CAN THE EMPLOYMENT IMPACTS OF MANUFACTURING EXTENSION HELP COUNTER INEQUALITY?

Lessons for Developing Nations from the U.S. Experience

by

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Introduction and research questions:

United States manufacturing firms employ over 13 million people and make $1.6 trillion worth of goods a year. Manufacturing accounts for more than 80% of all U.S. exports and roughly two-thirds of total U.S. research and development expenditures. Yet over 85% of manufacturing jobs are in establishments with fewer than 50 employees. Thus, any discussion of manufacturing's role in economic growth and its impact on inequality needs to incorporate such firms and the modernization services provided to them by manufacturing extension programs.

This paper reviews the development of U.S. manufacturing extension services over the last two decades and asks: (1) What do we know about the link between manufacturing and inequality in general? (2) Is it possible to measure the employment impacts of manufacturing extension services on client companies and on their wider communities? (3) Do any impacts to be found suggest that manufacturing extension can significantly influence overall trends in the manufacturing sector and in income inequality? (4) If not, are there *other* strategic advantages or public policy justifications for supporting manufacturing extension programs? And (5) What lessons can be learned from the first 25 years of manufacturing extension programs in the United States that could be of use in developing nations interested in attempting the same function?

Manufacturing and inequality:

The discipline of economics has powerful analytic tools capable of yielding enormous insights on questions of resource allocation, prices, efficiency, and productivity. However, many practicing economists would admit their discipline is somewhat less helpful when it comes to questions of distribution, equity, and inequality. Such considerations are often assumed as background "givens" at the outset of economic analysis, or more the province of moral philosophy. Methodologically distributional statistics are sometimes seen as distractions from single point summary measures of central tendency like the mean and median, or simply irrelevant to the "real" economic questions. Yet recent growing and persistent inequality, both absolute and relative, within even "successful" economies means that the inequality phenomenon should be treated as important in its own right, that its trends are worth tracking, that its patterns are worth analyzing, and that its explanations and remedies are worth searching for.

The OECD's recent analysis has demonstrated that "inequality is on the rise in most OECD countries."[1] While real disposable household income increased by an *average* of 1.7% annually over the two decades prior to the 2008 financial crisis, *within* most OECD countries the household income of the richest decile grew faster than that of the poorest decile, resulting in greater inequality and a ratio between these deciles' averages of 9:1. Oxfam puts it more starkly, pointing out that the richest 85 individuals in the world now have as much wealth as the entire bottom half of the world's population (or about 3.5 billion people).[2]

Various drivers of this growing inequality have been suggested by researchers *(see sidebar).* The individual hypotheses drawn from review of over 50 studies can be grouped into "modern general trends" (e.g. globalization, technology), demographics (e.g. changing family structure, migration), "sectoral shifts" (e.g. decline of manufacturing, rise of services, growth of informal sector), "labor force dynamics" (e.g. rising long-term unemployment, increasing use of part-time/ temporary workers, participation rates), "policy/regulatory shifts" (e.g. taxation, decline of the welfare state), or simply our changing statistical ability to capture different groups at either extreme of the income spectrum (e.g. the nondoms and the offnets). Attempts to get more specific about inequality trends and their causes, though, soon run into definition, measurement, and methodological issues.

Drivers of inequality recently considered by researchers

- globalization
- product cycle playing out internationally
- decline of manufacturing in developed countries
- technological change
- regulatory reforms
- changing demographics
- increase in single-person households
- changing labor force participation ratios
- rising long-term unemployment
- declining real value of minimum wage
- increasing use of temporary/contract workers
- growth of the informal sector
- inclusion of the "offnets"
- inclusion of the "nondoms"
- rising corporate executive pay
- large-scale EU migration from new member states to richer countries
- changes in taxation and benefit regimes
- decline of the UPUT welfare state
- increased use of tax havens
- real estate property boom
- rise of financial services
- offshoring

With regards to *bounding* the problem, in an era where the economic activities of a large corporation may be found spilling across multiple countries and regions, do we look at within-area, inter-area, or global inequalities? Do we look at total distributions or spatial distributions, given inequality between different areas' averages could have statistically widened, even though inequality within the overall population distribution remained the same? Which spatial unit do we recognize – the region, the functional metropolitan area, the legal city, or the individual suburb? How do we handle under-bounded cities with much economic activity outside their borders? And when employees have long commutes and do not live and work in the same jurisdiction do we count income at place of earning or at place of receipt?

With regards to the *type of inequality* to be addressed, are we talking about inequalities of *income* (a flow) or of *wealth* (a stock)? Do we count government benefits and transfers, like food stamps, unemployment insurance, and other safety net programs, in personal income?[3] Do we include or exclude self-employment income, proprietors' income, interest income, and dividend income? Do we start with gross or net or taxable income? Do we exclude deferred non-taxable income like pension contributions from current totals? Do we count hourly, weekly, monthly, or annual income, given shorter timeframes would capture more economic fluctuations and longer periods may be less representative? Which month do we choose to represent the year?

With regards to *types of individuals* to be included, are we comparing incomes across all workers, or just full-time workers? Do we exclude part-time workers whose earnings would bring the overall median down? Do we include the income of females who tend to earn less and work, on average, fewer hours than males, and who tend to be overly-represented in part-time jobs, in minimum wage occupations, and in the informal sector? Given that workers tend to earn more with increasing age, do we make any attempt to control for the age distribution when making comparisons between groups?

With regards to the *tools* we use to measure inequality, do we use inter-decile ranges identifying the top 10% and bottom 10% of the distribution, or the inter-quartile range (the difference between the 25^{th} and 75^{th} ranks), or the Gini coefficient (one summary measure of statistical dispersion representing a continuous-function's departure from a perfect equality situation), or the Theil Index (a specialized case of the generalized entropy index measuring, in effect, differences from randomness)? How valid and relevant is a comparison changes in distributions over time, if the summary statistic remains the same but individuals have moved around within it?

All these questions are quite aside from the *normative* issues surrounding "inequality" - its social value, the point at which our conscience says action should be triggered, and what we would *want* it to be. Is income inequality a natural and inevitable phenomenon within capitalism, or something for economic policy to address? If we believe it is somehow "natural" do we let gaps grow unabated, on the grounds that difference in itself provides an incentive to work, innovate, and prosper, and that market mechanisms like migration from low-wage areas to high-wage areas, and re-skilling of labor laid off from declining industries for in-demand occupations in high-growth industries, will produce an acceptable equilibrium over time after a "temporary" widening? If instead we do choose to influence inequality, then do we know the goal we want to move towards? How much inequality is "too much"? What would a "just distribution, justly arrived at" look like? [4] Do we have a reasonable expectation of being able to influence inequality if we try, or should we just focus on improving the lot of the worst off in society? If we intervene do we risk wasting scarce public funds swimming against the global economic tide for no net local result? While we pursue quantitative measures of income inequality, should we not also be interested in other inequalities, like unequal initial factor endowments, or inequalities of opportunity and access, for example, even though they are even more difficult to measure?

All the methodological choices do at least give researchers flexibility over which particular aspects of inequality they want to highlight, and a portfolio of studies employing different choices can help us illuminate more sides of the problem. However, this also may come with the price that, given an appropriate choice of research design - albeit a legitimate and rigorous one – many hypotheses are each supportable in their own way, and we are no closer to "truth". A promising alternative approach has also been suggested by McKinsey Global Institute (MGI) which has created an

"Empowerment Line". This analytic tool promises a more comprehensive benchmark to measure gaps that must be closed and inform the allocation of resources. The Line represents "the level of consumption required to fill eight basic needs - food, energy, housing, drinking water, sanitation, health care, education and social security – at a level sufficient to achieve a decent standard of living rather than bare subsistence". In applying this measure to India, MGI found some 680 million people experienced deprivation, which is more than 2.5 times the 270 million identified by the official poverty line.[5]

So what is the role of manufacturing in this growing inequality? Nearly all these studies are conducted under the following umbrella scenario. The reduction or removal of trade barriers, the falling real costs of transportation, the growth of global corporations capable of shifting investment and activity across borders, the development of the technology and infrastructure to manage global production chains, the growth of incomes and market demand for consumer goods in Asia-Pacific markets, and access to lower-cost labor in developing nations, have all brought about a "flatter" world[6] and an increasingly specialized global international division of labor. Routine manufacturing production in whole industries has shifted[7] out of the developed nations where it originated, and over to the BRIC, MINT, and N-11 countries[8] with their labor-cost advantages, weaker regulations, and lower environmental protection. The arrival of manufacturing there brings the possibility of higher incomes and an "industrial" way of life, although increasing integration into global production/consumption patterns also means such nations are more vulnerable to declines in demand from developed economies whenever a recession hits. Developed nations meanwhile are striving to adjust to their relative declines and to exploit their remaining comparative advantages of research, higher education, and scale of domestic consumption, in order to maintain employment in higher-tech activities (aerospace, communications, biotechnology, IT, robotics, computers, electronics, and financial services).

