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Industrial Growth in Indiana: Demand Side Decomposition, 2001-2006

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Abstract. This paper evaluates Indiana's economy by using an input-output (I-O) model to decompose output growth of two sectors into regional demand, external demand, the progress of import substitutions, and technological change. We use the Syrquin (1976, 1986, 1988) industry decomposition method to perform this analysis. We examine two industries that have been central to state level economic development policy: logistics and manufacturing of life sciences products. We found that the logistics sector has responded slowly during the post-recession growth experienced by many of the remaining sectors. However, the surgical sector performed well in terms of deepening interindustry linkages.

1. Introduction

The recession of 2001 was especially deep in Indiana, with double digit declines in manufacturing employment. This decline was particularly significant because 22 percent of Indiana's workforce was employed in the manufacturing sector. During this period, Indiana undertook several policy efforts to promote manufacturing and logistics. The bulk of these efforts were focused on the supply side, such as an elimination of the inventory tax, efforts in workforce development targeting manufacturing, and improvements in transportation infrastructure. The changes to these sectors during this period are of interest, as is the role demand side changes play in the industry.

The purpose of this research is twofold. First, we investigate changes in Indiana's economic sectors by decomposing output growth of each sector into regional demand, external demand, the progress of import substitutions, and technological change, using an input-output (I-O) model. Second, we evaluate the role demand has played in industrial initiatives set by the Indiana Economic Development Corporation. We do this by evaluating the demand side growth of targeted sectors through two case studies. We examine life sciences and logistics during the difficult period of 2001-2006.

2. Literature

There is no consensus of the directions and level of involvement that state and local governments should take in regional growth and development. Lewis' (2001) review of the literature suggests that there is a well-developed theory and a set of best practices of business incubation effects on economic development in the United States. Lewis concludes that state and local level economic development policies, such as state-supported technology incubators through tax incentives for research and development (R&D) and loan funds, play a great role in achieving state economic development goals with relatively low public sector cost per job, high survival rate, and low relocation rate to areas outside the local region. He also argues that it appears premature to hope that the for-profit agents can achieve the same goals if state funding is withdrawn.

Many states that are involved in business attraction and retention efforts and economic development programs are challenged to determine appropriate investment areas and funding priorities.

Whether the focus areas should relate to existing strengths or new areas for investment and development with higher risk is still under debate. Despite these challenges, states are increasingly active in developing strategic plans for economic development, many of which focus on ways to improve state science and technology infrastructure, technology transfer, and the workforce (Coburn and Berglund, 1995; Feller, 1992). Some plans assess existing science and technology capability, identify areas of strength, determine appropriate ways to stimulate further development, and outline investment strategies to build competitiveness (State Science and Technology Institute, 1997). Moreover, highly populated industrial areas and predominantly rural areas differ in their designs of economic development or science and technology strategic plans based on their different resources and backgrounds. In highly populated industrial areas plans often concentrate on science and technology development; build on existing areas of industrial strength; draw on strong research universities; rely on dense networks of firms, specialized workforces, and supporting organizations; and use existing local sources of capital (Calzonetti and Gatrell, 2000). In predominantly rural states, attention has only recently turned to science- and technology-based development. Still, these states commonly lack R&D-intensive industry, diverse metropolitan areas, a sophisticated workforce, local sources of capital, and strong research universities (Calzonetti and Gatrell, 2000; Lyons, 1995). Furthermore, many of them have close ties to resource extraction, such as mining, which historically does not lead to competitive development (Porter, 1990). Industry spinoffs from university-based research are also limited and face tremendous challenges, even in metropolitan areas associated with leading universities (Feldman, 1994).

Calzonetti and Gatrell (2000) and Calzonetti, Allison and Gatrell (1999) have studied the case of West Virginia, which is a predominantly rural state, and found that the state has deliberately selected new areas for state strategic investment rather than existing areas of strength as it wishes to make the transition to a "knowledge region." Information technologies, identification technologies, and workforce development were selected over technology areas in support of the chemical industry and metal industry, which represent the strongest industrial R&D sector in the state. As the state develops plans to build technology in rural areas and redefine resource extraction and mass production strategies, it is premature to conclude whether this new "knowledge region" strategy is successful in West Virginia.

Indiana approached the economic development strategic planning process differently than West Virginia. The state's leading economic development voice (the Central Indiana Corporate Partnership) commissioned a formal study of development opportunities in the late 1990s. This study, *Nurturing Central Indiana's Pillar Industries for 21st Century Midwestern Pre-eminence* (Battelle Corporation, 2000), identified three potential focus areas for state-level economic development policies: advanced manufacturing, life sciences and information technology.

The study employed location quotients and growth rates to identify sectors as potential areas to nurture through public policy. As with many studies of this type, the definition of clusters and the tools for measuring them were loosely defined. It is important to appreciate the institutional and national environment in which this study was crafted. Indiana possesses three Carnegie-ranked research institutions: Purdue University, Indiana University, and Ball State University. The state's land grant institution, Purdue University, is well known for engineering. Indiana University has the state's medical college and is heavily focused on biomedical research. Ball State University enjoys a national reputation in emerging media and information technologies. It is difficult to consider the study recommendations in light of the strengths of the three large public universities and not conclude that consideration was given to a strategic alignment of initiatives with the universities (see Section 5).

In the years immediately preceding the study Indiana created a statewide community and technical college system (IvyTech), so it is unsurprising that many of the policy recommendations of the Battelle study focused on education attainment. Business climate considerations and nurturing of the entrepreneurial climate were among the recommended strategies. The recommendations of the Battelle study are consistent with the types of state-level policy recommendations for high technology reviewed by Lewis (2001). The experience in Indiana is a particularly relevant example of a holistic development policy in action.

3. Changes in Indiana's sectors from 2001 to 2006

The 2001 recession, though mild nationally, was severe in Indiana. The state's heavy reliance on the manufacturing sector meant that the deep reductions in manufacturing employment in the fall and winter of 2001 were felt especially hard in Indiana, as well as the surrounding states of Ohio and Michigan. The loss of manufacturing employment also impacted other sectors, and though the U.S. as a whole experienced a mild recession, Indiana did not enjoy positive growth in employment until 2004.

