Import Competition and the Great US Employment Sag of the 2000s*

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May 2013

Abstract

Even before the Great Recession, U.S. employment growth was unimpressive. Between 2000 and 2007, the economy gave back the considerable jump in employment rates it had achieved during the 1990s, with major contractions in manufacturing employment being a prime contributor to the slump. The U.S. employment "sag" of the 2000s is widely recognized but poorly understood. In this paper, we explore an under-appreciated force contributing to sluggish U.S. employment growth: the swift rise of import competition from China. We find that the increase in U.S. imports from China, which accelerated after 2000, was a major force behind recent reductions in U.S. manufacturing employment and that through input-output linkages with the rest of the economy this negative trade shock has helped suppress overall U.S. job growth.

Keywords: Trade Flows, Labor Demand

JEL Classifications: F16, J23

*Dorn acknowledges funding from the Spanish Ministry of Science and Innovation (ECO2010-16726 and JCI2011-09709). Autor and Hanson acknowledge funding from the National Science Foundation (grant SES-1227334).

1 Introduction

During the last decade of the twentieth century—christened the "Roaring Nineties" by Alan Krueger and Robert Solow (2002)—the U.S. labor market exhibited a vigor not seen since the late 1960s. Between 1991 and 2000, the employment to population ratio rose by 1.5 percentage points among both white and black males, and by 3 to 7 percentage points among white and black females (Figure 1).[1] In the year 2000, following five years of rapid wage growth accompanied by minimal inflation, the national unemployment rate reached a nadir of 4.0 percent, its lowest level since 1969. Just one year later, however, the U.S. labor market commenced what Robert Moffitt (2012, p. 201) terms a "historic turnaround" in which the gains of the prior decade were undone. Between 2001 and 2007, white and black male employment rates ceded all of their gains achieved between 1991 and 2000. The rapid growth of female employment rates halted simultaneously, and reversed course among some subgroups. While the growth rate of the U.S. working age population was virtually identical during the 1990s and the 2000s, averaging 1.1 to 1.2 percent in both decades, the growth rate of employment averaged only 0.9 percent between 2000 and 2007—that is, during the seven years *before* the onset of the Great Recession—versus 1.4 percent between 1990 and 2000.[2]

This *pre*-Great Recession U.S. employment "sag" of the 2000s is widely recognized but little understood. In one of the first in depth analyses of the falling U.S. employment-population ratio over 2000 through 2007, Moffitt (2012) studies a panoply of potential causes including wage levels, age structure, family structure, taxes, transfers, minimum wage policies, and population health. Only one of these factors is found to have substantial explanatory power: declining male wage rates, which, Moffitt's analysis suggests, can potentially explain up to half of the observed decline in male employment. Yet, this explanation leaves unanswered the question of *why* male wages fell. Ultimately, the concurence of falling wages and falling employment to population ratios suggest an inward shift in labor demand, the ultimate cause of which at present has not been established.

In this paper, we explore an under-appreciated force contributing to the U.S. employment sag of the 2000s: the swift rise of import competition from China. Between 1990 and 2000, the

[1] The U.S. monthly seasonally adjusted unemployment rate averaged 4.0 percent in 2000, the lowest level since 1969, when the annual average was 3.5 percent (www.bls.gov).

[2] See http://www.bls.gov/ilc/#laborforce for data on the size and the employment rate of the working age population.

share of world manufacturing exports originating in China increased from 2% to 5%, before even more accelerated climbs to 12% in 2007 and to 16% in 2011. China's export surge is the outcome of a major expansion in its manufacturing capacity, unleashed by economic reforms in the 1980s and 1990s (Naughton, 2007). Since 1990, China has accounted for over three quarters of the growth in manufacturing value added by low and middle income countries, as its share of manufacturing output within this group has risen from 15% to 44% (Hanson, 2012). For U.S. manufacturing, China's expanding role in global trade is a major shock. Not only is China's export growth concentrated in the sector buts its growth in imports, in particular from the United States and other high income countries, has been comparatively sluggish, reflected in China's sizable positive trade balance that has been more or less matched in the United States by persistent negative trade balances. During the last decade, China's average current account surplus was 5% of GDP, the mirror image of the U.S. current account deficit over the period. U.S. industries, and labor-intensive sectors in particular, have endured a major expansion in global supply, without benefiting from a compensating shift in global demand of comparable magnitude.

As shown in Figure 2, the U.S. manufacturing sector's exposure to Chinese exports, defined as the share of Chinese imports in U.S. domestic absorption—that is, the ratio of Chinese imports to the sum of U.S. domestic manufacturing output plus total imports less total exports—rose from approximately one-half of a percent in 1991 to over six percent by 2009, the last year for which consistent U.S. output data are available. Equally noteworthy in this figure is the sharp rise in Chinese imports after 2001, following China's accession to the World Trade Organization (Pierce and Schott, 2012). U.S. exposure to Chinese imports increased by 1.7 percentage points between 1991 and 2001, and continued to rise by more than twice that amount again—an additional 4.0 percentage points—in the six years between 2001 and 2007. Not surprisingly, U.S. exposure to Chinese imports declined during the Great Recession, albeit modestly. But by 2009, it already exceeded its 2007 level by an additional 0.4 percentage points. And by 2011, Chinese manufacturing imports in real dollar terms had risen by an additional 14 percent relative to 2007.

As Chinese imports to the United States surged, U.S. manufacturing employment underwent a historic contraction (Figure 3). Although the level of employment in U.S. manufacturing had been declining modestly since the start of the 1980s, this trend gained pace in the mid-1990s and accelerated sharply in the 2000s: employment in U.S. manufacturing fell by 9.7 percentage points between 1991 and 2001 and by an additional 16.1 percentage points between 2001 and 2007.[3] Figure 3 offers a prima facie case that the sharp decline in U.S. manufacturing may account for some portion of the U.S. employment sag during the 2000s. The overall U.S. employment growth rate of 0.9 percent between 2001 and 2007 was half as rapid as the rate of 1.8 percent between 1991 and 2000. This overall deceleration, however, combines a roughly 40 percent slowdown in employment growth in non-manufacturing and a near-tripling of the rate of decline of manufacturing. Indeed, excluding manufacturing reduces the observed deceleration in employment growth between 2001 and 2007 by about 30 percent. Since adverse shifts in demand for manufactured goods are likely to have negative spillovers to related non-manufacturing sectors—as we document below—this simple 30 percent figure by no means constitutes the full contribution of manufacturing decline to the weak U.S. job creation record of the 2000s.