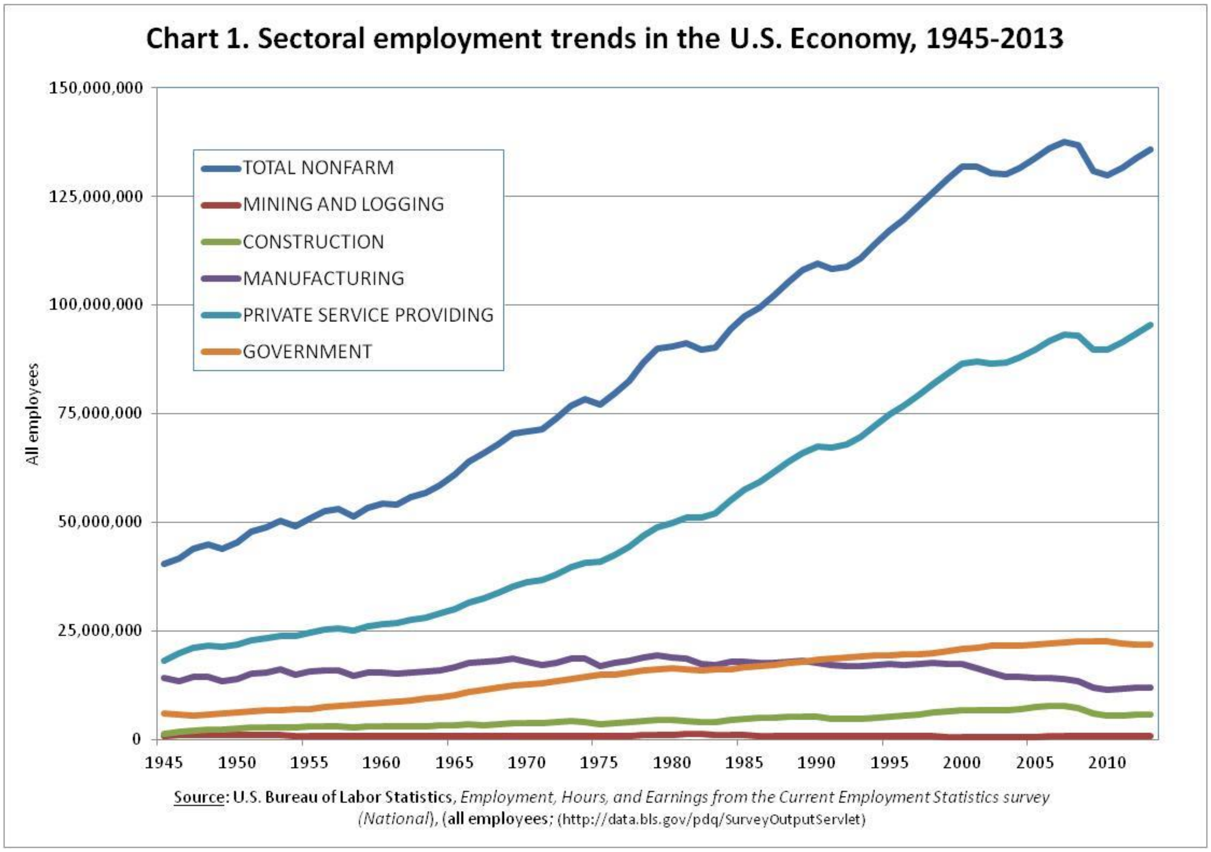
Within this integrated global modernization scenario, manufacturing is a key variable because of its employment and wage differences to services, its potential for development of totally new industries in new places free of past locational inertia, the higher productivity gains and wages it potentially brings, and its relative high multiplier effects. However, there are few empirical studies of how this is really playing out in terms of manufacturing either promoting or reducing inequality in developing nations, with many of the studies that do exist focusing on India.

The OECD finds a "rising gap between the earnings of the highly skilled and those of the low skilled" which springs from several factors, including greater integration in trade and financial markets shifting labor demand in favor of highly-skilled workers, and technological progress shifting production in favor of skilled labor.[9] Sen seems to agree for manufacturing in India, noting that a steady increase in wage inequality there since the mid-1980s has been accompanied by an increase in employment of Indian skilled workers.[10] Kakalapudi's econometric analysis using a cost-function framework comparing Indian manufacturing in 1992/3 and 2005/6 finds imported manufacturing technology is significant for increasing inequality in the low-tech industries while it has been domestic technology has contributed to the rise in skill demand for high-tech industries.[11] Ramaswamy goes deeper to estimate a skill-wage bill share equation for 46 three-digit industries spanning 1981-2004 and 113 four-digit industries for 1993-2004. His results suggest a positive contribution to wage inequality in Indian manufacturing from changes in output, the capital:output ratio, and contract worker intensity.[12] Galbraith et al, while acknowledging manufacturing pay inequality has risen between 1979 and 1998, find that change more related to sectors, and that it accelerates in the period following the introduction of reforms. Continued inequality in the post-reform period in India can be attributed to rising relative pay in the electricity sector.[13]

The Globalization Trend Lab finds different answers about inequality for developed and developing nations: in the former it is deindustrialization, lower levels of unionization, and the "financialization" of the economy that are largely responsible for the increases in inequality, while in the emerging economies it is unbalanced growth between cities and countryside which drives the trend.[14] Elveren confirms this for Turkey, where the provinces with the highest shares of manufacturing in GDP are located around Istanbul and saw an increase in regional specialization and industrial concentration between 1980 and 2001.[15] Velde and Morrisey examined earnings in manufacturing for five African countries in the early 1990s and found evidence of a "pure capital city premium" equivalent to between 12% and 28% of nominal average earnings. This locational premium is higher for skilled workers than for less-skilled, and the authors argue it exceeds the plausible consumer price differentials between the capital city and other areas.[16]

Heintz has addressed the question of whether expansion of manufacturing exports from developing countries to affluent markets improves or worsens inequalities. He found that a 10% increase in manufacturing output is associated with only a 4% increase in employment, and so we are witnessing a situation of "job-poor growth" where only "improving real wages when employment expands will raise the growth rate of wage income among manufacturing workers in developing economies.[17] Suwanmana's econometric analysis of inequalities in Thailand finds an increase in the Gini coefficient form 1985-95 was allied with "education, occupation and minimum wage zone", and a decrease in the Gini from 1995-2005 was associated with education and urbanization. He thus suggests greater policy focus on elementary and lower secondary education.