The beginning of the recession was accompanied by a robust effort by the state to promote selected industries, the three broad sectors identified in the Battelle Corporation report, as appropriate growth industries for the state. These were advanced manufacturing and logistics, the biosciences and information technology. Indiana responded to the report with the creation of initiatives in these sectors. Private sector initiatives in the biosciences and advanced manufacturing and logistics included a very active trade group in both areas (BioCrossroads and Conexus[1]). At the state level, significant efforts were undertaken to target these industries, the most significant being the elimination of the inventory tax. Increased focus on workforce development initiatives aimed at the manufacturing workforce and commitment to long-term improvements in the state's transportation infrastructure were also a hallmark of the period.[2] Of interest are the changes in these industries over this time period. This section addresses these questions by examining changes in seven indicators from 2001 to 2006.

This report differs from other industry analyses in that the data employed are from National Accounts directly obtained from input-output (I-O) tables. The use of these long-term data is an unfortunate absence in the literature that this study aims to remedy. The source of the data is IMPLAN's[3] 2001 and 2006 Indiana industry I-O tables. The 2006 Indiana I-O table is deflated to 2001 constant prices for an analysis in real terms using the Bureau of Labor Statistics' producer price index and the Bureau of Economic Analysis' import price index. The deflation method follows the United Nations' I-O Handbook's double deflation method.[4] Five hundred and nine sectors in the original 2001 I-O table and the deflated 2006 I-O table are aggregated into 38 sectors under 3-digit North American Industry Classification System (NAICS) codes. Sector details are presented in Appendix Table A1. We believe the use of the Input-Output approach marks an important departure from other development policy analyses. It is especially useful when evaluating a comprehensive statewide policy. While there are other studies of specific state level development studies (see Hicks and LaFaive, 2011), we believe an econometric model of sub-sector growth during this time period would be unable to disentangle the multiple initiatives undertaken by the state. As a consequence, this methodology offers an extension to an important policy question.

We begin with the production index, which is calculated from the value of total output at 2001 constant prices. This illustrates the sectoral growth performance in 2006. The employment index also shows the sectoral growth performance in 2006 compared with 2001. The import ratio, defined as the import share of total consumption (Indiana's supply plus imports less exports), shows the degree of import dependency. The domestic export[5] ratio is the share of Indiana's total production which is exported to other states in the U.S.. The foreign

[1] www.biocrossroads.com, and www.conexusindiana.com

[2] In 2006 the state leased the Indiana Toll road for $3.8 billion, using these funds to finance completion of Interstate 69 from Indianapolis to Evansville.

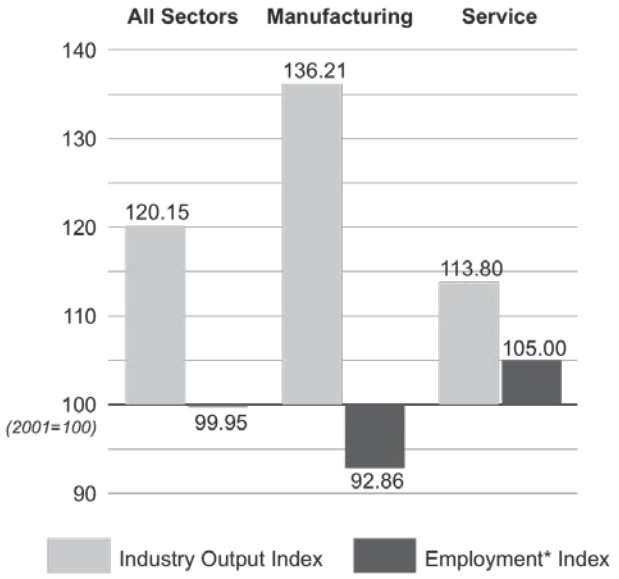
[3] Minnesota IMPLAN Group, www.implan.com. There are some limitations in the IMPLAN's Input-Output data. When the state sectoral data are not available, IMPLAN estimates the data by normalizing the distribution which is controlled by the state and national level totals. This practice can cause the state sectoral data to look like the U.S. normalized version. However, IMPLAN tries to avoid the problem by making sure that output data in some sectors which are likely to be concentrated in only certain states (such as logging), are based on other reliable data (such as each state's employment share in logging) and not by the normalization method alone. IMPLAN claims that the latest version of its data (from year 2008 onward) provides a more accurate calculation for trade flow data by using the double constrained gravity model to determine imports, exports, and local demand through better Regional Purchase Coefficients (see footnote 5 for how the domestic exports and imports were calculated for IMPLAN data before 2008). With all these limitations, however, IMPLAN data is still considered the best available resource to date for Input-Output data. The authors believe that Indiana's sectoral data mostly mirrors the national sectoral data. Moreover, some large sectors of Indiana, such as the manufacturing and logistics sectors, certainly influence the national pattern.

[4] United Nations. 1999. Handbook of Input-Output Table: Compilation and Analysis. New York, pp. 226-240.

[5] Domestic export data from IMPLAN are residuals based up from allocating the total supply first to the total demand for goods by local consumers based on each sector's Regional Purchase Coefficients (percentage of products produced and used locally), and then foreign exports. Any residuals of local supply are presumed to have been shipped to the rest of the U.S., which in turn becomes other states' domestic imports. IMPLAN derives RPCs by a set of econometric equations.

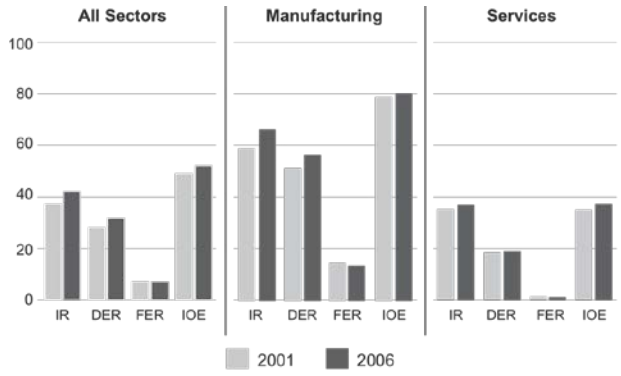
export[6] ratio is the share of Indiana's exports to the rest of the world as a share of total Indiana production. Both the domestic and foreign export ratios indicate Indiana's export orientation. The induced output by exports indicates what proportion of output was induced both directly and indirectly by total exports.[7] The power of dispersion is the conventional measure of backward linkages in the I-O framework, which could be translated as a sector's output multiplier (direct plus indirect).[8] Figures 1 and 2 provide graphical displays of several indicators, and results of the detailed 38 sectors are shown in Appendix Table A2.