In this paper, we explore how much of the U.S. employment sag of the 2000s can be attributed to rising import competition. The hypothesis that rising China imports contribute to declining U.S. manufacturing employment is not novel to this paper. Recent literature estimates that a significant fraction of this decline is due to to rising Chinese import competition, in particular after 2001. We expand on this body of work in two significant ways. The first is conceptual. Several recent papers explore the impact of China trade on local labor markets (Autor, Dorn, and Hanson, forthcoming) or on employment in trade-impacted sectors (Autor, Dorn and Hanson, 2013; Autor, Dorn, Hanson and Song, 2013; Bloom, Draca and Van Reenen, 2011; Pierce and Schott, 2012), but the linkage between these subunits of analysis and changes in aggregate employment rates is unspecified. Distinct from this work, we apply a simple market-clearing model to consider how these industry effects aggregate to national employment while accounting for sectoral reallocation.[4] A second difference with prior literature is that our analysis is not confined to the manufacturing sector. Using input-output matrices to analyze upstream and downstream product linkages between industries, we estimate the impact of manufacturing trade shocks on employment *outside* of manufacturing (as well as

[3]Using County Business Patterns data, we calculate that U.S. manufacturing employment was 18.3 million in 1991, 16.6 million in 2001, 13.9 million in 2007, and 11.4 million in 2011.

[4]In conducting our analysis at the industry level, our paper is closest in spirit to Pierce and Schott (2012), which explores how China's 2001 WTO accession affected U.S. manufacturing employment. Pierce and Schott use tariff changes following WTO accession as a source of identification, while we capture changes in China's competitive position using the covariance between growing Chinese import penetration of the U.S. and other rich country product markets at the level of four-digit SIC manufacturing industries. The link between industry level and aggregate employment in the Pierce and Schott paper is not modeled.

within). Our analysis extends the literature on the labor market impacts of imports of intermediate inputs (e.g., Feenstra and Hanson, 1999; Hummels, Jorgensen, Munch, and Xiang, 2013), which focuses on how offshoring affects the internal industry structure of production and employment, to explore the intersectoral transmission of trade shocks working through changes in the demand for inputs by manufacturing industries from other sectors and changes in the supply of inputs from manufacturing to the rest of the economy.

Our results suggest that rising import competition from China has contributed significantly to the decline in U.S. manufacturing employment since 1991, with most of the adverse employment effects occurring between 1999 and 2007. The employment decline in trade-exposed industries stems both from a reduction in the number of firms and a reduction in employees per firm, and consists of declines in both production and non-production employment. Taking into account input-output linkages between sectors, our estimates suggest that import competition in manufacturing has also contributed to a slowdown of employment growth in non-manufacturing industries that supply services to trade-exposed manufacturing firms. The implied quantitative magnitudes are large. Our baseline estimates imply that of the substantial decline in US manufacturing employment between 1999 and 2007, 16% is due to the direct effect of Chinese import competition. Our preliminary estimates incorporating input-output linkages further indicate that over half of this 1999-2007 manufacturing employment decline could be due to Chinese import competition. Importantly, however, this computation ignores any employment gains that would occur through other general equilibrium channels, such as further expansion in employment in manufacturing or service industries experiencing an increase in relative price (because the prices of industries competing with Chinese imports are declining). With this strong caveat, our results nevertheless suggest that the direct and indirect effects of Chinese import competition could be a key factor in the US employment sag of the last decade.

We begin in Section 2 by describing our empirical approach to estimate the effects of exposure to trade shocks and providing a brief discussion of the data. Section 3 gives our primary OLS and 2SLS estimates of the impact of trade shocks on outcomes. Section 4 expands the analysis to include intersectoral linkages. Section 5 considers the impact of Chinese trade on additional labor market outcomes. Section 6 applies a simple conceptual model to consider what our industry-level results imply for aggregate employment. Section 7 concludes.

2 Empirical approach

To motivate our analysis, consider the change in China's export supply capacity in the last two decades. Rapid industrial productivity growth (Hsieh and Ossa, 2011; Zhu, 2012), rural to urban migration flows in excess of 150 million workers (Li, Li, Wu, and Xiong, 2012), and massive capital accumulation (Brandt, Van Biesebroeck, and Zhang, 2012) permitted manufacturing production to expand at a breathtaking pace. What did this growth mean for U.S. manufacturing employment? We seek to capture the changes in U.S. industry employment induced by shifts in China's competitive position, accounting for input-output linkages between industries. We subsequently consider how these industry demand shifts can be aggregated to national totals.

2.1 Industry Trade Shocks

Our baseline measure of trade exposure is the change in the import penetration ratio for a U.S. industry over the period 1991 to 2011, defined as,

$$\Delta IP_{j,\tau} = \frac{\Delta M^{UC}_{j,\tau}}{Y_{j,91} + M_{j,91} - E_{j,91}}, \tag{1}$$

where for U.S. industry j, $\Delta M^{UC}_{j\tau}$ is the change in imports from China over the period 1991 to 2011 and $Y_{j0} + M_{j0} - E_{j0}$ is initial absorption (measured as industry shipments, Y_{j0}, plus industry imports, M_{j0}, minus industry exports, E_{j0}). We choose 1991 as the initial year as it is the earliest period for which we have disaggregated bilateral trade data for a large number of country pairs that we can match to U.S. manufacturing industries.[5] The quantity in (1) can be motivated by tracing export supply shocks in China—due, e.g., to productivity growth—through to demand for U.S. output in the markets in which the United States and China compete. Trade models with a gravity structure, as in Arkolakis, Costinot and Rodriguez-Clare (2012), yield such a specification. Supply-driven changes in China's exports will tend to reduce demand for U.S. industrial production. Over the period we consider, China enjoyed rapid TFP growth, human and physical capital accumulation, urban labor force growth, and improvements in the country's infrastructure, following the country's transition from a centrally planned economy to a more market-oriented one, all of which contributed to

[5]Our empirical approach requires data not just on U.S. trade with China but also on the countries' trade with other partners.

its export surge (Naughton, 2007; Hsieh and Klenow, 2009).