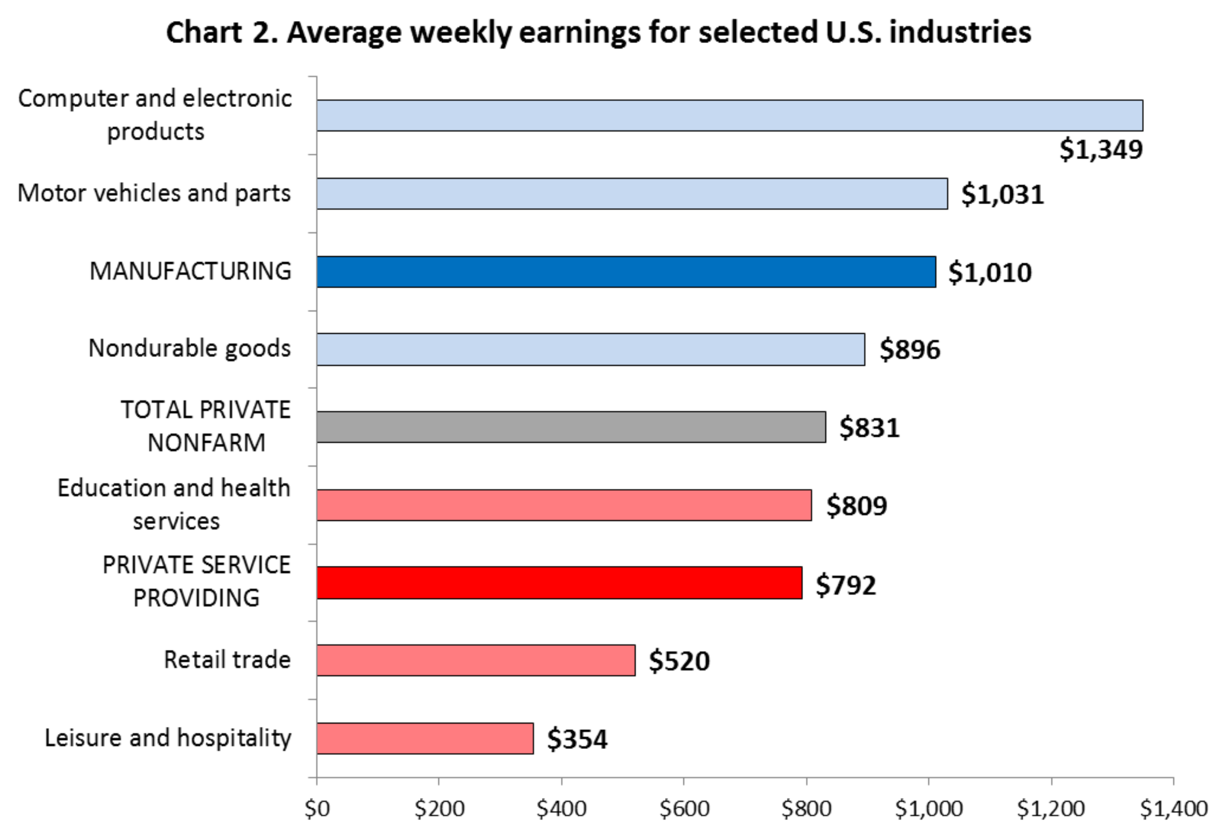
Within the U.S., the manufacturing picture has been more studied and is perhaps clearer. The absolute size of the official total U.S. labor force more than tripled between 1945 and 2013 to reach 136 million workers. U.S. manufacturing employment has declined over the last 60 years relative to the total workforce while services employment has grown. The absolute number of manufacturing workers has remained relatively constant around an average of 16 million, but the services workforce has grown by more than five times, from 18.1 million in 1945 to 95.4 million in 2013 *(see Chart 1)*. It is thus the services story that has largely been driving any increased inequality of earnings in the U.S., but manufacturing has been, in a sense, the victim of its own success. Lepre notes that in 2012 just 94,000 people working in the steel industry produced 14% more output than nearly 400,000 workers did in 1980.[18] Dunn and Morris point out that "in the two decades prior to the recession labor productivity in manufacturing roughly doubled, with output rising 65% and labor hours declining by 20%"[19] such that while in 1950 the top 20% had 17.3% of family income, by 2010 this was 20%, and the Gini coefficient had risen from 0.379 to 0.440. Galbraith and Conceicao examine manufacturing wage inequality in the Appalachian Region, and find it largely conditioned by macroeconomic cycles. From 1977-82 falling wages and inequality predominated, but the gap with the rest of the nation has widened since 1982. They conclude: "In essence, periods of exceptional prosperity are necessary to reduce inequality in American manufacturing pay. Conversely, steep recessions tend to worsen pay inequality".[20]



Average weekly earnings sector-wide in U.S. manufacturing in 2013 were $1,010, or 22% *higher* than the median earnings across all industries, compared to only $792 in services, which is 5% *lower* than the all-industry median. This gap is even greater for particular industries within each of these two sectors: workers in computer electronics manufacturing earned $1,349 a week, compared to only $354 in the individual services industry "leisure and hospitality" – a difference of almost four times the earnings level *(see Chart 2).* The manufacturing to services shift has meant the route into the middle class for low-skilled blue-collar labor that was a major source of growing prosperity in the 1950s and 1960s, has largely disappeared because the employment growth that has occurred has been in services, which are mostly lower paid.

There is further inequality within manufacturing itself, with individual industries paying vastly different wages and employing different numbers of workers. For example, employees in "computer and peripheral equipment" manufacturing can earn a third more than those in "nondurable goods" manufacturing, but there are only 159,000 employed in that higher-paying industry, compared to over 1.5 million employees in the lower-paid industry. Wheeler finds a connection between total employment and the relative earnings of high and low-skilled workers within two-digit U.S.

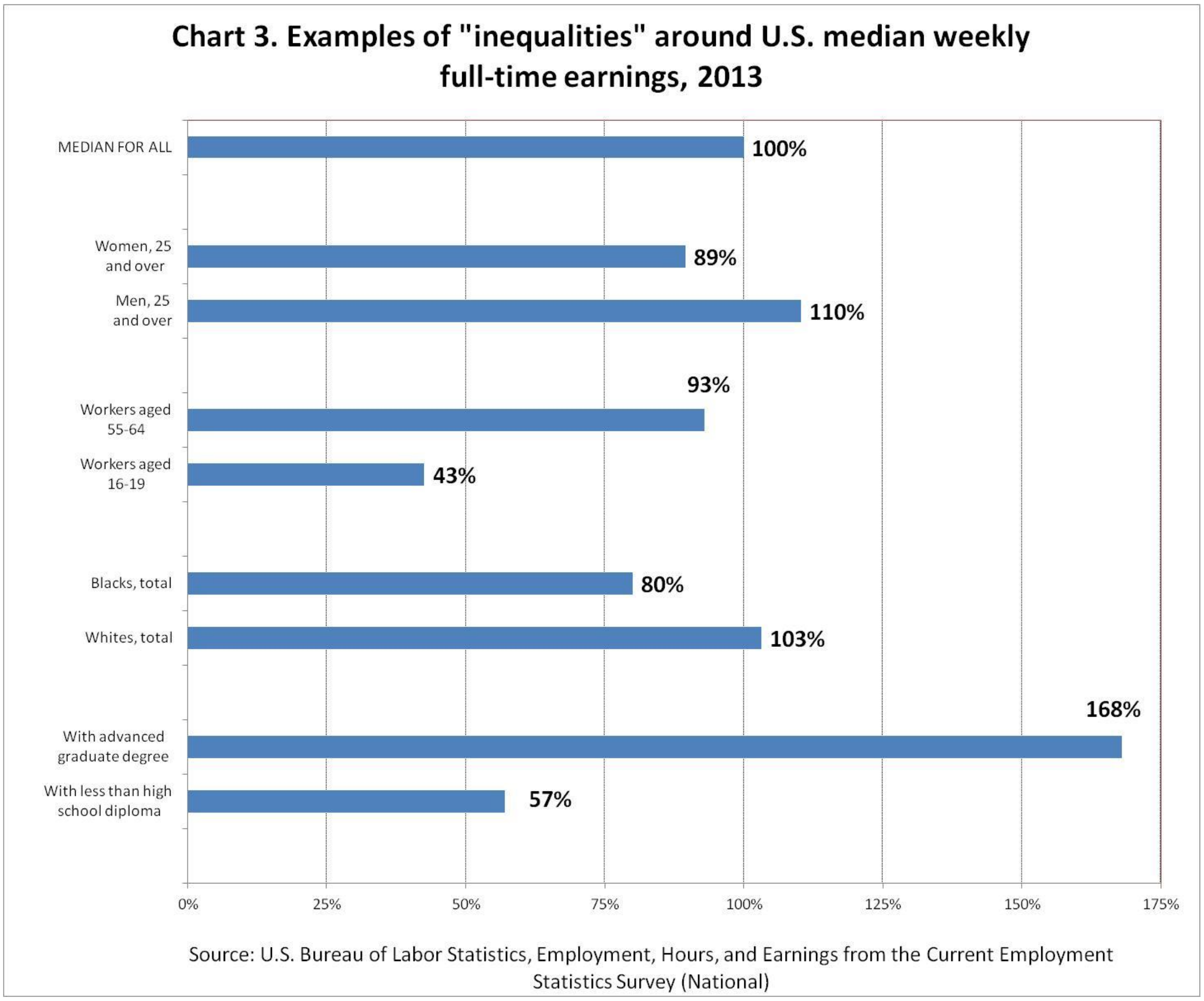
manufacturing industries across states and a collection of metropolitan areas between 1970 and 2990. Wage dispersion falls significantly as employment expands, offering support for policies that emphasize a return to growth for helping with inequality.[21]



Source: U.S. Bureau of Labor Statistics, *Current Employment Statistics*, Dec. 2013.

Not all inequality in the U.S. can be ascribed just to industry differences, however *(see Chart 3).* There are many other dimensions along which average wages differ in the U.S., including, for example, *gender* (with men earning 110% of the national median wage and women 89%), *race* (with blacks earning 80% of the median and whites 103%) and, most significantly, *education* (where those workers lacking a high school diploma earn only 57% of the national median while those at the other end of the attainment spectrum, with an advanced graduate degree, earn 168% of the national figure). Some parts of these group differences are doubtless related to the industry of employment while others are not, and some are intertwined in obfuscating ways. Greene and Hoffnar find that deindustrialization in the U.S. is likely to reduce the gender gap in hourly earnings, but at the cost of lower earnings for both males and females, with the drop in earnings being particularly large for males.[22] Not exactly positive progress on inequality, perhaps, but these contrasts *do* draw attention to the difficulty of attributing causality in the analysis of inequality.

So income inequality is substantial and apparently growing globally, and manufacturing is involved in the overall emerging global production scenario which is driving it, but manufacturing is not necessarily the only driving force.