Results in Table A2 of the Appendix illustrate that the 2001-2006 output increase in Indiana's manufacturing sector total was 36.21 percent, surpassing by a large margin the increase of all sector totals (20.15%). However, in terms of employment during the same period, total full-time and part-time employment in Indiana declined by 1,661 jobs or 0.05 percent. Although employment in several sectors, such as services, animal production, utilities, and transportation, increased in Indiana, the gain was offset by a decline in manufacturing employment of 43,631 jobs, or around 7.14 percent of its 2001 employment (Figure 1). The production indices show that output had no growth in such sectors as crop production, animal production, utility, construction, printing, electrical equipment, transportation and warehousing, art and entertainment, and other services, although some of these sectors (animal production, utility, and transportation and warehousing) had experienced employment growth. We note briefly that agricultural productivity as reported may be heavily influenced by subsidies during this period.



*Employment includes both part-time and full-time.
For complete information of detailed sectors, see Appendix Table A2.

Figure 1. Industry Output Index and Employment Index of Indiana sectors, 2006 (at constant 2001 prices).



Definitions—IR: Import Ratio; DER: Domestic Export Ration; FER: Foreign Export Ratio; IOE: Inducted Output by Exports.
For complete information of detailed sectors, see Appendix Table A2.

Figure 2. Main growth indicators of Indiana sectors, 2001 and 2006 (at constant 2001 prices).

Most of Indiana's manufacturing sectors trade heavily with other states, as observed in the high import ratio and domestic export ratio shown in Figure 2. The import ratio increased in most sectors, which means these sectors increased their dependency on imports. The domestic export ratio increased in most sectors and the foreign export ratio declined, but combining domestic and foreign

[6] IMPLAN's foreign export and import data of non-services sectors are from the U.S. Department of Commerce (also appearing in the U.S. Census). The foreign export and import data of services sectors are from the Bureau of Economic Analysis (BEA) National Income and Product Account export and import of broad service categories. IMPLAN uses the BEA 1997 benchmark imports and exports (2002 benchmark for 2008 data onward) to distribute those broad service categories. Therefore, IMPLAN's total foreign export value should be higher than the total foreign export value reported by the Department of Commerce.

[7] The index is computed as the percentage of the following output induced by exports (X^e) against output total (X), and X^e is computed from $X^e = (I - A^d)^{-1}E$, where I, A^d and E respectively denote the identity matrix, the input coefficient matrix of domestically produced goods, and the export vector. The difference between X and X^e yields the induced output by domestic final demand (X^d) from the equation $X^d = (I - A^d)^{-1}[(I - M^{\wedge F})D$, where $M^{\wedge F}$ is the diagonal matrix of the final import demand dependency ratio, and D is the column vector of domestically produced and imported goods.

[8] The power of dispersion of each sector is defined as the sum of the element of the corresponding column in the Leontief inverse given in the previous note.

exports resulted in an export ratio increase in all sectors. The rise in the import ratio associated with the rise in the export ratio is possible because industries in Indiana are practicing both export promotion and import liberalization. There is no regulation or encouragement from the state to restrict the use of imports, and Indiana's economy is highly interwoven with the U.S. economy as a whole.

Sectors with output growth can be classified into four categories, shown in Figure 3, according to their export performance and their degree of import dependency. The first is characterized by an increasing import ratio but decreasing combined (domestic and foreign) export ratio. Mining, wood product, retail trade, management, health care, and accommodation and food services are included in this category. The second category is characterized by the coexistence of an increasing export ratio and import dependency. Included in this category are food, beverage and tobacco, paper, plastics and rubber, nonmetallic mineral product, primary metal, fabricated metal, machinery, transportation equipment, and administrative and waste management. The third category shows a decrease of both import and export ratios. Textile and leather, chemical, computer and electronic product, miscellaneous manufacturing, wholesale trade, finance and insurance, educational services, and public administration fall into this category. The last category has an increasing export ratio and a decreasing or at least non-increasing import dependency. Forestry and fishing, petroleum and coal, furniture, information, real estate and rental, and professional and technical services fall into this category (see Figure 3).

The degree of total dependency of each sector on export markets is indicated by the ratio of output induced by exports. This indicator shows the percentage of each sector's production, generated both directly and indirectly, by the total exports for the year. The figures for the entire economy and for all manufacturing in 2001 and 2006 show that Indiana depends quite heavily on exporting markets, increasing during the period and higher than both the domestic and foreign export ratios combined in 2006. This margin is mainly due to the indirect inducement of production. The same tendency is observed in each sector, and it indicates that the dependency on exports is much higher than it looks from the export ratio figures. As exports increasingly drive outputs in a sector, the backward linkages become stronger.

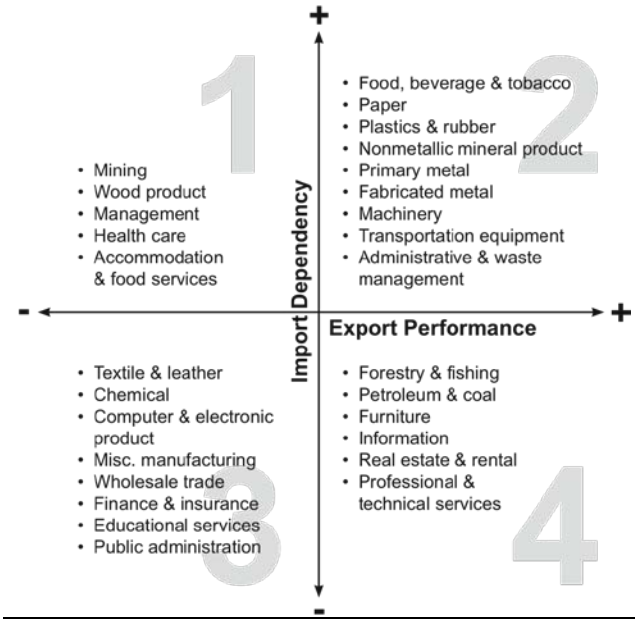


Figure 3. Import dependency and export performance of Indiana's sectors with output growth.