One concern about (1) as a measure of trade exposure is that observed changes in the import penetration ratio may in part reflect domestic shocks to U.S. industries that affect U.S. import demand. Even if the dominant factors driving China's export growth are internal supply shocks, U.S. industry import demand shocks may still contaminate observed bilateral trade flows. To develop an instrumentation strategy, we observe that the supply-driven component of China's export growth should be evident in the growth of its shipments to other high-income countries. To capture this supply-driven component in U.S. imports from China, we instrument for trade exposure in (1) with the variable,

$$\Delta IPO_{j\tau} = \frac{\Delta M^{OC}_{j,\tau}}{Y_{j,88} + M_{j,88} - X_{j,88}} \tag{2}$$

where $\Delta M^{OC}_{j,\tau}$ is the growth in imports from China during the period 1991 to 2007 in eight other high income countries excluding the United States.[6] The denominator in (2) is initial absorption in the 1988 industry. The motivation for the instrument in (2) is that high income economies are similarly exposed to growth in imports from China that is driven by supply shocks in the country. The identifying assumption is that industry import demand shocks are weakly correlated across high-income economies.[7]

Figure 4 plots the value in (1) against the value in (2) for all U.S. manufacturing industries at the four digit level, as defined below, which is equivalent to the first-stage regression in our subsequent estimation without detailed controls. The coefficient is 0.98 and the t-statistic and R-squared are 7.0 and 0.62 respectively, indicating the strong predictive power of import growth in other high income countries for U.S. import growth from China.

Modeling the China trade shock as manifested in (1) may appear to ignore the existence of global production chains. China's export production relies to an important degree on imported intermediates. During the 1990s and 2000s, approximately half of China's manufacturing exports were produced by export processing plants, which import parts and components from abroad and assemble these inputs into final export goods (Feenstra and Hanson, 2005). The importance of processing plants in China's exports may appear to suggest that the country's

[6]These countries are Australia, Denmark, Finland, Germany, Japan, New Zealand, Spain, and Switzerland, which represent all high income countries for which we can obtain disaggregated bilateral trade data at the Harmonized System level back to 1991.

[7]See Autor, Dorn, and Hanson (forthcoming) for further discussion of threats to identification using this instrumentation approach.

production is limited to product assembly and other simple tasks. Because assembly occurs at the end of the production chain, the gross value of China's exports may overstate the actual value added in China. However, recent evidence suggests that the domestic content of China's exports is both large and growing. Koopman, Wang, and Wei (2012) find that the share of domestic value added in China's total exports rose from 50% in 1997 to over 60% in 2007. Even within the export processing sector, domestic value added rose from 32% of gross exports in 2000 to 46% in 2006 (Kee and Tang, 2012). Importantly, our instrumental variable strategy does not require that China is the sole producer of the goods it ships abroad; rather, we require that the growth of its gross manufacturing exports is driven largely by factors internal to China (as opposed to shocks originating in the United States), as would be the case if, plausibly, the recent expansion of global production chains involving China were primarily the result of its massive increase in manufacturing capacity.

To account for how complexities in global production may affect the transmission of trade shocks in China to U.S. industries, we refer the reader to the detailed analysis in Autor, Dorn, Hanson and Song (2013, ADHS hereafter), who study the impact of industry-level trade shocks on the employment and earnings trajectories of affiliated workers. ADHS develop six alternative measures of changes in import competition at the industry level, which they use alongside our principal measure in (1). These include (i) the change in import penetration from China calculated using the gravity model of trade, (ii) changes in import penetration due to trade with all low-wage countries and not just China, (iii) changes in import penetration due to China in all domestic and foreign markets that U.S. industries serve (and not just the U.S. market), (iv) changes in net imports (imports – exports) from China, (v) changes in the net labor content of U.S. trade with China, and (vi) changes in import penetration due to China net of changes in imported intermediate inputs from China. ADHS document that each of these six measures performs well in capturing industry-level trade shocks that are manifest in excess worker separations, mass layoffs, and firm closures, with the qualitative impacts of trade on labor-market outcomes being similar across these measures. In light of these results, we limit our focus in this paper to the import penetration measure in (1).

2.2 Data sources

Data on international trade for 1991 to 2011 are from the UN Comrade Database,[8] which gives bilateral imports for six-digit HS products. To concord these data to four-digit SIC industries, we first apply the crosswalk in Pierce and Schott (2009), which assigns 10-digit HS products to four-digit SIC industries (at which level each HS product maps into a single SIC industry) and aggregate up to the level of six-digit HS products and four-digit SIC industries (at which level some HS products map into multiple SIC industries). To perform the aggregation, we use data on US import values at the 10-digit HS level, averaged over 1995 to 2005. The crosswalk assigns HS codes to all but a small number of SIC industries. We therefore slightly aggregate the 4-digit SIC industries so that each of the resulting 395 manufacturing industries matches to at least one trade code, and none is immune to trade competition by construction. All import amounts are inflated to 2007 US$ using the Personal Consumption Expenditure deflator.

Our main source of data on U.S. employment is the County Business Patterns for the years 1991, 1999, 2001, 2007 and 2011. CBP is an annual data series that provides information on employment, firm size distribution, and payroll by county and industry. It covers all U.S. employment except self-employed individuals, employees of private households, railroad employees, agricultural production employees, and most government employees.[9]

The CBP does not disclose information on individual employers, and to preserve confidentiality, information on employment by industry is sometimes reported as an interval instead of an exact count. Moreover, some establishments are not identified at the most disaggregate level of the industry classification. However, the CBP always reports the exact number of establishments in each of 13 establishment size classes for each industry cell. When employment in is unavailable for an industry-establishment size cell, we impute employment by using non-suppressed industries to calculate the average number of workers per establishment in that size class, then multiplying by the number of establishments in the suppressed industry-size cell. We assign firms with 2-digit or 3-digit industry codes to associated 4-digit industries using the empirically observed distribution of employment at the 4-digit level.

To supplement the employment and establishment count measures available from the CBP, we utilize the NBER-CES Manufacturing Industry Database for the years 1976 through 2009

[8] See http://comtrade.un.org/db/default.aspx.

[9] CBP data is extracted from the Business Register, a file of all known U.S. companies that is maintained by the U.S. Census Bureau; see http://www.census.gov/econ/cbp/index.html.