For the purposes of this paper, it is suggested that continued statistical pursuit of the different hypotheses has two disadvantages. First, it tends to see trends as part of the longer sweep of history, and therefore influenceable only at the margin if at all, rather than the product of laws, regulations, historical context, and institutional and human "agency". Second, they measure at the ends of the scale spectrum: either global macroeconomic forces are the causal factors, or trends are read off from the counts of individual entities responding atomistically to those trends. Neither of these two positions leads us directly to any practical grounds on which to act.

What is suggested instead here is not that we abandon the recent body of statistical work on inequality, as we will always need to be able to measure changes over time, and such analyses and modeling do give us very powerful insights. Rather, we need to look at the two domains that tend to get neglected as a result of the default analytical choices. First, the *regional* scale, or territorial production complex, below the national scale and above the individual city, where outcomes are less than global but more than just the sum of the individual parts. Second, the role of *agency*, or intentional public action. It is in this space – policy choice and program action at the regional scale - that the example of manufacturing extension services to be highlighted here finds utility and the promise of change.

Manufacturing Extension in the USA

Given this case for the importance, the persistence, and the growth of inequality, what role, if any, can the modernization services provided by manufacturing extension centers to manufacturers play in countering it? To help answer this we can examine the services and the scale of manufacturing extension in its most mature form: the Manufacturing Extension Partnership of the National Institute for Standards and Technology (NIST-MEP), in the United States.

The U.S. National Institute for Standards and Technology (NIST) started life as the National Bureau of Standards (NBS) in 1901, and was the U.S. government's first physical science research facility. It became NIST in 1988. Born at the dawn of the Age of Electricity and now functioning in the Information Technology/Life Sciences Age, NBS/NIST has always had an anchor role with regards to weights and measures.[23] This function may not seem very glamorous but about 80% of world trade involves standards and regulations which often insist on specified measurement requirements. The basic research, measurement tools, and technical services provided by this small agency that remains largely invisible to the general public, are now deeply integrated into many of the systems and operations that collectively drive the wider economy, like manufacturing cells, satellite systems, communication and transportation networks, and laboratories.

In addition, NIST has also been responsible for more specific technological progress in, for example, image processing, DNA diagnostic "chips," smoke detectors, automated error-correcting software for machine tools, atomic clocks, X-ray standards for mammography, the scanning tunneling microscope, pollution-control technology, and high-speed dental drills. The cutting edge nature of its research program is attested to by the five Nobel Prizes won by NIST staff.

NIST's current mission is to "promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life".[24]
NIST pursues this mission using its "core competencies" of measurement science, rigorous traceability, and development and use of standards.

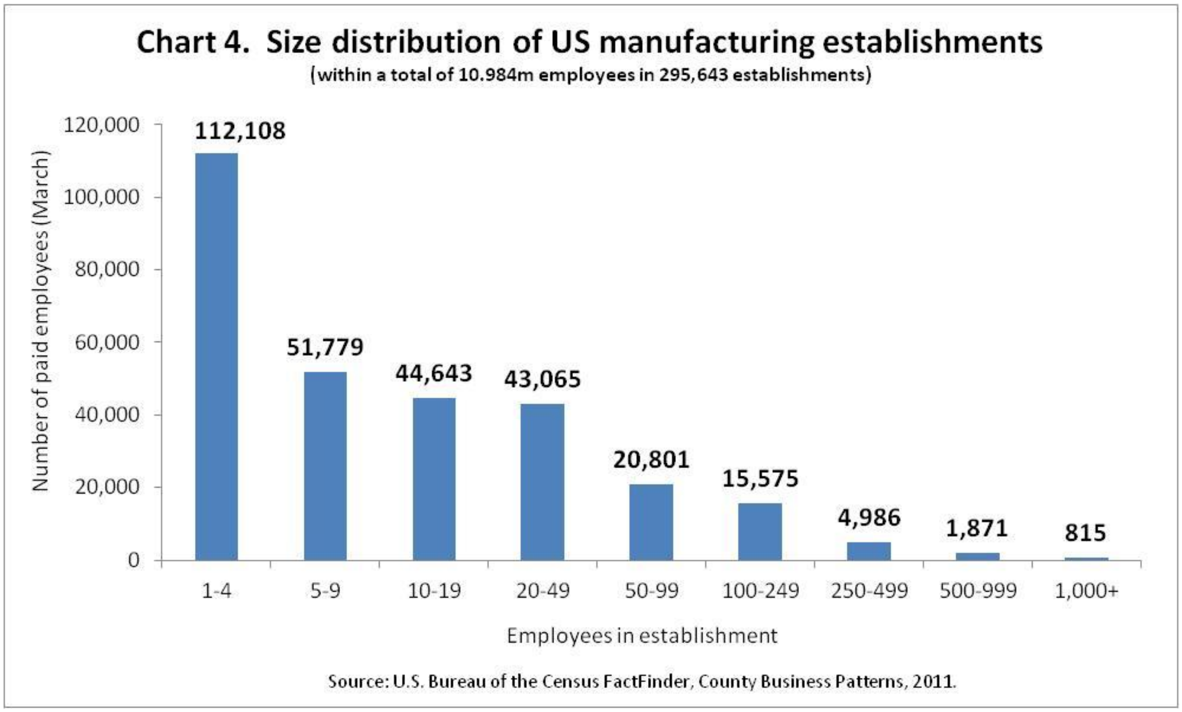
Programs within NIST:

1987 to date:	Malcolm Baldrige National Quality Award.
1988 to date:	Hollings Manufacturing Extension Partnership (MEP)
1990-2007:	Advanced Technology Program (ATP)
2007-2011:	Technology Innovation Program (TIP)
2007-2011:	Technology Reinvestment Program (TRP)

More recently, NIST has also housed several industry programs *(see sidebar)* which in many other countries might be considered "industrial policy." These programs have together provided "targeted investments in transformational R&D" and early-stage investments to accelerate the development of innovative technologies that promise "significant commercial payoffs."[25] The programs have fluctuated and evolved largely due to the different U.S. Congresses' variable interest over time in providing funds. The federal budget specifically for NIST-MEP[26] to provide modernization services to small and medium-sized manufacturers (SMMs) is housed within the NIST and the U.S. Dept. of Commerce budget allocation: for 2014 NIST-MEP could receive $153.1 million[27] out of the U.S. federal government's total planned outlays of $3.8 trillion.[28]

The customer focus for the activity funded by MEP's outlay is the group of some 293,000 small and medium-sized manufacturers. For while the iconic images of U.S. manufacturing are of large plants with long assembly lines operated by thousands of workers inside huge hangar-sized facilities, the reality is that the large majority of U.S. manufacturing employment occurs in small and medium-sized establishments:[29] over 85% of manufacturers have fewer than 50 employees (and using the NIST cut-off of fewer than 500 employees, that figure is 99%). In fact, only 0.9% of manufacturing establishments have 500 employees or more *(see Chart 4).*

SMMs are where, in the 1970s and 1980s, the productivity differential against leading Japanese and German manufacturers was greatest. Since these smaller companies are often found in multiple tiers of suppliers to the large end-assembly manufacturers, it was argued their productivity level held back the whole of U.S. manufacturing. It was suggested that SMMs are this way because they face various barriers. First, they may lack the scale of profits and savings needed to make significant investments in new plant, equipment, and technology. Second, they lack the larger plants' surplus time and specialist staff who can be spared from the production line and dedicated to searches for improvement. SMMs' real dynamic is more likely to be "all hands on deck all the time", living from sale to sale with no ability to put their heads above the trenches of hourly production needs. Third, they may lack the latest information on new technologies, market trends, and product research. Fourth, they can be family-owned and operated shops, rather than shareholder-owned and professionally staffed enterprises. Finally, they often lack the organized political clout and lobbying advantages of their giant corporate siblings.



To address some of these needs, Congress established the NIST--MEP in 1988 to act as "a catalyst for strengthening American manufacturing – accelerating its ongoing transformation into a more efficient and powerful engine of innovation driving economic growth and job creation".[30] Through a variety of its own national programs *(see sidebar),* NIST assists SMMs (defined as those with fewer than 500 employees), and also partners with states by providing a large share of the funding for manufacturing extension centers within each state in the country and in Puerto Rico. These local MEP-affiliated centers provide direct technical assistance to manufacturers in that state. The state centers then also partner with other organizations within the same state, including universities, community colleges, trade unions, and economic development organizations, to assist in providing direct client technical assistance *(see sidebar for typical services provided).*

NIST-MEP national initiatives:

E3: Economy, Energy, Environment
ExporTech
Innovation-Driven Growth
Interagency Network of Enterprise Assistance Providers
Lean Product Development
Next Generation Rail Supply Chain Connectivity
Supplier Scouting
Technology Driven Market Intelligence
Technology Scouting

The particular services provided by an individual state manufacturing extension center now run the gamut from simple plant layout studies, through comprehensive manufacturing assessments, to new product development advice, and referrals to appropriate private consultants *(see sidebar).*

Direct client services are delivered through a variety of mechanisms, including through a state center's own individual manufacturing extension agents, through their institutional partners' staff, through contracted private sector consultants, and via collaborative consortia of client companies themselves. The state centers are the anchors for a national network of some 1,200 individual technical experts.