The deepening of interindustrial linkage during the period of 2001-2006 is indicated by the change in the power of dispersion. The index shows how many units of total Indiana output will be generated across the whole economy by one unit of final demand to a sector. Sectors with a prominent index increase were few in the manufacturing sectors, but more in the services sectors. However, most manufacturing sectors had a higher index than services sectors. To sustain economic development, it is desirable for sectors with strong backward linkages (strong power of dispersion) to grow rapidly (have high output growth). These sectors for Indiana are food, beverage, and tobacco product manufacturing and chemical manufacturing. In these sectors, either a change toward more regional inputs has occurred in the output commodity composition or the competitiveness of the input supplying sectors has strengthened. In contrast, a decrease of the index is due either to a shift to an input-saving production technology or a substitution of the inputs from regional products to imported ones. A decrease of the index was prominent in crop production, animal production, utilities, plastics and rubber, machinery, computer and electronics, electrical equipment, transportation equipment, furniture, and transportation and warehousing.

In sum, the changes in the above indicators from 2001 to 2006 suggest that domestic export had a significant impact on the output and export growth of the Indiana economy. However, it should also be

pointed out that Indiana is still struggling with its high import dependency, which results in significant leakages from the Indiana economy. This may not be viewed as negatively when examined at the national level. Moreover, Indiana's trade with the rest of the world and its interindustrial linkages, except for those of services sectors, are still weak.

4. Factors of sectoral growth, 2001-2006

We now turn our attention to decomposing the types of growth associated with each sector of the Indiana economy. The well-known Syrquin model is used to conduct a decomposition analysis in an input-output framework (Syrquin, 1976, 1986, 1988), which is an extension of the original development of Chenery (1960) and Chenery, Shishido, and Watanabe (1962). The application of Syrquin's model requires separating the import matrix and the using a non-competitive import type of input-output table.[9] The technique separates demand effects into domestic consumption expansion and export expansion and also is able to indicate the progress of import substitution. Two non-competitive-import type input-output tables of Indiana are used in this analysis to see differences between 2001 and 2006. The data sources are IMPLAN's 2001 and 2006 Indiana's industry I-O tables. As indicated above, the 2006 Indiana I-O table is deflated to 2001 constant prices for an analysis in real terms, and the sectors are aggregated into 38 larger sectors (Appendix Table A1).

4.1. The model

Syrquin's equilibrium output equation,

$$X_t = (I - A^d_t)^{-1}(D^d_t + E_t) \quad (1)$$

is used, where X is the output vector, A^d is the input coefficient matrix of domestically produced goods, D^d is the column vector of domestic final demand of domestically produced goods, E is the export column vector, and t is the base period.

The import dependency ratio of final demand in each industry j is defined as $m^F_{jt} = (D_{jt} - D^d_{jt})/D_{jt}$ $(j = 1,\ldots,n)$, and the equation could be rewritten as $D^d_t = D_t - \hat{M}_t D_t = (I - \hat{M}_t) D_t$, where D_{jt} is the column vector of domestic final demand of domestically produced and imported goods, $\hat{M}$ is the import matrix of the final import demand dependency ratio, where the diagonal elements are import coefficients and off-diagonal elements are all zero, and m^F_{jt} is the jth element of $\hat{M}$.

Taking $B^d_t = (I - A^d_t)^{-1}$ as the inverse matrix of the input coefficient matrix of domestically produced goods, then equation 1 could be written as

$$X_t = B^d_t[(I - \hat{M}_t) D_t + E_t] \quad (2)$$

The change in gross output in $t+1$ period is

$$\begin{aligned}
\Delta X &= B^d_{t+1}[(I - \hat{M}^F_{t+1}) D_{t+1} + E_{t+1}] \\
&\quad - B^d_t[(I - \hat{M}^F_t) D_t + E_t] \\
&= B^d_{t+1}[(I - \hat{M}^F_{t+1})(D_{t+1} - D_t) \\
&\quad + B^d_{t+1}(E_{t+1} - E_t) \\
&\quad + B^d_{t+1}(\hat{M}^F_t - \hat{M}^F_{t+1}) D_t \\
&\quad + (B^d_{t+1} - B^d_t)[(I - \hat{M}^F_t) D_t + E_t] \\
&= B^d_{t+1}[(I - \hat{M}^F_{t+1}) \Delta D + B^d_{t+1} \Delta E \\
&\quad + B^d_{t+1}(\hat{M}^F_t - \hat{M}^F_{t+1}) D_t \\
&\quad + (B^d_{t+1} - B^d_t)[(I - \hat{M}^F_t) D_t + E_t] \quad (3)
\end{aligned}$$

The fourth term in equation 3 is deduced as follows:

$$\begin{aligned}
&(B^d_{t+1} - B^d_t)[(I - \hat{M}^F_t) D_t + E_t] \\
&= B^d_{t+1}[(B^d_t)^{-1} - (B^d_{t+1})^{-1}] B^d_t[(I - \hat{M}_t) D_t + E_t] \\
&= B^d_{t+1}(A^d_{t+1} - A^d_t) X_t \quad (4)
\end{aligned}$$

This represents outputs induced directly and indirectly by changes in intermediate demand based on changes in the input coefficients of the domestically-produced goods. Consequently, the equation showing the changes of gross output could be rearranged as follows:

$$\begin{aligned}
\Delta X &= B^d_{t+1}[(I - \hat{M}^F_{t+1}) \Delta D \\
&\quad + B^d_{t+1} \Delta E \\
&\quad + B^d_{t+1}(\hat{M}^F_t - \hat{M}^F_{t+1}) D_t \\
&\quad + B^d_{t+1}(A^d_{t+1} - A^d_t) X_t \quad (5)
\end{aligned}$$

[9] Typically, input-output data are presented with imports classified as either competitive, that is perfect substitutes, or as non-competitive. If they are noncompetitive, then they are not grouped with domestic products but are viewed as a nonproduced input into a sector, analogous to labor and capital.

where the components of output change are decomposed as:

$B^d_{t+1}[(I - M^{\wedge F}_{t+1})\,\Delta D$ (5.1)
the effect of structural changes in domestic final demand

$B^d_{t+1}\,\Delta E$ (5.2)
the effect of structural changes in exports

$B^d_{t+1}\,(M^{\wedge F}_t - M^{\wedge F}_{t+1})D_t$ (5.3)
the effect of import substitution on domestic final demand

and

$B^d_{t+1}\,(A^d_{t+1} - A^d_t)X_t$ (5.4)
the effect of changes in input coefficients of the domestically produced goods, which could be interpreted as import substitution on intermediate demand and technological changes.