(the latter being the latest year available).[10] We use these data to calculate various controls for the production structure in each each industry, including production workers as share of total employment, the log average wage, the ratio of capital to value added, computer investment as share of total investment, and high-tech equipment as share of total investment. Additionally, we create industry pre-trend controls for the years 1976 through 1991, including the changes in industry log average wages and in the industry share of manufacturing employment.

A final data source used in our analysis is the U.S. Bureau of Economic Analysis 1992 input-output table for the U.S. economy, which we use to trace upstream and downstream demand linkages between industries both inside and outside of U.S. manufacturing.[11] We discuss our application of input-output tables in more detail below.

3 Initial employment estimates

We begin the analysis by examining the impact of trade exposure on employment in U.S. manufacturing industries over the period 1991 through 2011 using a set of simple bivariate regressions, which we embellish in subsequent tables.

We begin by fitting models of the following form:

$$\Delta L_{j\tau} = \alpha_\tau + \beta_1 \Delta IP_{j\tau} + \gamma X_{j0} + e_{j\tau}, \tag{3}$$

where $\Delta L_{j\tau}$ is 100 times the annual log change in employment in industry j over time period τ; $\Delta IP_{j\tau}$ is 100 times the annual change in import penetration from China in industry j over period τ as defined in (1); X_{j0} is a set of industry-specific start of period controls (specified later); α_τ is a period specific constant; and $e_{j\tau}$ is an error term. We fit this equation separately for several subperiods of 1991 through 2011 (1991-1999, 1999-2007, 2007-2011), as well as a single stacked first difference model which includes a vector of time effects, one per subperiod. Variables specified in changes (denoted by Δ) are annualized since equation (1) is estimated on periods of varying lengths. Additionally, the elements in the vector of controls X_{j0}, when included, are each normalized with mean zero so that the constant term in (1) reflects the

[10] A joint effort between the National Bureau of Economic Research (NBER) and U.S. Census Bureau's Center for Economic Studies (CES), the NBER-CES database contains annual industry-level data from 1958-2009 on output, employment, payroll and other input costs, investment, capital stocks, TFP, and various industry-specific price indexes. Data and documentation are at http://www.nber.org/data/nberces5809.html.

[11] These data are at http://www.bea.gov/industry/io_benchmark.htm.

change in the outcome variable conditional only on the variable of interest, $\Delta IP_{j\tau}$. Most outcome variables are measured at the level of 395 four-digit manufacturing industries, while later models estimate spillovers to 87 non-manufacturing sectors. Regression estimates are weighted by start-of-period industry employment, and standard errors are clustered at the 3-digit industry level to allow for unspecified error correlations within larger industry sectors.[12]

Table 1 summarizes the import exposure and employment variables used in initial estimates of equation (1). The employment-weighted mean industry saw Chinese import exposure rise by 0.5 percentage points per year between 1991 and 2011, with far more rapid penetration during 1999 through 2007 than during 1991 through 1999: 0.8 versus 0.3 percentage points, respectively. Penetration was highly right-skewed among manufacturing industries, with the mean increase exceeding the median by a factor of 3.6. We find a similar pattern of import penetration change and skewness in the eight other high income countries used to construct the import penetration instrument. Skewness reflects China's strong comparative advantage in labor-intensive manufacturing, including apparel, consumer electronics (e.g., assembly of computers and cellphones), footwear, furniture, and children's toys. Manufacturing decline accelerated throughout the sample: the average industry in our sample contracted by 1.2 log points per year between 1991 and 1999, by 3.2 log points per year between 1999 and 2007, and by 5.3 log points per year in the final period 2007 to 2011, which comprises the Great Recession. The within-industry growth rate of non-manufacturing employment also slowed across the three subperiods of our sample, but the deceleration was not nearly as pronounced as in manufacturing.

Column 1 of Table 2 presents a simple stacked OLS first-difference model for the three time periods summarized in Table 1 (1991-1999, 1999-2007, 2007-2011) with no covariates other than time dummies. Accordingly, the time dummies in this model reflect the (weighted) mean annual within-industry change in employment. Column 2 adds the observed import exposure measure (without instrumentation). This measure is negative and highly significant, consistent with the hypothesis that rising import penetration may lower domestic employment. Nevertheless, we would not expect this OLS point estimate to be consistent. If, plausibly, growth in import penetration is driven partly by outward shifts in domestic demand for

[12] There are 136 three-digit manufacturing industry clusters encompassing the 395 four-digit industries. Because our non-manufacturing data have already been extensively aggregated to 87 sectors for concordance with the SIC hierarchy system, we do not additionally cluster standard errors among these sectors and each of the 87 non-manufacturing sectors is treated as a single cluster.

industry output, this will tend to cause domestic employment and foreign imports to grow simultaneously, which will bias the OLS point estimate towards zero. Column 3 mitigates this simultaneity bias by instrumenting the observed change in industry import penetration with changes in other-country China imports as outlined above. The point estimate of −0.83 implies that a one percentage point rise in industry import penetration reduces domestic industry employment by 0.8 percentage points (t-ratio of 2.8).

The remaining four columns of Table 2 present bivariate estimates of this relationship separately for various subperiods. The relationship is large and statistically significant during 1991 through 1999, and 1999 through 2007, but is close to zero and insignificant during the final four years of the sample, 2007 through 2011. This latter pattern likely reflects the onset of the 2007 financial crisis and Great Recession, which led to a substantial dislocation of worldwide trade patterns between 2007 and 2009, associated with disruption to credit markets that finance most trade flows (Chor and Manova, 2012). Globally, trade fell by 30 percent relative to GDP between 2007 and 2009 (Eaton, Kortum, Neiman, and Romalis, 2011). In the United States, imports plus exports divided by GDP fell by a stunning 22% from the first quarter of 2008 to the first quarter of 2009, before recovering by 2010. These exaggerated cyclical swings in trade surrounding the Great Recession mix with the continued secular growth in China's exports to the United States over the period, adding substantial noise to the data for the 2007-2011 interval.