> **Typical state manufacturing extension center services:***
>
> Comprehensive manufacturing Assessments
> Plant layout studies
> Private consultant brokering and referral
> Strategic business planning
> New product development advice
> Process mapping
> Lean manufacturing
> Agile manufacturing
> Six Sigma
> Green/sustainable manufacturing
> Referral to product/process experts
> Worker training
> ISO attainment and compliance
> Supply chain optimization
> Consortia support.
>
> *not every center offers all services.

While industrial policy and technical assistance provided by governments to the private sector are not unusual across countries, this U.S. manufacturing extension example does embody distinctively "American" characteristics of government programs, such as: being: a federal system of nationally-funded and overseen but locally-provided services; functioning as a partnership (between different levels of government and between public and private sectors); having an emphasis on technology; expecting client involvement and self-help; and expecting to ramp down federal support as affiliate manufacturing extension centers mature and start to charge for their services.

Part of the "next generation strategy" for the NIST-MEP, announced in January 2014, is the creation of new public-private "Manufacturing Innovation Institutes" to "…strengthen the manufacturing sector, boost advanced manufacturing, and attract the good paying jobs that a growing middle class requires". The first Institute will be headquartered in North Carolina, will function as a consortium of businesses and universities led by North Carolina State University, and will address manufacturing innovation for next-generation power electronics. Two additional institutes (to be led by the U.S. Department of Defense) will focus on "digital manufacturing and design innovation," and on "lightweight and modern metals manufacturing," but are still in the selection process and will be awarded in early 2014.

Each new Institute is designed to serve as "a regional hub bridging the gap between applied research and product development, bringing together companies, universities and other academic and training institutions, and Federal agencies to co-invest in technology areas that encourage investment and production in the U.S." This new MEP model shifts the emphasis somewhat from direct technical assistance services, where expertise is created within an extension center to be accessed by the external client, and more over to functioning like a "teaching factory" providing opportunities for training and shared assets to help small manufacturers access cutting-edge capabilities and equipment for their product families.

In terms of overall program impacts for the U.S. version, by 2010, after almost a quarter-century of operations, NIST-MEP was able to boast that:

> "No other program provides as much bang for the buck. For every one dollar of federal investment, the MEP generates nearly $20 in new sales growth and $20 in new client investment. This translates into $2.5 billion in new sales annually."[31]

Manufacturing extension programs, or closely-related activities under different agency names, have now spread to ten other countries (Argentina, Australia, Austria, Canada, China, Germany, Japan, Korea, Spain, and the United Kingdom). Six of them (Australia, Canada, Germany, Japan, Spain, and the United Kingdom) have created formal agencies, institutions, or programs like the United States' MEP.[32]

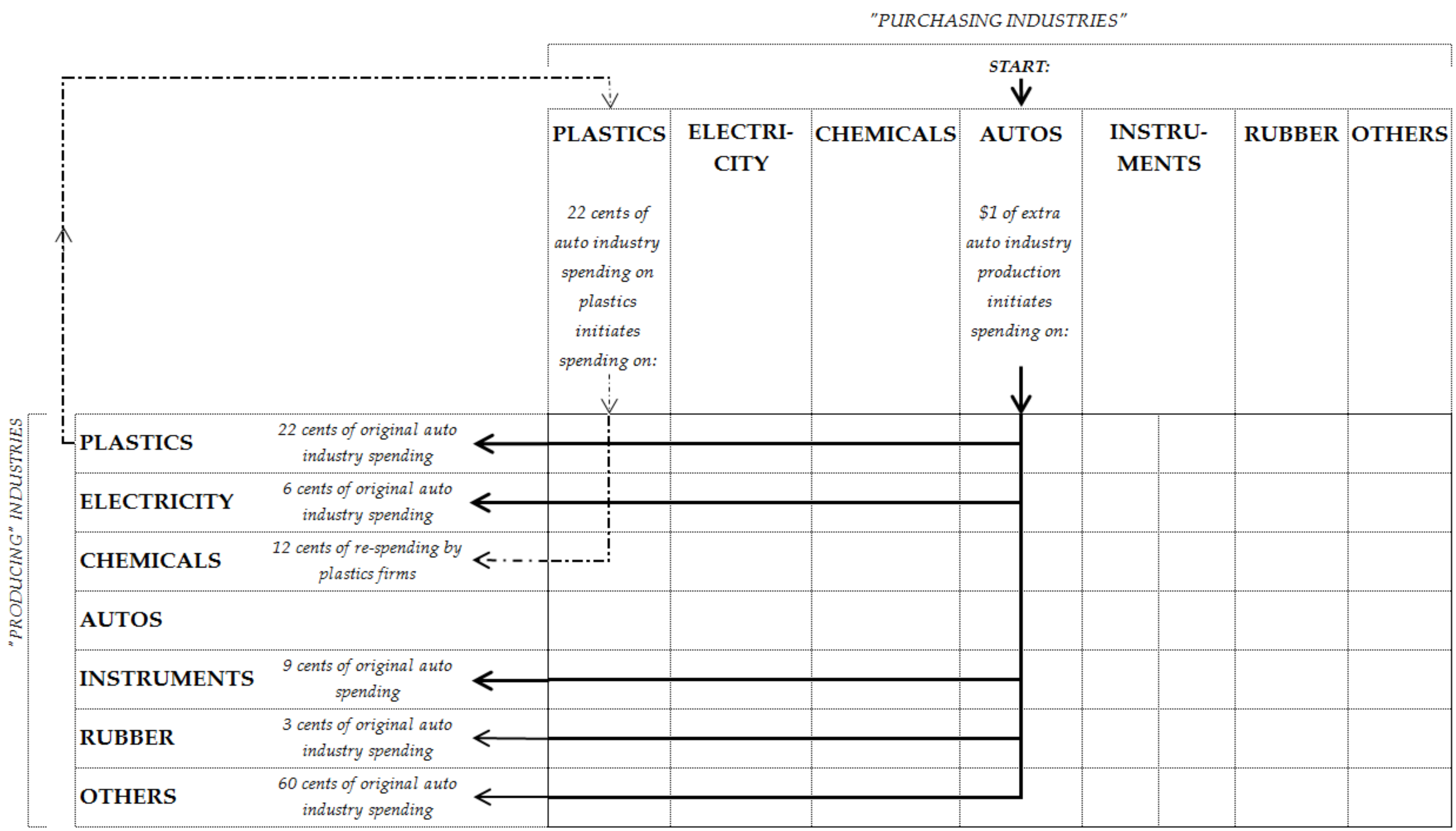
Estimating the employment impacts of manufacturing extension through input/output analysis:

The process of economic development works through the effect of firms making purchases from, and sales to, each other during the course of goods and services production, and then their workforces in turn consuming those goods and services paid for with earnings from their jobs. The conventional way of summarizing this "circular" economic activity analytically is to construct a large matrix of the production and purchasing relationships between all the different industries in the economy known as an "input-output table". Such a table can be used for describing and modeling a region's economy and for predicting the change in overall economic activity (the *output*) that will result from a change in demand from one or several parts of it (the *input*).

A simple example of an input-output table is given in Figure 1. Here the names of all the industries in the economy are listed across the top of the table, but also down the side. When an industry's name appears at the top it is acting there as a "purchasing" industry for the goods and services produced by industries listed down the side. When an industry's name appears down the side, it is acting there as a "producing" industry for the goods and services consumed by the industries listed across the top. Since industries purchase inputs order to produce outputs, they appear along both axes. Each cell in the body of the table represents the point where purchasing firms in an industry at the top of a column conduct transactions with producing firms in the intersecting row down the side. There is usually a number in each cell (but omitted from Figure 1 for visual clarity) known as an "input-output coefficient" (or sometimes the "technical coefficient"). This coefficient is a measure of the interaction between the two industries linked by that cell.

To understand generally how the input-output logic works first visualize an initial $1 of purchasing activity "dropped in" at the top of a column representing the auto industry in Figure 1. This $1 enters at the point marked "START" at the head of the auto industry column, and represents an increase in demand by auto industry firms for the kinds of inputs they need to make cars. Since many different kinds of inputs are needed, parts of this $1 flow down that auto industry column and emerge at the left side of the table in different producing industry rows (following the solid lines and arrows down and left through the cells in Figure 1. The flow destinations at the side show how parts of the original $1 of auto demand have been spent on the products of those producing industries.

Fig. 1. A simplified example of modeling inter-industry relationships through the input-output table



Source: Author.