Syrquin's model compares, given a change of domestic production to satisfy, the effects on domestic production due to: (1) the structural change in domestic final demand (FD) derived from (5.1); (2) the structural change in exports (EE) derived from (5.2); (3) the import substitution effect on domestic final demand (ISFD) derived from (5.3), i.e., it indicates how much the change in the import coefficient in the final demand sector has increased or decreased output; and (4) the effect of import substitution on intermediate demand (ISID) and technological changes (TC) derived from (5.4), i.e., it indicates how much the change in the input coefficients of the year for comparison and of the base year has increased or decreased output. Note that equation 5.4 is not only the influence of the change in the sector's input coefficient; rather, it is the aggregate influence on the sector of the change in the whole input structure of the economy.

Furthermore, the effect of the domestic final demand (equation 5.1) can also be divided into: $B^d_{t+1}[(I - M^{\wedge F}_{t+1})\,\Delta D] = B^d_{t+1}[(I - M^{\wedge F}_{t+1})\,(\Delta HH + \Delta FED + \Delta SLG + \Delta CAP + \Delta INV)]$, where *HH* is the effect due to household consumption, *FED* is the effect due to federal government consumption, *SLG* is the effect due to state and local government consumption,[10] *CAP* is fixed capital formation, and *INV* is the effect due to increase in inventory. Note that in general, improvement in inventory management techniques and sales forecasting will lead to a reduction in stock. Fixed capital formation (fixed assets investment) and inventory investment (increase in stock) show opposite movements. During periods of economic growth, fixed assets investment will be high and inventory investment decreases. On the other hand, during economic declines, the level of fixed assets investment will be low and inventory increases.[11]

The effect of exports (equation 5.2) can also be divided into: $B^d_{t+1}\,\Delta E = B^d_{t+1}\,(\Delta ED + \Delta EF)$, where *ED* is the export effect of domestic export, i.e., export from Indiana to other states within the U.S., and *EF* is the export effect of foreign export.

4.2. Results of the decomposition

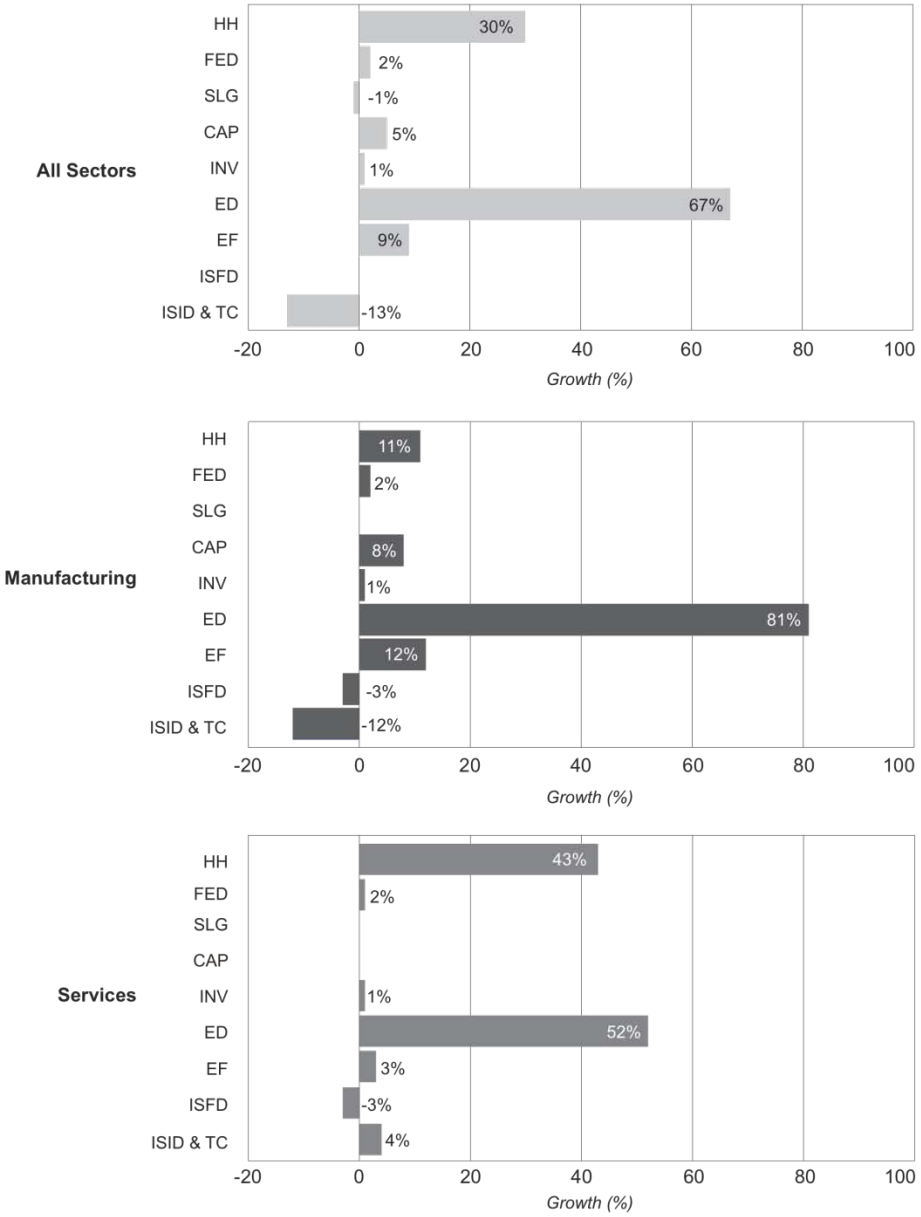
Table A3 in the Appendix gives results of the decomposition of output growth during the five years from 2001 to 2006. For the all-sector total, the output growth was mainly brought about by the expansion of domestic export (67%), followed by household demand (30%) and foreign export (9%). The expansion could offset the small contraction of state and local government consumption (SLG, -1%) and the import substitution on intermediate demand and technological changes (ISID & TC, - 13%). The sector with the largest negative import substitution effect on domestic final demand (ISFD) and ISID & TC and growth in domestic final demand (FD) and exports (EE) is sector 17: Fabricated Metal Product Manufacturing. The slightly negative ISFD and ISID & TC in some sectors and growth in FD and EE means the increase of production for final demands and exports was only big enough to maintain the constant proportion of regional and export demand, but not good enough to substitute the use of imports. Also, having high FD and EE but at the same time having negatives ISFD and ISID & TC was also probably caused by the increased horizontal division of labor, i.e., certain commodities produced in this sector increased their export while other commodities increased their imports.

