}
\end{aligned}
\qquad (10)
$$

where: $I_{it}/PROD_{it-1}$ is R&D expenditure expressed as a proportion of production

α_i is an industry specific intercept (fixed effects)

$CAP_{it-1}/RPRDV_{it-1}$ is the real capital stock relative to real production

$RWAGE_{it-1}$ is the real average wage

$RPRDV_{it-2}$ is real production

RR_{it-1} is profitability measured as price over unit labour cost

[12] As the Hirsch study focuses on the effects of collective bargaining on investment activity, it also includes firm dummies indicating the degree of unionisation as well as a variable for union density per industry.

MS_{it-1} is the share of the value of domestic demand for the output of industry i accounted for by imports from low- and high-wage countries respectively.
$YEAR_{mt}$ is a set of time dummies
Subscript i represents industry i.
First differences are denoted by d.

The real average wage is simply total real wages divided by total employment per industry, while the profitability variable is calculated as the producer price divided by labour compensation[13] (Source: OECD STAN database). Although the data used in the estimation of equation (10) are the same as in the share analysis above, the industries are more aggregated in this section according to the more limited sectoral breakdown of the R&D data.[14] Table 5 shows the results using this specification for the high-skill sectors.[15] Again, we report two sets of results in first difference form: one using import penetration from the high-wage countries and the other using import penetration from low-wage countries.

The first variable – the capital/output ratio – is expected to have a positive sign due to the assumed complementarities between capital and R&D investment. However, we found this variable to be both statistically insignificant and incorrectly signed. Meanwhile, an increasing real average wage could affect investment in R&D both negatively or positively.[16] Although, the results show that the real average wage has no significant impact on R&D investments, the negative sign is indicative of factor substitution between R&D and labour.

[13] Source: OECD STAN database.
[14] In this section, the HS sector includes ISIC 3520-3522, 3522, 353+354, 355+356, 3820-3825, 3825, 3830-3832, 3832, 3845 and 385. The LSB sector covers ISIC 31, 36, 371, 372, 381, 3842+3844 and 39. The LSA sector includes ISIC 32, 33, 34 and 3843.
[15] We only show the results for the high-skill sectors for two main reasons: first, the R&D equations for the low-skill sectors had poor explanatory power and most of the variables were not statistically significant; second, explaining R&D movements in the high-skill sectors is our main task as, according to our earlier results, it is only in this sector where technology (proxied by R&D) has a significant impact on inequality.
[16] Although rising labour costs mean that less money is available for investment, increased labour costs may make the industry less competitive and induce R&D investments aimed at decreasing the need for labour (ie, factor substitution).

Table 5: US R&D investment equations ($dln(I_{it}/PROD_{it})$) for US high-skill sectors

Equation	HS (1)	HS (2)
$dln(CAP_{it-1}/RPRDV_{it-1})$	-0.324 (-1.348)	-0.231 (-0.969)
$dlnRWAGE_{it-1}$	-0.242 (-1.137)	-0.249 (-1.123)
$dlnRPRDV_{it-2}$	0.595 (3.567)	0.572 (3.517)
$dlnRR_{it-1}$	0.147 (0.686)	0.088 (0.404)
$dlnMSO_{it-1}$	0.107 (2.092)	
$dlnMSNO_{it-1}$		-0.004 (-0.101)
N	180	180
R^2	0.347	0.332
SEE	0.109926	0.111133

Notes: (i) OLS estimation for annual data sample period of 1973-1994 using White's heteroskedasticity consistent Ses (fixed effects and full set of time dummies included); (ii) 't' statistics are in parentheses; (iii) MSO=US imports from OECD countries (as defined in previous tables; MSNO=US imports from non-OECD countries (as defined in previous tables).

A growing market, or increases in real production, is positively and significantly correlated with an increasing R&D intensity, which is what we expected. Meanwhile, the effect of an increase in profitability on R&D investments can be positive or negative. On the one hand, high profits create less pressure for investing in technology in order to transform products (or the production process) in comparison to low profits. On the other hand, high profits make it easier for firms to finance investments in R&D. We find that increases in profitability, measured as price over unit labour cost, are not statistically significant but tend to have a positive sign.

Finally, the key result shown in the above table is that growing import penetration from high-wage countries has a significant positive effect on R&D investments in the US high-skill sectors, while imports from low-wage countries have no impact. Our previous analysis of the US wage and employment shares within the high-skill sectors showed that trade had no impact on skill upgrading, while technological change was important. It therefore seems that trade also has an indirect effect on skill-upgrading in the high-skill sectors when we take into account its impact on R&D investments.

In summary, we find some evidence that 'defensive innovation' seems to occur in the high-skill sectors. Although it is not driven by import competition from low-wage countries but from high-wage countries, such defensive innovation will also reduce competition from low-wage as well as high-wage countries, thereby partly explaining why imports from low-wage countries seem to have had no impact on US inequality in high-skill sectors. Again, in comparison to other studies, this result therefore places relatively more weight on the trade-based explanation for skill-upgrading than the technology-based explanation. However, more work is needed on this topic before any strong conclusions can be drawn.[17]

5. Conclusions

An increase in US imports from low-wage countries, helped by the large appreciation of the dollar in the early 1980s, seems to explain some of the rise in US inequality in *low-skill-intensive* sectors. Rapid technological change does not seem to be an important determinant of labour market inequality in these sectors - which is not surprising given the low technological nature of these industries. By contrast, technological change - proxied by R&D expenditure - seems to be strongly positively correlated with the rise in US inequality in our sample of *high-skill-intensive* sectors.