In this fictitious input-output table, for every $1 spent by a firm in the auto industry in the course of making a car, some 22 cents of it may be spent on body parts and molding made by firms in the plastics industry. Another 8 cents of the dollar may be spent on the electricity needed to run the machines necessary to make cars in the factory. Another 9 cents may be spent on the sensors dials and controls for the dashboard, made by firms in the instruments industry. Another 3 cents may be spent on tires and brake linings made by firms in the rubber products industry, and so on, until the whole initial dollar of extra spending by the auto industry has been accounted for.

The value of the initial $1 of extra spending by the auto-maker is known in input-output analysis as the "direct effect", and it represents the *initial change in final demand.* This initial change then generates other "indirect effects". For in order that the plastics industry can make its *own* 22 cents of extra product to supply the increase in final demand from the auto-maker, plastics industry firms will themselves have to buy inputs from their own supplying firms in other industries. So the plastics industry, now acting as a purchasing industry at the top of the table, will call for 22 cents of purchases from other industries. Following the dashed line in Figure 1, 14 cents of the 22 will be spent by plastics manufacturers on polyethylene, chlorine, resins, etc., produced by the chemical products industry. Another 8 cents may have to be spent on the power to heat the furnace that the plastics company uses to convert the source stock into processed plastic car body parts. Then in the next round, the 14 cents of extra spending made by the plastics industry as purchaser, on the chemicals industry as producer, will itself re-appear as additional demand at the top of the table , but this time at the top of the chemical products industry column, for re-spending on that industry's suppliers.

This re-spending goes on for a number of rounds, until enough additional production has occurred to satisfy the final demand made by the auto-maker. The sum of the value of all the re-spending of parts of the initial dollar is called the "indirect effect" of the initial change in final demand (called above the "direct" effect).

The input-output table is thus a "map" of the interrelationships between different industries in the economy, as expressed through their patterns of purchasing and producing with each other. The input-output coefficients represent the sum total effect of several rounds of purchasing and producing. Input-output analysis is thus essentially an accounting framework using a matrix form. The matrix can be rendered into equations, and the equations can be solved to yield numerical values for the changes in total industrial output resulting from a change in any part of demand, given the relationships embodied in the table.

In practice, there are several hundred industry columns and rows, and several inter-linked input-output tables that can be constructed – for industries, for commodities, for institutions, and for imports and exports – in order to give a complete set of regional and national accounts. The whole set of input-output tables for the U.S. national economy is the *Benchmark Input-Output Accounts*, and is compiled for almost 400 industries by the U.S. Dept. of Commerce's Bureau of Economic Analysis (BEA) based on data collection by the Census Bureau.[33] When the main input-output table for industries described here is then linked to other tables for institutions (e.g. governments and households) and for exports, the resulting framework is a larger "social accounting matrix system" (SAMS). Within a SAMS, the effects of additional household spending resulting from the earlier industry changes can also be predicted, giving a third group of effects known as the "induced effects". These stem from both the direct effects (the initial changes in final demand) and the indirect effects (the secondary activity). The sum of the direct, indirect, and induced effects is referred to as the "total effects".

To summarize, for the purposes of modeling the employment impacts of manufacturing, we now have four types of effects. The *direct* effects are the initial changes in demand by (in this example) the auto industry. The *indirect* effects are the effects within the firms supplying the auto industry with the goods and services it needs to produce the additional output represented by the direct effects. The *induced* effects are the additional household spending generated by both the direct and indirect changes. The direct effects are of most interest when assessing the project itself, and the other effects are of interest when considering the wider economic impacts of the project.

Since 1996, NIST MEP has used an independent third party organization to conduct an on-going collection of data on real impacts for clients (the direct effects) through a standardized survey *(see Appendix A for a copy of the survey questions)*. Every client is contacted one year after an initial project is completed, and the survey collects data on the business impact of the services provided by their local manufacturing extension center. Some of these data (jobs created or saved, sales, and capital investment) can be directly entered into an input-output model.

The author has developed a methodology[34] for using these client data within the Implan modeling software for estimating the employment impacts of manufacturing extension services to clients,[35] along with a state summary chart for model results *(see Figure 2).* The summary shows the direct, indirect, induced and total impacts for "output", "employment", and "value-added", with value-added being composed of the three elements of "personal income" (which includes both "employee compensation" and "proprietors' income"), "other property-type income", and "indirect business taxes".

Figure 2

What total impact does this state's manufacturing extension center have on this state's economy?

Over the last fiscal year, the state's manufacturing extension center has helped 81 clients create or retain 646 jobs, increase sales by $74.6 million, and make modernising capital investments of $9.8 million, through 101 distinct assistance projects.

These changes within clients have resulted in additional purchases, output, personal income, and taxes elsewhere in the state which would not otherwise have occurred.

These economic impacts can be modeled by computer to see what their value is for the whole state economy. *

	DIRECT EFFECTS	+	INDIRECT EFFECTS	+	INDUCED EFFECTS	=	TOTAL EFFECTS
	(impacts within the client companies themselves)		(impacts in other industries as client companies purchase inputs from them)		(impacts on all other industries caused by expenditures of new household income generated by the direct and indirect effects)		(the sum of the direct, indirect, and induced effects)
Output:	**$136,361,460**		**$66,951,692**		**$48,026,236**		**$251,339,388**
Employment:	**646**		**449**		**468**		**1,563**
Total value added:	**$34,928,346**		**$28,370,632**		**$25,323,661**		**$88,622,639**
Personal income:	$23,086,139		$16,179,722		$12,930,963		$52,196,824
Employee compensation:	$22,036,377		$14,298,824		$11,246,418		$47,581,619
Proprietors' income:	$1,049,763		$1,880,449		$1,684,541		$4,614,753
Other property-type income:	$10,672,925		$9,220,640		$9,169,460		$29,063,025
Indirect business taxes:	$1,169,281		$2,970,719		$3,223,242		$7,363,242

* Input data are from a direct survey of clients, and include: "jobs created/retained", "increased sales", and "capital investments". These are only three of many different likely outcomes achieved by the state center's work with clients.

Table 1 contains the never before brought together summary results from the authors' employment estimation studies of manufacturing extension centers in nine different states using this input-output methodology. The variation in jobs created or retained in clients as a direct result of manufacturing extension services varies across state centers from just four jobs up to 954 jobs, and reflects several factors including the number and type of manufacturing clients served, the differences in state size, and the degree of maturity of the centers at the time.

Table 1. Summary findings from 9 U.S. state manufacturing extension employment impact modeling studies

STATE STUDY NUMBER *	IMPACT EFFECTS				TYPE II
	DIRECT +	INDIRECT +	INDUCED =	TOTAL	MULTIPLIER
EMPLOYMENT IMPACTS:					
1	5.0	2.9	4.3	12.2	2.4
2	12.0	24.4	17.6	54.0	4.5
3	954.0	801.0	756.3	2,511.3	2.6
4	4.0	2.5	2.8	9.3	2.3
5	5.0	13.5	8.1	26.6	5.3
6	646.0	448.8	468.4	1,563.2	2.4
7	11.0	24.1	17.0	52.1	4.7
8	51.0	85.9	64.4	201.3	3.9
9	341.0	272.9	278.1	892.0	2.6
9-STUDY TOTAL:	2,029.0	1,676.0	1,617.0	5,322.0	2.6
9-STUDY MEDIAN:					2.6
EMPLOYEE COMPENSATION IMPACTS:					
1	$262,108	$111,684	$99,916	$473,708	1.8
2	$397,047	$792,406	$320,581	$1,510,034	3.8
3	$32,513,376	$26,047,839	$18,154,571	$76,715,786	2.4
4	$141,242	$68,822	$52,608	$262,672	1.9
5	$163,625	$435,016	$151,489	$750,130	4.6
6	$22,036,377	$14,298,824	$11,246,418	$47,581,619	2.2
7	$366,426	$786,480	$310,418	$1,463,324	4.0
8	$1,176,317	$21,472,611	$1,188,536	$4,537,464	3.9
9	$11,290,300	$7,402,304	$5,516,066	$24,208,670	2.1
9-STUDY TOTAL:	$68,346,818	$71,415,986	$37,040,603	$157,503,407	2.3
9-STUDY MEDIAN:					2.4

* individual state names masked for confidentiality.

Source: Author's own state studies using client follow-up survey data.

The nine-study "Type II multiplier" (the total effects divided by the direct effects) is 2.6 jobs, meaning each job created or saved within a client company plays into a total of 2.6 jobs for the wider economy. So the 2,029 within-client jobs are part of a wider total of over 5,300 jobs created of saved in the state. These 2,029 client jobs are also associated with $68.3 million of additional employee compensation, or over $33,000 per job. Employee compensation has a median multiplier of 2.4, so the $68.3 million is part of $157.5 million in additional employee compensation for the wider economy.