A simple long-difference model for the change in manufacturing employment over the full 1991 through 2011 period (column 7) also indicates a well-determined negative relationship between import penetration and U.S. manufacturing employment. Figures 5a and 5b offer additional insight into these patterns by plotting OLS and reduced form relationships between industry trade exposure and changes in log industry employment between 1991 and 2011. In each figure, the solid red line corresponds to a weighted bivariate regression of the employment variable on the exposure measure, while the dashed green line corresponds to a bivariate regression where both the independent and dependent variable are winsorized at the 5th and 95th percentiles to reduce the influence of outliers. Notably, trimming leads to a slightly more negative estimated relationship between import penetration and industry employment, suggesting that the estimate in column 7 of Table 2 may understate the relation between China import penetration and U.S. manufacturing employment.

An obvious challenge for our analysis is that industries that are subject to greater import competition may be exposed to other economic shocks that might be confounded with China trade. We begin to address this concern in Table 3 by incorporating extensive controls for potential industry confounds. Additionally, we offer falsification tests, described below. We consider three groups of variables that proxy for different potential confounds. A first set addresses sectoral skill intensity. The sectors with the largest increase in Chinese import exposure from 1991 to 2011 were those intensive in the use of production workers, as would be expected given China's comparative advantage in labor intensive goods. These sectors include toys, sports equipment, and other products; apparel, leather (footwear), and textiles; and furniture and wood products. Also exposed is machinery, electrical machinery, and electronics, reflecting China's large global role in final assembly of consumer electronics. The least exposed sectors include food products, beverages and tobacco, chemical and petroleum products, and transportation equipment. These have in common intensive use of natural resources (land, oil reserves) or physical capital. Despite these broad sectoral contrasts, ADHS document that there remains wide variation in the change in industry import penetration *within* broad sectors defined by production worker intensity. This within-sector variation is central to our identification strategy. To account for this cross-sector heterogeneity, the first set of controls added to the specifications in Table 3 is a set of indicator variables designating ten broad manufacturing sectors. These sectors are chosen to consist of industries that have relatively similar production-worker employment shares.[13] Their inclusion means that the regression identifies the industry-level impacts of trade exposure using primarily variation in import growth among industries with similar skill intensities.

In recent decades, technological progress within manufacturing has been most rapid in computer and skill intensive sectors (Doms, Dunne, and Troske, 1997; Autor, Katz, and Krueger, 1998). To capture the extent to which industries are exposed to technical change, we add a second set of control variables, drawn from the NBER-CES database, measuring the intensity of their use of production labor and capital. These variables, summarized in Appendix Table 1, include the share of production workers in total employment, the log of the average wage, the ratio of capital to value added (all measured in 1991), as well as computer and high-tech equipment investment in 1990, each expressed as a share total 1990 investment.

U.S. manufacturing as a *share* of employment has been in decline since the 1950s, and manufacturing employment has also been in numerical decline since the 1980s. This longstanding

[13]Sector indicators de-meaned so as not to change the interpretation of the constant.

secular trend highlights a concern that the correlation we document between rising industry trade penetration and contemporaneous, within-industry declines in manufacturing employment during 1991 through 2011 could potentially predate the recent rise in import exposure. In that case, our estimates would likely overstate the impact of trade exposure in the current period. We therefore add measures of pretrends in industry employment and earnings in Table 3, specifically the change in the industry's share of U.S. employment, and the change in the log of the industry average wage, both measured over the interval 1976 – 1991 (summarized in Appendix Table 1).

The eight columns of Table 3 permute among combinations of these three groups of industry controls: sector indicators, industry-level controls for production structure, and industry-level controls for pretrends. Among these variable groups, only one has a substantial impact on the point estimates: accounting for broad sector dummies roughly halves the estimated relationship between (instrumented) import penetration and employment. We infer that growth in import exposure is correlated with broader sectoral trends that are in turn absorbed by the sector dummies. When sector dummies are added, the Table 3 models find that neither the production nor the pre-trend variables has any appreciable effect on the magnitude or precision of the coefficient of interest. Notably, inclusion of sector dummies also markedly increases the precision of the coefficient of interest, so significance is essentially unaffected by inclusion of these many controls (including all sets simultaneously in column 8). The three panels of Table 3 also explore the consistency of these estimates among three time intervals within the sample: the long first difference from 1991 – 2011, the 1999 – 2007 interval encompassing the employment sag of the 2000s, and an extended 1999 – 2011 window, which additionally includes the years from the start of the Great Recession to the end of our sample. Across all time periods and among all specifications with sector dummies included, we find a consistently precise and highly robust point estimate for the impact of import exposure on industry employment on the order of -0.68, meaning that a one percentage point rise in import penetration is found to reduce industry employment by approximately two-thirds of one percent.

As a further robustness test, Appendix Table 2 summarizes a simple falsification exercise in which we regress changes in industry employment in earlier decades of manufacturing data on the instrumented change in industry import exposure during the 1991 through 2011 period. It would be problematic for our identification strategy if *future* growth in Chinese import exposure predicted industry employment declines in the era *prior* to China's trade opening.[14] The estimated relationship between our China trade exposure measure and industry employment is statistically insignificant and close to zero in both the 1970s and 1980s (1971–1981 and 1981–1991). The point estimate becomes economically large (−0.57) in the subsequent decade (1991–2001), and attains significance at the 10 percent level. The relationship is large and highly significant in the final decade of the sample (1999–2007). This pattern of results is consistent with the hypothesis that the within-industry correlation between rising import penetration and declining manufacturing employment in the 1990s and 2000s emanates from contemporaneous trade shocks rather than longstanding factors driving industry decline whose origin predates these shocks.

To develop a rough sense of the economic magnitude of these estimates, we can compare the unconditional change in manufacturing employment in each period measured by the intercept term in column 1 of Table 3 to the conditional change in column 8, after accounting for import exposure and controlling for other confounds.[15] This simple benchmark implies that 16 percent of the within-industry decline in manufacturing during 1999 through 2007 is explained by rising import penetration.[16] For the periods 1991-2011 and 1999-2011, the corresponding values are 11 and 8 percent. These direct effects imply that, absent the increase in imports from China, US employment between 1999 and 2007 would have declined by 21.3 (8×-2.66) percent instead of the actual decline of 25.4 (8×-3.17) percent. This benchmark is quite crude in that it takes account of neither type of general equilibrium effect we discussed in the introduction—upstream and downstream demand linkages among industries, which could magnify these shocks, and general equilibrium price effects on unaffected, or only lightly affected, industries, which would dampen these impacts. We address both issues below.