Percentage changes for the entire economy, total manufacturing, and total services are displayed in Figure 4. For the manufacturing sector total (sectors

[10] In an input-output table, state and local government consumption is the total government expenditure less transfer payments to households and other types of institution (although these transfer payments are included in a Social Accounting Matrix). Therefore, IMPLAN's state and local government consumption value should be lower than the total state and local government expenditure value reported by the U.S. Census which also includes transfer payments.

[11] Inventory to sales ratios in the United States have seen a significant long-term decline since the mid 1990s, most likely as a result of improved logistics techniques and technology.

7-23), the expansion of domestic and foreign exports (81% and 12%) contributed to the manufacturing output growth more than other factors, and there were contractions in ISFD and ISID & TC. These results suggest that Indiana's manufacturing growth remains dependent on its manufacturing exports rather than technological improvement or the effects of import substitutions. For the services sector total (sectors 27-37), the expansion of domestic export (52%) and household demand (43%) contributed the most to output growth. Interestingly, the ISID & TC in the services sectors contributed around 4% to the services sectors' output growth.



Notes: HH = Household Demand, FED = Federal Government Demand, SLG = State and Local Government Demand, CAP = Capital Demand, INV = Inventory Additions/Deletions, ED = Domestic Export, EF = Foreign Export, ISFD = Import Substitution of Domestic Final Demand, ISID = Import Substitution of Intermediate Demand, TC = Technological Change. For complete information of detailed sectors, see Appendix Table A3.

Figure 4. Demand side's factors of growth, 2001-2006.

The fixed assets investments in the all sector total and the manufacturing sector total are positive and higher than the inventory investment, suggesting that during the period of 2001-2006 Indiana still experienced economic growth. However, accumulated inventory in the services sector totaled 1% more than its fixed assets investment during the same period.

Appendix Table A4 shows how much each sector contributed to the total output growth in Indiana during the 2001-2006 period. Transportation equipment manufacturing contributed 26% to the increase in total sector output. This sector also contributed the most to the domestic and foreign exports, ISFD, and ISID & TC, suggesting that Indiana's transportation equipment manufacturing not only is the most important sector contributing to the growth of Indiana's economy through export earnings, but also has the most significant improvement in technology and import substitutions. The main sector contributions to selected growth factors are illustrated in Figure 5.

In sum, the decomposition analysis here has clarified the following points. First, domestic export is the largest factor of growth in many sectors. Second, foreign exports in the manufacturing sector total contributed to Indiana's growth more than Indiana's household demand in this sector total. Third, state and local government's consumption contracted during the 2001-2006 period. Fourth, there was not much change in the input coefficient matrix and in the levels of import substitution. Last, but not least, Indiana continued to enjoy an economic boom during the 2001-2006 period.

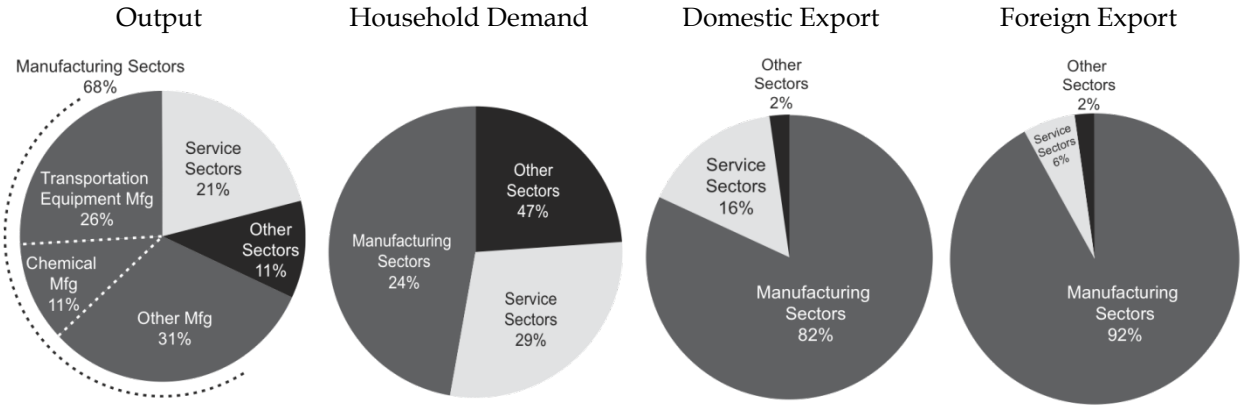


Figure 5. Share of main sectors in selected factors of growth, 2001-2006.
For complete information on detailed sectors, see Appendix TableA4.