Extension's impacts on manufacturing and inequality in perspective

NIST reports that since the national MEP's inception in 1988 the system has completed over 490,000 customer engagements (for an average of 20,400 a year[36]). In FY 2012 alone, NIST-MEP reports serving 31,373 manufacturers for whom extension helped generate $2.5 billion in new sales, $4.1 billion in retained sales, $900 million in cost savings, and $2.5 billion in new capital investments, as well as creating or saving 61,139 jobs.[37]

These are impressive numbers given NIST-MEP's relatively small budget size, but need to be put in perspective to gauge any potential impact on overall inequality. The U.S. manufacturing sector consists of over 295,000 establishments employing 11 million workers or 8.8% of the total U.S. workforce, and these employees receive a total annual payroll of $575 billion.[38] Even restricting the count to "small and medium-sized establishments" there are still 293,000 manufacturing establishments with over 9.7 million employees and $386.4 billion in payroll. So what is extension's impact relative to the whole SMM sector, in terms of *market penetration, employment*, and *inequality* impacts?

The estimated average annual national *market penetration* of the SMM sub-sector by the total NIST-MEP national system of centers, measured in terms of an estimated 20,400 manufacturers served annually (where "services" provided can vary in size and complexity and therefore impact) versus market size, is just under 7%. (This can only be an estimate because some clients will have more than one service project in a year and different state centers have slightly different ways of defining and bounding a project).

If the median multiplier of 2.6 for *employment impacts* found in the nine individual state studies *(Table 2)* also holds for the national program, then the measured national direct effects of 61,139 jobs within clients play into a modelled total effect of 159,000 jobs per year throughout the economy. This figure is equivalent to only 0.1% of the total U.S. workforce of 135.9 million. Remember that the maximum number of jobs in the manufacturing sector in any one year during the whole 1945-2013 period was 19,427,583 (in 1979), and the number in 2013 was 11,980,667 – a difference of 7.5 million jobs. Thus, at an annual rate of 61,139 jobs created or saved in SMMs by manufacturing extension services, it would take over a century of MEP service to restore the peak level of manufacturing jobs in the post-WWII period *assuming no other job loss*. Given that actual absolute annual manufacturing job loss in the U.S. has been greater than 61,139 in about four out of every ten years between 1945 and 2013, it will realistically take much longer to have that kind of impact on the sector as a whole.

With regards to *inequality*, there is less that can be definitively said, as wage records are not collected on the clients' saved and retained jobs. What can be confidently surmised from the extension process model is that clients helped by manufacturing extension are better off after services than before, that the new or retained workers are earning more than they would have before, and that the enterprise as a whole is more competitive and therefore a better bet for creating the jobs of the future.

Manufacturing extension's impacts, though programmatically excellent, are, given these relative impact numbers, unlikely to impact significantly the larger historical macro-trends of structural shifts and deindustrialization involved. We must thus look instead to other potential impacts to justify manufacturing extension. Fortunately there are several, they are worthwhile, and they are probably *not* achievable through other types of policy in the way they are with manufacturing extension. They are: the further upgrade of those firms most likely to succeed, process improvements leading to better run companies, the multiplier effect, the consortia effect, and the benefits of public sector service modernization.

First, there is the "starfish theory" that increased efficiency, output, and sales are always significant to the individual company that experiences them – not the best economic justification for public expenditure, perhaps, but better than spending that finances "bridges to nowhere" that achieves nothing at all. Furthermore, given that a higher proportion of SMMs are family-owned and run enterprises than is the case with large manufacturers, focusing on this segment means there is a higher chance of benefits remaining local. In the Wisconsin example, companies became clients for engagements only after they had undergone an initial comprehensive assessment which was partly to ascertain whether they were "ripe" for moving up to the next level – which meant having a committed and engaged "A" team of owners and executives, being willing to develop and implement a strategic business plan, and having the wherewithal to make investments in modernizing change. Critics might say that such "picking winners" to begin with guarantees the extension program will show later "success", but the counter is that backing failing companies is not a good bet for growing the jobs of the future. A longer than one-year follow-up might even reveal how some of the assisted companies even became the new product innovators and export-earners five or ten years down the road.

Second, there are definite business efficiency benefits to providing clients with technical assistance for process improvements that may not show up in employment or sales impact numbers. Companies that have been engaged are likely to improve and simply be better managed and operated enterprises than they were before, or would otherwise have been. They may have achieved ISO compliance, Baldrige standards, developed substitute product lines with a more promising future, or become more green and sustainable, for example.

Third, multiplier effects with manufacturing are higher than most other industrial activities. If each job comes with 1.6 other jobs for a total of 2.6, then the additional tax revenues from those individuals at a rough total tax level of almost 40% of gross income,[39] probably pays back the U.S. Treasury its initial investment. Indeed, modeling studies elsewhere suggest that total payback to the taxpayer from NIST-MEP spending can be as high as $3.56 in public tax returns per $1 of initial public expenses.[40]

Fourth, manufacturing extension, in working with groups of small and medium-sized companies, frequently encourages group service delivery and consumption. Companies benefit by being in consortia for collaborative solving of some problems, in order that they can compete more effectively over other things.[41]

In Wisconsin, for example, the state manufacturing extension partnership provided early funding for the Wisconsin Regional Training Partnership (WRTP), initially a loose consortium of 72 "metal-bending" companies in the Greater Milwaukee/Southeastern Wisconsin region, a national core center for the small engines industry. Such companies suffered from a shortage of skilled machinists, and were trapped in a cycle of out-competing each other over a limited local supply only to have employees hop away for another 50 cents an hour three months later. This situation worked as a disincentive to provide training, since one employer's investment would simply benefit another though the skilled worker being "poached" away. As a result, at the time 30% of companies responding to a Wisconsin Manufacturers and Commerce (a private industry group) survey said they were having difficulties hiring skilled people.[42] Within the WRTP employers agreed to solve the problem collaboratively by setting up in-plant training labs with the local technical college and agreeing on competencies and skill standards and curricula for machinists.[43] As a result, WRTP companies increased the total supply of labor they needed, individuals had a more portable skill set because it was understood and recognized, and companies could focus more on where they really wanted to compete – against Japanese and German companies – rather than on cannibalizing each other for no net gain.

The WRTP has now expanded to 125 organizations and gone beyond just manufacturing, but still retains its emphasis on worker training for skills as the lead issue. It has placed over 1,200 low-income people into jobs with an average starting wage of over $10 per hour plus benefits. Successful individual participants raised their earnings by 165% over previously, to more than $22,000 in their first year on the job.[44]

Fifth, manufacturing extension has not only improved client companies, but it has also encouraged public sector service modernization by linking private and public sectors. The traditional public sector, and particularly the higher education part of it, can be characterized by being a world of extremely clever people working on theoretical problems within ivory towers sometimes walled off from the rest of society. In the Wisconsin example, parts of 64 expert individual manufacturing extension agents were funded by the NIST-MEP grant to deliver services to manufacturers, but most of them were "bought out" of their permanent positions. These agents were mostly drawn from universities (both public and private), technical colleges (public), and a few from trade unions (nonprofit).

The NIST-MEP ethos of customer service and outcome measurement as a basis of judging individual performance was at first unusual for lifelong government employees. Extension agents were expected to get out of their offices and go on-site with clients to see their challenges first hand, to build ongoing relationships, and to conduct engagements that led to measurable results and client satisfaction. In this situation, academic theory met real world problems, and both benefited. The state MEP thus played a role beyond its weight in a wider movement to transform government activity with performance metrics, continuous improvement, managing for results, and accountability,

Conclusion and lessons for developing nations:

This paper has reached some answers to the research questions posed at the outset.

(1) What do we know about the link between manufacturing and inequality in general? The international shift of manufacturing has been a significant phenomenon within overall globalization that is being accompanied by increasing income inequality. But inequality also exists within the manufacturing sector between different individual product line manufacturing industries, and between individuals and social groups for many other demographic, age, and educational reasons. Manufacturing also contributes to modernization, if that is a trajectory desired. The manufacturing environment is generally characterized by delivery of supplies from multiple smaller companies who themselves need to be organized into networks and chains, a regular pattern to its production operations, a discipline of shift work, regular wages, and the drive to continuously improve by squeezing out non-value-added time and effort. It thus has a “regularizing” imprint on daily cycles of labor, income receipt, commuting patterns, and even urban social life.

(2) Is it possible to measure the employment impacts of manufacturing extension services on client companies and their wider communities? It is indeed possible to measure client employment impacts through a follow-up survey generating data usable for input-output modeling. Phrasing the survey questions to include the condition that reported impacts would not otherwise have come about without extension services gives added support for a causal link. The direct impacts are then the numbers reported by the client and are real. The indirect and induced employment gains can only be estimated, and that depends on access to a reliable system of national accounts disaggregated to a fine-grained individual-industry scale.