[14]To carry the analysis back to 1971, we employ the NBER-CES data, which covers a longer time horizon than the County Business Patterns data that it used in our main estimates. A disadvantage of the NBER-CES database is that is currently only updated through 2009, which is two years less current than the CBP. To improve comparability, we use the NBER data in *all* columns of Appendix Table 2, including for the post-1990 period (unlike in Tables 2 and 3, where we use CBP data). The Appendix Table 2 regressions also include 10 broad sector dummies since the Table 3 estimates suggest that they may address an important confound. These estimates also differ from those in Tables 2 and 3 in that the import exposure variable corresponds to the long 1991 – 2011 change in all columns.

[15]Recall that aside from the import exposure measure, all covariates in these regression models are demeaned so as not to affect the interpretation of the constant.

[16]This fraction is calculated by comparing the intercepts in columns 1 and 8 of the second panel of Table 3: $0.16 = 1 - 2.66/3.17$.

4 Accounting for sectoral linkages

A contribution of our paper is that we are able to explore both the direct and the indirect effects of trade shocks on industry employment, the latter of which accrue through sectoral linkages inside and outside of manufacturing.[17] For example, the chemical and fertilizer mining industry—which is in non-manufacturing— sells 85 percent of its output to the manufacturing sector. Its largest single manufacturing customer is the phosphatic fertilizer industry, which accounts for 26 percent of its sales. Similarly, the iron and ferroalloy ores industry sells 92 percent of its output to the manufacturing sector, two thirds of which goes to the blast furnace and steel mill industry. Accordingly, a shock to the demand for a given domestic manufactured good may indirectly impact demand for, and reduce employment in, industries that supply inputs to the affected industry, which typically includes both manufacturing and non-manufacturing sectors. Conversely, an adverse trade shock to the suppliers of a given industry (e.g., the upstream suppliers of tires to the automobile industry) may also affect downstream industries. This effect is generally ambiguous. On the one hand, from the perspective of downstream industries, the trade shock may constitute a decline in the cost of purchased inputs, and thus would tend to expand employment in the downstream industries.[18] On the other hand, it may destroy existing long-term relationships for specialized inputs as those inputs suppliers are driven out of business, thus creating a force towards contraction in the downstream industries.

To study these inter-industry linkages, we envisage an economy along the lines of that studied by Long and Plosser (1982) and Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi (2012), where each industry uses, with different intensities, the output of other industries as inputs. We apply this methodology to the Bureau of Economic Analysis' input-output tables for 1992. We choose the 1992 input-output table since it largely predates the China trade shock and hence the linkages observed there are unlikely to be endogenous to the subsequent shock. To estimate the change in import penetration that a given industry faces due to linkages with

[17]Pierce and Schott (2012) also examine upstream and downstream linkages within manufacturing. An important feature of the current paper is that we measure the impact of these linkages outside of manufacturing as well.

[18]Consistent with this reasoning, De Loecker, Goldberg, Khandelwal, and Pavcnik (2012) find substantial negative domestic product price effects from trade liberalization in India and Goldberg, Khandelwal, Pavcnik, and Topalova (2010) document that greater availability of imported intermediate inputs is associated with more rapid introduction of new product varieties by domestic firms, also in the Indian context.

its *downstream* buyers, we calculate the following quantity for each industry j,

$$\Delta IP^D_{j\tau} = \sum_g w^D_{gj} \Delta IP_{g\tau}, \tag{4}$$

which is equal to the weighted average change in import penetration during time interval τ across all industries g that purchase from industry j. These weights w^D_{gj} are defined as

$$w^D_{gj} = \frac{\mu^U_{gj}}{\sum_{g'} \mu^U_{g'j}}, \tag{5}$$

where μ^U_{gj} is the 1992 "use" value in the BEA input-output matrix for the value of industry $j's$ output purchased by industry g, such that the weight in (5) is industry $g's$ share of total inputs purchased from industry j. Thus, (4) is a weighted average of the trade shocks faced by the downstream purchaser's of $j's$ output.[19] When industry $j's$ purchasers—that is, its downstream buyers—suffer a negative trade shock they are likely to reduce demand for $j's$ output. Similarly, to compute the upstream shock faced by each industry j—that is, the average of the trade shocks faced by the industries from which j purchases inputs—we make the same calculation after reversing the j and g indexes in the input-output table. We instrument both the upstream and downstream trade shocks analogously to our main import shock measure: using contemporaneous changes in China imports in eight other high income countries to calculate *predicted* upstream and downstream shocks for each industry, where these predictions serve as instruments for the measured domestic values.

Importantly, we define input-output linkages exclusive of an industry's own four-digit-industry purchases. Our motivation for doing so is that for many four-digit industries the primary purchaser of its inputs is itself, introducing potential collinearity between gross import penetration in (1) and downstream (or upstream) import penetration, as shown in (4). By excluding the own industry in (4), the main industry effect of import penetration in (1) embodies two subeffects: a negative effect working through final demand, in which greater supply of final goods to U.S. consumers from China depresses U.S. industry product demand,

[19]Since our *direct* shock variable only reflects manufacturing trade, all downstream shocks to a sector emanate by definition from shocks to their downstream manufacturing purchasers. Of course, these shocks affect both manufacturing and non-manufacturing industries equally to the degree that they supply inputs to manufacturers g that are directly shocked. Similarly, upstream shocks—that is, shocks to the suppliers of goods to a given sector—emanate from trade shocks to these industries' *manufacturing* sector suppliers, though again both manufacturers and non-manufacturers may have upstream suppliers in manufacturing.

and an additional negative effect working through input demand, as the U.S. industry purchases less from itself given the greater availability of Chinese input supply. Implicitly, the coefficients we estimate in Tables 2 and 3 capture the combined impacts of import competition on employment emanating from both final goods' and input markets.

Upstream and downstream exposure measures are summarized in Appendix Table 3. Logically, the indirect exposure measures are substantially smaller in magnitude, and have far less cross-industry variation, than the direct exposure measures. In the average manufacturing industry, the direct trade shock is five times larger than the upstream shock and over three times larger than the downstream shock.