5. Deepening of interindustrial linkages: case studies

It is desirable that manufacturing sector growth accompany deepening interindustrial linkages. Deepening usually proceeds through Hirshman's backward linkage effects. In this section, a close examination of the deepening of backward linkages is given, highlighting two industries determined to be important as Indiana Initiatives.[12] One is Life Sciences with a focus on surgical and medical instrument and supplies manufacturing, which is composed of two sub-sectors: surgical and medical instrument manufacturing, and surgical appliance and supplies manufacturing. The other is Logistics, which is the transportation and warehousing sector and is comprised of ten sub-sectors: air transportation, rail transportation, water transportation, truck transportation, transit and ground passenger transportation, pipeline transportation, scenic and sightseeing transportation and support, postal service, couriers and messengers, and warehousing and storage. The analysis in this section uses the most disaggregated sectoral classification of the Indiana I-O table of 509 sectors for 2001 and 2006 and deflates the 2006 Indiana I-O table to 2001 constant prices.

Flowcharts 1 and 2 clarify whether the main inputs are from Indiana or imported and also separates the output destinations. Figures in percentages show input coefficients as percentages, in the case of

[12] These sectors are listed in the Indiana Initiatives in the Indiana Economic Development Corporation's webpage: 1) advanced manufacturing 2) agriculture 3) film 4) information technology 5) insurance 6) life sciences 7) logistics, and 8) motorsports.

intermediate inputs and value-added, or shares in output, in the case of final demands and exports.

Flowchart 1 illustrates the main inputs and all outputs of the surgical and medical instrument and supplies manufacturing sector. Although this sector is not yet well developed in Indiana, it is considered to be a promising export sector in the near future. During the period, the total output and the composition of inputs had improved substantially in absolute terms, though the regional input percentage coefficients decreased in several major input sectors. The regional transactions within the sector increased from 4.6% to 6.7%, while the imported inputs from the sector also increased from 1% to 3%. The increase in the share of Indiana inputs like chemical manufacturing, specialized design services, and the surgical instrument manufacturing itself could reflect the increase of more sophisticated products in the surgical instrument manufacturing or the output diversification within the sector. At the same time, the sophistication of the products increased the ratio of imported inputs for many sectors, such as chemical manufacturing, fabricated metal product manufacturing, computer and electronic product manufacturing, scientific research and development, and management. Output was mainly directed to the expanding domestic market (14.6 % to Indiana industries and 33.1% to the rest of the U.S. in 2006). The foreign export share is 23.3% in 2006, a small decline but still a good size. In sum, this industry is promising since its output has grown rapidly, though its regional backward linkages have grown quite slowly due to its early stage of development.

Flowchart 2 illustrates the main inputs and all outputs of the transportation and warehousing sector. Unlike the previous sector, this sector's output basically contracted in terms of real prices. Moreover, by observing the regional input percentage coefficients, it is apparent that Indiana's inter-industrial linkages of this sector became weaker during the period as the regional input percentage coefficients declined in almost all major input sectors except for petroleum and coal products manufacturing and professional and technical services. The decline in regional input coefficients in most input sectors means that Indiana's transportation and warehousing sector has begun to use more imported inputs in 2006, as information from the flowchart suggests. Also, as the information from Table 3 suggests, although this sector had improved its import substitution on domestic final demand, it did not succeed in improving its import substitution on intermediate demand and technological changes. All final demands and exports contracted except for the federal government consumption and the increase in inventory. The sector output was used more as intermediate input to other industries in Indiana as its share in total output increased from 40.4% in 2001 to 49.5% in 2006. In sum, opportunity remains to deepen inter-industrial linkages upstream in the transportation and warehousing sector.

6. Concluding remarks

This paper examined the growth of Indiana's economy from 2001 to 2006 using time series from input-output analysis. This was supplemented with a detailed decomposition of the demand side growth from selected life sciences manufacturing and logistics. We found that the logistics sector responded slowly to the post recession growth experienced by much of the remainder of the economy. However, the surgical sector performed quite well in terms of interindustrial linkage deepening. This suggests that this industry will continue to be an engine of growth for the state.

These two industries are a focus of two of the state's three public research institutions, Purdue University and Indiana University. Information technology is an area of focus by the third research institution, Ball State University. Further research on this sector as well as the role of university research and development linkages to these three industries would provide an important understanding of the role of public policy and R&D policy on regional economic growth. This paper addresses the post recession adjustment of two sectors of Indiana's economy. The effect the 2007-2009 downturn played on intra-industry leakages and growth provides another important avenue for further research.