(3) Does any evidence of impacts suggest that manufacturing extension can significantly influence overall trends in the sector and income inequality? Clearly, at the individual client level, extension has an impact. Nationally, the scale at which manufacturing extension services have been funded and delivered -- even in the nation that pioneered, championed, and persisted with them for a quarter of a century -- means that they are unlikely to change significantly the macroeconomic indicators of manufacturing. To the extent that centers select clients ready to move to the next stage, and from growing industries, it may be that inequality is even being contributed to by working with successful companies having better than average prospects of paying higher wages. However, if the choice is between having such higher-paying jobs or not, having them is to be preferred, and may even lead to wider wage upgrade as their successful growth leads to more purchases from suppliers and more local spending over time. It is also possible that against the background of a smaller developing economy, extension activities might have a relatively larger impact than in the U.S.

(4) If not, are there other strategic advantages or public policy justifications for supporting manufacturing? There are several other strategic justifications for such activity, including positive support for the companies most likely to succeed, the multiplier effect of employment impacts, the consortium effects, and the benefits of public sector service modernization.

(5) What lessons can be learned from the first 25 years of manufacturing extension programs in the United States that could be of use in developing nations attempting the same function?

The first lesson is the manufacturing extension should not be seen as a way to start whole manufacturing industries, or reverse larger macroeconomic trends such as deindustrialization and a shift to services. It can, however, make individual companies who are ready for modernizing change more competitive.

Second, be faithful to the core principles as the best defenses of a manufacturing extension program. Build in core elements like: a clear mission, a well-defined client group, demand-driven services, customer focus, performance measurement, seamless service delivery, detailed follow-up, accountability and continuous improvement. Have the structure be a partnership to leverage additional resources for the mission and maintain stakeholder interest and support. (NIST's national investments in the state centers leverage almost another $300 million in additional resources for the mission.) Involve manufacturers themselves in the planning, priority-setting, and governance structures.

Third, make a judicious strategic choice of clients using clear objectives. Work with companies poised to move to the next level, rather than trying to save failing companies or serving politically well-connected or locally prominent ones.

Fourth, try the simpler interventions first, rather than the latest expensive solutions. In the Wisconsin experience, clients often first approached the state MEP with definite ideas of what they thought they needed, such as expensive manufacturing systems software (MSS) or "larger" machines. By putting potential clients through a comprehensive manufacturing assessment first, it was often found that equivalent gains could be made much more cheaply through, for example, a plant layout study. Most medium-sized manufacturers had their plant layout embedded when smaller and never outgrew it even when they reached five times their original size. As a result, they were often moving product in and out of inventory multiple times, or having over two-hundred manual touches on the same item, when simple plant layout revisions could eliminate many of these unnecessary steps.

Finally, make a discipline of detailed measurement, recording, cost tracking, and post-service follow-up. For although the amount, nature, and care with following up on impacts for the client by NIST-MEP is unusually thorough, detailed and systematic for a government program, and helped with internal continuous improvement of center services, it still omitted key things. For example, NIST's own sample studies show that "new product development" services can yield some of the greatest impacts and returns over time from all the extension services offered, but were also the slowest to appear. If returns take up to five years to bear fruit for a company while the client impact follow-up survey takes place only one year after services conclude, then extension is missing key demonstration information on the best thing it can do.

Appendix A. Copy of the NIST-MEP Client Follow-Up Survey form

Center Code: XX1 **Activity Type:** All **Activity Substance:** All **Act Delivery Mode:** All

Client Reporting Beneficial Impacts	Number Reporting Impact			Percent of Total
Clients who had made enough changes as a result of assistance to comment on impact	25	of	35	71.4%
Clients reporting beneficial impacts in one or more of six key categories	15	of	35	42.9%
Clients reporting any beneficial impacts (six categories OR "other" impacts)	22	of	35	62.9%

Impact Data	Of Those Asked, Number Reporting Impact in Category			Percent with Impact	Number Qualifying Impact in Category				Net Quantified Impact
Sales	7	of	25	28.0%	5	of	7	$	2,100,000
Labor Costs	11	of	25	44.0%	8	of	11	$	(128,000)
Material Costs	7	of	25	28.0%	4	of	7	$	(99,000)
Inventory Level	6	of	25	24.0%	5	of	6	$	(338,000)
Net Job Creation	4	of	25	16.0%	4	of	4		10
Jobs Retained	3	of	25	12.0%	2	of	3		3

Client Investment	Of Those Asked, Number Reporting Impact in Category			Percent with Impact	Number Qualifying Impact in Category				Net Quantified Impact
Client Capital Investment	9	of	25	36.0%	9	of	9	$	685,100
Other Project Related Costs to Client	5	of	25	20.0%	3	of	5	$	70,178

Customer Satisfaction	Number	Percent
1- very dissatisfied	0	0.0%
2- dissatisfied	0	0.0%
3- neutral	3	8.6%
4- satisfied	20	57.1%
5- very satisfied	12	34.3%
Total Reporting	35	100.0%
Average Rating	4.26	

About the Data	Earliest	Latest
Project Close Dates	Oct-95	Dec-96
Survey Dates	Oct-96	Oct-97

		Number	Percent
Records Attempted		36	100.0%
Survey Protocol Completed	35	97.2%	
Protocol Led to Impact Questions		25	69.4%

About the author:

Dr. Chris Thompson was the first Executive Director of the Wisconsin Manufacturing Extension Partnership, the NIST-MEP state affiliate for the U.S. state of Wisconsin. As a later consultant to NIST, he developed an original methodology for estimating the employment impacts of manufacturing extension centers using an input-output model, and authored the *NIST Guide to Communicating the Impacts of Manufacturing Extension* in use across the 72 centers of the NIST-MEP system. He has also consulted for several individual U.S. states' manufacturing extension centers, and has published academic articles on this topic.

His other work has been in a variety of economic development topics, including high technology regional development in the U.S., regional economic change in the peripheral countries of Europe, public and private venture capital, high-speed rail, workforce training and investment, government performance, and international technology transfer. He has consulted for the European Union, the Arriyadh Development Authority of Saudi Arabia, and the World Bank.

He has a Ph.D. from the University of Cambridge, UK, a Masters from the University of California at Berkeley, and a B.Sc.(Hons.) from University College London, UK. He is currently a Senior Associate with the National League of Cities (NLC) in Washington DC, a nonprofit member association representing some 19,000 cities, municipalities and townships, and providing professional development opportunities and best practice research to elected officials across the U.S.

The views and arguments expressed in this paper are his own, and are in no way to be taken as official statements of NIST-MEP or NLC, unless explicitly referenced.

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[24] "Mission, Vision, Core Competencies, and Core Values." http://www.nist.gov/public_affairs/mission.cfm

[25] "How ATP works," NIST, http://www.atp.nist.gov/atp/overview.htm.

[26] Sometimes referred to as the "Hollings Manufacturing Extension Partnership" in recognition of an early Congressional supporter. However this paper follows the more commonly appearing acronym on the NIST website: "MEP"; http://www.nist.gov/mep/index.cfm.

[27] Amount requested as of April 2013. See *President's FY 2014 Budget Request for NIST Supports Research in Advanced Manufacturing, Cybersecurity*, NIST Public and Business Affairs, April 10, 2013.

[28] *Fiscal Year 2014, Historical Tables, Budget of the U.S. Government*, Executive Office of the President of the United States, Office of Management and Budget, Washington DC.

[29] U.S. industry data are generally reported for "establishments", i.e. single physical locations, which are not the same as "enterprises", i.e. the business entities which may have more than one location.

[30] NIST Hollings Manufacturing Extension Partnership homepage, http://www.nist.gov/mep/index.cfm

[31] *MEP Information for Stakeholders*, http://www.nist.gov/mep/stakeholders/index.cfm.

[32] *Research and Reports*, NIST Hollings Manufacturing Extension Partnership, http://www.nist.gov/mep/impacts-reports-research.cfm

[33] *Input-Output Accounts Data*, U.S. Dept. of Commerce, Bureau of Economic Analysis. http://www.bea.gov/industry/io_annual.htm; and *BEA Briefing: A Primer on BEA's Industry Accounts*, by Streitwieser M, *Survey of Current Business*, June 2009.

[34] *A Guide for Communicating the Impacts of Manufacturing Extension,* by Thompson C, National Institute of Standards and Technology, Manufacturing Extension Partnership, Gaithersburg, MD.

[35] *Implan*, Minnesota Implan Group LLC, Stillwater, MN, http://implan.com/index.php?option=com_content&view=article&id=870&Itemid=136

[36] This is only a rough figure, given the early years were a ramp-up period when NIST was still launching state centers around the country.

[37] *Manufacturing Extension Partnership: Making an Impact on U.S. Manufacturing*, NIST-MEP, http://www.nist.gov/mep/upload/MEP-PARTNERING-IMPACTS-2013-2.pdf

[38] U.S. Bureau of the Census FactFinder, *County Business Patterns*, 2011.

[39] In the U.S. the author pays 28% of gross income for federal income tax, 9% for state income tax, and an 8% local sales tax.

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