Table 4 presents instrumental variables estimates of the effects of import exposure on industry employment akin to those in Table 3, here augmented with the upstream and downstream import exposure measures, $\Delta IP^{D}_{j\tau}$ and $\Delta IP^{U}_{j\tau}$. All models include the ten manufacturing sector dummies introduced earlier. We exclude the industry production and pre-trend controls used in Table 3 since these were shown to have little effect conditional on sector dummies—but they do absorb degrees of freedom, which is problematic in a setting with three instrumented endogenous variables that are themselves correlated.

The first four columns in Table 4A consider manufacturing employment, for the 1991 to 2011 period, as do the first four columns in Table 4B, for the 1999 to 2007 period. For manufacturing industries, upstream industry effects are, somewhat surprisingly, negative and significant in both time periods, whereas downstream industry effects are only consistently negative and significant during the employment sag period of 1999 to 2007 (Table 4b). The additional explanatory power of these variables for trends in manufacturing employment is substantial. Comparing the intercepts in columns 1 and 5 of Tables 4A and 4B implies that direct and indirect changes in manufacturing industry exposure can explain 34 percent of the decline in manufacturing between 1991 and 2001 and 61 percent of the decline between 1999 and 2007.[20] These estimates also contain some puzzles, however, that leave our interpretation somewhat tentative. In particular, we find substantially larger adverse effects of upstream than downstream trade exposure on industry employment, which is opposite to the expected pattern.

Columns 6 through 9 of Tables 4A and 4B turn our attention to the impact of trade exposure shocks accruing through interindustry demand linkages on employment in non-

[20] These calculations are $0.34 = 1 - 2.03/3.08$ and $0.61 = 1 - 1.25/3.17$.

manufacturing industries. Consistent with our reasoning above, growth in an industry's downstream trade exposure is found to reduce industry employment. This effect is large but imprecise during the 1999 through 2011 period.[21] When we focus on the period of rapidly increasing trade penetration from 1999 to 2007, however, the effect of downstream exposure is both large and precisely estimated. To benchmark its magnitude, observe that the constant term in the regressions in the middle panel of Table 4B *rises* from 1.66 to 1.99 when the downstream measure is included, suggesting that within-industry growth in non-manufacturing employment would have been approximately three-tenths of a percentage point *faster* than observed during the 2000's were it not for the tightening of competitive conditions in U.S. manufacturing induced by rising import competition from China. Conversely, the growth in upstream penetration is found to have a negligible, and never significant, effect on industry employment, consistent with expectations.[22]

The final set of columns in Tables 4A and 4B pool manufacturing and non-manufacturing sectors, while including direct, upstream and downstream trade exposure measures as well as separate intercepts for manufacturing and non-manufacturing sectors. These estimates reinforce the conclusion from earlier columns that inclusion of upstream and downstream import exposure linkages provides substantial additional explanatory power for both the trend deceleration of non-manufacturing employment growth in the 2000s and the trend acceleration in manufacturing decline seen simultaneously.

In section 6, we provide a more rigorous accounting of these employment effects that additionally accounts for offsetting effects on employment stemming from declining prices of final consumption and intermediate goods. Before turning to this exercise, we explore several additional industry outcomes of interest.

5 Exploring additional industry outcomes

We have so far focused exclusively on the effects of trade exposure on industry employment. Numerical employment is only one margin along which industries may adjust, however. Oth-

[21] The non-manufacturing estimates do not include sector dummies (unlike the manufacturing estimates) since our non-manufacturing industry scheme is already highly aggregated and, moreover, does not collapse down readily to a 1 or 2 digit scheme since we had to extensively modify the SIC to concord it with the input-output scheme used by the BEA.

[22] Note that there is no 'direct' trade exposure effect in non-manufacturing since our trade measures are confined to manufactured goods.

ers may include, wages, establishment size, establishment shutdown, production versus non-production employment, and of course, changes in output. Employing a combination of CBP and NBER-CES data, we explore these outcomes for manufacturing in Tables 5a and 5b.[23] The first table studies the long change between 1991 and 2011, while the latter of focuses only on the 'great sag' period of 1999 through 2007.

Many of the results in Tables 5a and 5b are in line with expectations, given results on how import penetration affects employment in Tables 2 and 3. Trade shocks reduce the count of establishments (in the 1999-2007 period), average employment per establishment, the average industry wage bill, and the nominal value of industry shipments. Production employment declines proportionately more than non-production employment, and the *nominal* value of shipments falls by roughly the same amount as employment.

These tables also contain some informative surprises, however. First, we find that trade exposure predicts a rise in real industry log wages—that is the real wage bill divided by the headcount. Given that production employment falls faster than non-production employment, however, a logical interpretation of this pattern is that worker composition shifts towards more highly paid non-production workers as employment falls. More surprisingly, we also find no effect of trade exposure on log average wages of either production or non-production workers. This result, which is also consistent with Autor, Dorn and Hanson (forthcoming), suggests either that wages are 'downward sticky' in manufacturing or, perhaps more plausibly, less highly paid workers are those most likely to be laid off within each subgroup of workers, leading to an upward shift in wages among those employed as a result of unobserved changes in composition (consistent with Autor, Dorn, and Hanson, 2013).

A second surprising result in Table 5a is that although nominal shipments decline by -0.80 log points for a one log point increase in industry import exposure, we find no effect on the real value of industry shipments, suggesting that shipments deflators must be rising faster in industries experiencing rapid growth in penetration, an intuition that is confirmed in column 12. A candidate explanation for this unexpected pattern is that some heavily exposed sectors have phenomenal productivity growth, which may potentially be an artifact of measurement. To explore this possibility, the lower panels of both tables 5a and 5b drop the 18 computer-related industries in our panel of 395 industries. Computer industries experienced a strong

[23]Appendix Table 4 summarizes these outcome variables. As in Table 4, regression models include 10 sector dummies as well as a constant.

growth of import competition combined with a rapid product development that complicates the measurement of 'quality adjusted' output. Once computer-related industries are excluded from the estimates, we find sensibly that increases in trade exposure decrease both nominal *and* real shipments, and (logically) have no significant effect on the industry-specific shipments deflator. This result accords with Houseman, Kurz, Lengermann, and Mandel's (2011) finding that official U.S. manufacturing industry productivity statistics often conflate declines in import prices with gains in domestic industry productivity. This may well be the case here. Our subsequent work on this paper will more fully explore these patterns. Notably, while the exclusion of computer-related industries strongly affects the estimates for the real value of shipments, other outcomes like employment counts or wage bills are only modestly affected.