We also tried to establish why skill-biased technological change was so rapid during the early 1980s in the USA. Given that the technological change seemed to be strongly positively correlated with rising imports - associated with the deterioration in US trade competitiveness due to the appreciation of the dollar over this period - we investigated whether the two were connected by estimating some R&D expenditure

[17] The approach we use is designed for firm-level data which makes it somewhat difficult to apply on industry data. A second limitation is that we lack information on two major explanatory variables: firm size and market concentration. Accordingly, in our specification, industry differences in these two variables are picked up by the fixed effects.

equations. We found that growing import penetration from high-wage countries had a significant positive effect on R&D investments in the high-skill sectors over our sample period, while imports from low-wage countries had no impact. Meanwhile, our analysis of the wage and employment shares within US manufacturing sectors showed that trade had no impact on skill upgrading in the high-skill sectors, while technological change was important. Accordingly, it seems that trade may also have had an indirect effect on skill-upgrading in the high-skill sectors when we take into account its effects on R&D investments via 'defensive innovation'. Although it is not driven by import competition from low-wage countries but from high-wage countries, such defensive innovation will also reduce competition from low-wage as well as high-wage countries and therefore partly explains why imports from low-wage countries seem to have had no impact on US inequality in high-skill sectors. In summary, in comparison to other studies, our results place more weight on the trade-based explanation for skill-upgrading in the United States relative to the technology-based explanation. However, further work is needed before any strong conclusions can be drawn regarding the role of defensive innovation in the "trade and wages" debate.

DATA APPENDIX: 4-DIGIT SECTORS

We group together industries which we classify as high or low-skill-intensive. In particular, we form two low-skill groups, *LSA* and *LSB*, and one high-skill grouping we call *HS*. *LSA* consists of ISIC sectors 3200, 3300 and 3400 (ie, Textiles, Apparel and Leather; Wood Products and Furniture; Paper, Paper Products and Printing). *LSB* consists of ISIC sectors 3600, 3700 and 3810 (ie, Non-Metallic Mineral Products; Basic Metal Industries; Metal Products); *HS* consists of ISIC sectors 3500, 3820, 3830, 3850 (Chemical Products; Non-electrical Machinery; Electrical Machinery; Professional Goods). We pool the data across eighteen 4-digit ISIC sectors for *LSA*, across ten 4-digit ISIC sectors for *LSB*, and across twenty two 4-digit ISIC sectors for *HS*. Our annual sample period extends from 1973 to 1993. Given that we lose one observation because we estimate a first difference model, our estimation period 1974-1993 therefore provides us with 340 observations for *LSA* (ie, 17*20); 200 observations for *LSB*; and 440 observations for HS. The specific 4-digit ISIC sectors used in the estimation of wage and employment shares are as follows:

LSA:

ISIC3211 Spinning, weaving and finishing textiles.
ISIC3212 Manufacture of made-up textile goods, except wearing apparel.
ISIC3213 Knitting mills.
ISIC3214 Manufacture of carpet and rugs.
ISIC3215 Cordage, rope and twine industries.
ISIC3219 Manufacture of textiles not elsewhere classified.
ISIC3220 Manufacture of wearing apparel except footwear.
ISIC3231 Tanneries and leather finishing.
ISIC3233 Manufacture of prods. of leather except footwear and apparel.
ISIC3240 Manufacture of footwear except rubber or plastic.
ISIC3311 Sawmills, planting and other wood mills.
ISIC3312 Manufacture wooden, cane containers, small cane ware.
ISIC3319 Manufacture wood and cork products N.E.C.
ISIC3320 Manufacture of furniture, fixtures except primary metal.
ISIC3411 Manufacture of pulp, paper and paperboard.
ISIC3412 Manufacture of containers and boxes of paper, paperboard.
ISIC3419 Manufacture of articles of pulp, paper and paperboard NEC.

LSB:

ISIC3610 Pottery, china and earthware.
ISIC3620 Glass and glass products.
ISIC3691 Structural clay products.
ISIC3692 Cement, lime and plaster.
ISIC3699 Non-metallic mineral products, NEC.

ISIC3710 Iron and steel basic industries.
ISIC3720 Non-ferrous metal basic industries.
ISIC3811 Cutlery, hand-tools and general hardware.
ISIC3812 Furniture and fixtures primarily of metal.
ISIC3819 Fabricated metal prods. Except mach. and equip. NEC. NEC.

HS:
ISIC3511 Basic industrial chemicals.
ISIC3512 Fertilisers and pesticides.
ISIC3513 Syn. resins, plastic mat., man-made fibres exc. glass.
ISIC3521 Paints, varnishes and lacquers.
ISIC3522 Drugs and medicines.
ISIC3523 Soap, cleansing preparations, perfumes cosmetics.
ISIC3529 Chemical products, NEC.
ISIC3530 Petroleum refineries.
ISIC3540 Misc. prods. Of petroleum and coal.
ISIC3551 Tire and tube industries.
ISIC3559 Manufacture of rubber products, NEC.
ISIC3560 Plastic products, NEC.
ISIC3824 Manufacture of special industrial mach. and equip. except 3823.
ISIC3825 Office, computing and accounting machinery.
ISIC3829 Machinery and equipment except electrical not elsewhere classified.
ISIC3831 Electrical indust. mach. and apparatus.
ISIC3832 Radio, telecomm. equip. and apparatus.
ISIC3833 Electrical appliances and housewares.
ISIC3839 Electrical apparatus and supplies.
ISIC3851 Prof. Scientific and control equip.
ISIC3852 Photographic and optical goods.
ISIC3853 Watches and clocks.

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