6 Benchmarking total employment effects

TBA

7 Conclusion

TBA

References

Acemoglu, Daron, Vasco Carvalho, Asuman Ozdaglar and Alireza Tahbaz-Salehi. 2012. "Network Origins of Aggregate Fluctuations" Econometrica

Arkolakis, Costas, Arnaud Costinot, and Andres Rodriguez-Clare. 2012. "New Trade Models, Same Old Gains?" *American Economic Review*, 102(1): 94-130.

Autor, David H., David Dorn and Gordon H. Hanson. forthcoming. "The China Syndrome: Local Labor Market Effects of Import Competition in the United States." *American Economic Review*.

Autor, David H., David Dorn, Gordon H. Hanson and Jae Song. 2013. "Trade Adjustment: Worker Level Evidence." Mimeo, MIT.

Autor, David H., Lawrence F. Katz, and Alan B. Krueger. 1998. "Computing Inequality: Have Computers Changed the Labor Market?" *Quarterly Journal of Economics*, 113(4), 1169-1213.

Bernard, Andrew B., J. Bradford Jensen, Stephen J. Redding, Peter K. Schott, 2007. "Firms in International Trade." *Journal of Economic Perspectives*, 21(3): 105-130.

Bloom, Nicholas, Mirko Draca, and John Van Reenen. 2011. "Trade Induced Technical Change? The Impact of Chinese Imports on Diffusion, Innovation, and Productivity." Mimeo, Stanford University.

Brandt, Loren, Johannes Van Biesebroeck, and Yifan Zhang. 2012. "Creative Accounting or Creative Destruction? Firm-Level Productivity Growth in Chinese Manufacturing." *Journal of Development Economics*, 97(2): 339-351.

Chor, Davin. 2010. "Unpacking Sources of Comparative Advantage: A Quantitative Approach." *Journal of International Economics*, 82: 152-167.

Chor, Davin, and Kalina Manova. 2012. "Off the cliff and back? Credit conditions and international trade during the global financial crisis." *Journal of International Economics*, 87(1), 117–133.

di Giovanni, Julian, Andrei Levchencko, and Jing Zhang. 2011. "The Global Welfare Impact of China: Trade Integration and Technological Change." Mimeo, University of Michigan.

De Loecker, Jan, Pinelopi Goldberg, Amit Khandelwal, and Nina Pavcnik. 2012. "Prices, Markups, and Trade Reform." NBER Working Paper No. 17925.

Doms, Mark, Timothy Dunne, and Kenneth R. Troske. 1997. "Workers, Wages, and Technology." *Quarterly Journal of Economics*, 112(1): 253-290.

Eaton, Jonathan, and Samuel Kortum. 2002. "Technology, Geography, and Trade." *Econometrica*, 70(5), 1741-1779.

Eaton, Jonathan, Samuel Kortum, Brent Neiman, and John Romalis. 2011. "Trade and the Global Recession." NBER Working Paper No. 16666.

Feenstra, Robert C., and Gordon H. Hanson. 2005. "Ownership and Control in Outsourcing to China: Estimating the Property Rights Theory of the Firm." *Quarterly Journal of Economics*, 120(2), 729-762.

Goldberg, Pinelopi, Amit Khandelwal, Nina Pavcnik, Petia Topalova. 2010. "Imported Intermediate Inputs and Domestic Product Growth: Evidence from India." *Quarterly Journal of Economics*, 125(4): 1727-1767.

Hanson, Gordon. 2012. "The Rise of Middle Kingdoms: Emerging Economies in Global Trade." *Journal of Economic Perspectives*, 26(2): 41-64.

Houseman, Susan, Christopher Kurz, Paul Lengermann, and Benjamin Mandel. 2011. "Offshoring Bias in U.S. Manufacturing." *Journal of Economic Perspectives*, 25(2): 111–132.

Hsieh, Chang-Tai, and Peter J. Klenow. 2009. "Misallocation and Manufacturing TFP in China and India." *Quarterly Journal of Economics*, 124(4): 1403-1448.

Hsieh, Chang-Tai, and Ralph Ossa. 2011. "A Global View of Productivity Growth in China." NBER Working Paper No. 16778.

Hummels, David, Rasmus Jorgensen, Jakok Munch, and Chong Xiang. 2013. "The Wage and Employment Effects of Offshoring: Evidence from Danish Matched Worker-Firm Data." Mimeo, Purdue University.

Koopman, R., Z. Wang, and S. Wei. 2012. "Estimating Domestic Content in Exports when Processing Trade is Pervasive." *Journal of Development Economics,* 99(1): 178-189.

Krueger, Alan B. and Robert M. Solow. 2002. *The Roaring Nineties: Can Full Employment Be Sustained.* New York: Russell Sage Foundation.

Krugman, Paul. 1980. "Scale Economies, Product Differentiation, and the Pattern of Trade." *American Economic Review*, 70(5): 950-959.

Li, Hongbin, Lei Li, Binzhen Wu, and Yanyan Xiong. 2012. "The End of Cheap Chinese Labor." *Journal of Economic Perspectives*, 26(4): 57-74.

Long and Plosser. 1982.

Moffitt, Robert A. 2012. "The Reversal of the Employment-Population Ratio in the 2000s: Facts and Explanations." *Brookings Papers on Economic Activity*, 1, 201–264.

Naughton, Barry. 2007. *The Chinese Economy: Transitions and Growth*. Cambridge, MA: MIT Press.

Pierce, Justin R. and Peter Schott. 2009. “A Concordance between Ten Digit Harmonized System Codes and SIC/NAICS Product Classes and Industries.” NBER Working Paper No. 15548.

Pierce, Justin R, and Peter K Schott. 2012. “The Surprisingly Swift Decline of U.S. Manufacturing Employment.” NBER Working Paper No. 18655, December.

Shikher, Serge. 2011. “Putting Industries into the Eaton-Kortum Model.” *Journal of International Trade and Economic Development*, 21(6): 807-837.

Zhu, Xiaodong. 2012. "Understanding China’s Growth: Past, Present, and Future." *Journal of Economic Perspectives*, 26(4): 103-24.