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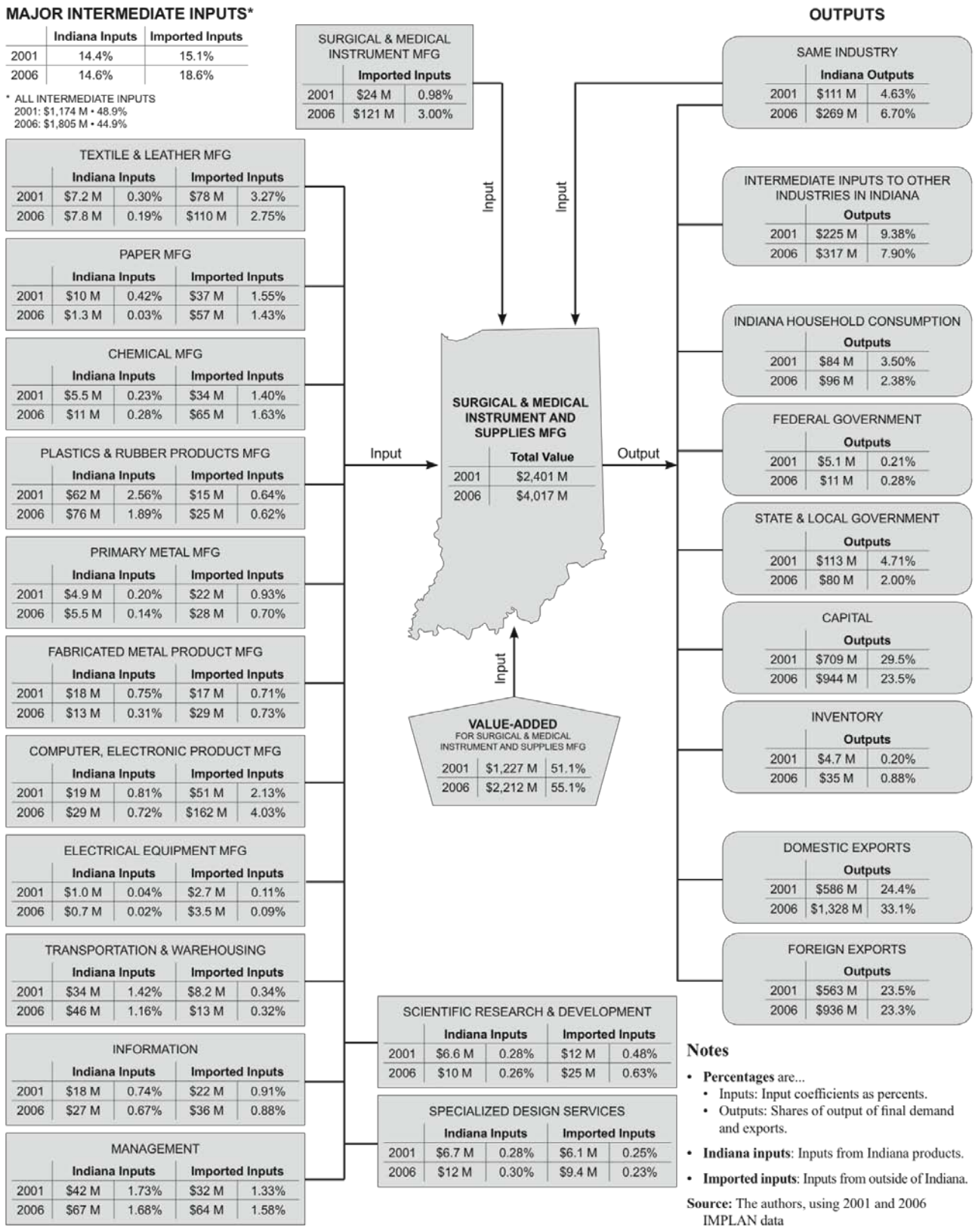
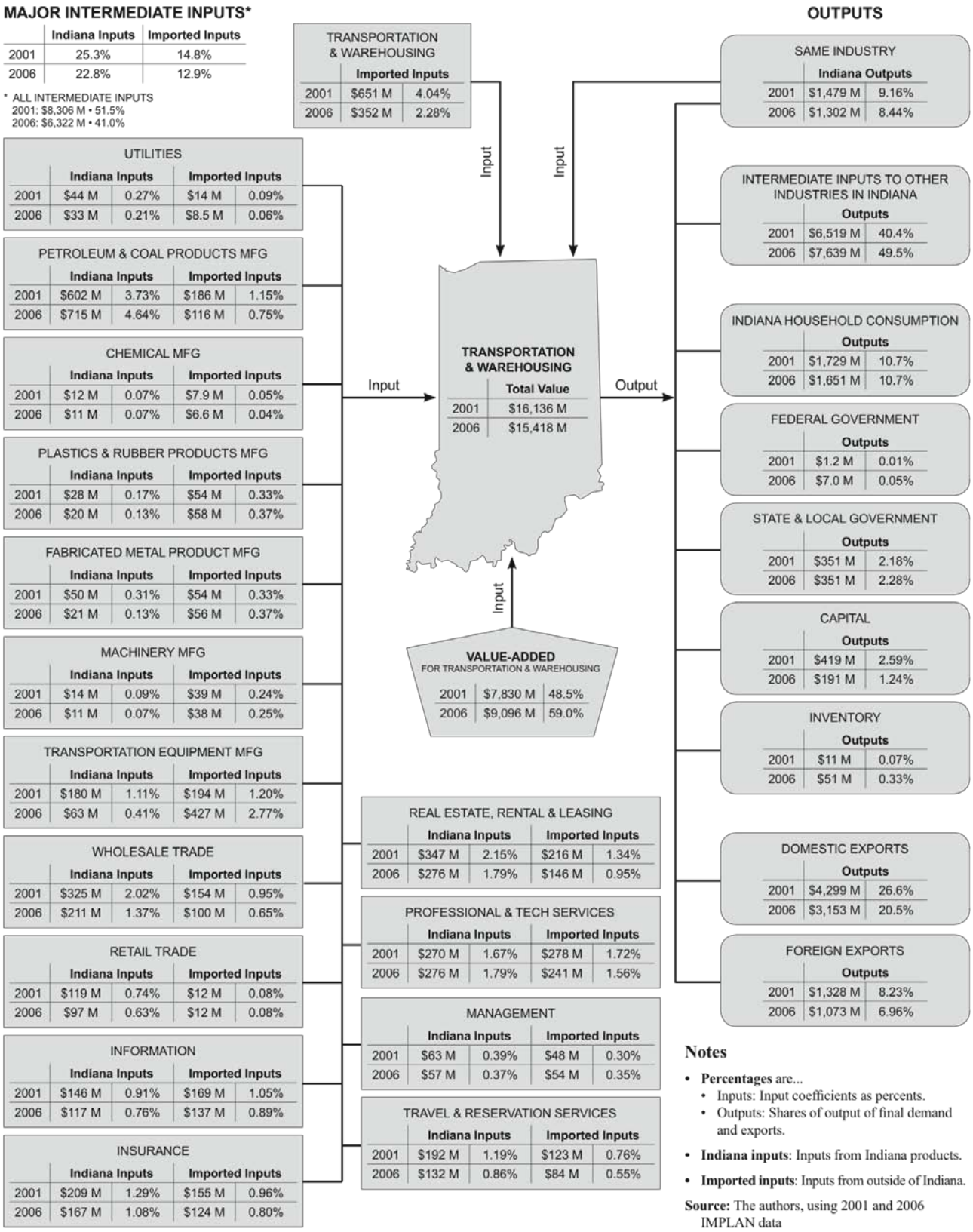
Flowchart 1. Surgical and medical instrument and supplies manufacturing, 2001 & 2006 (in millions of dollars at 2001-constant prices).



Flowchart 2. Transportation and warehousing, 2001 & 2006 (in millions of dollars at 2001-constant prices).



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Appendix.

Table A1. List of sectors.

	Aggregated Sectors	NAICS
1	Crop Production	111
2	Animal Production	112
3	Forestry, Logging, Fishing, Hunting, Trapping, and Support Activities for Agriculture and Forestry	113, 114, 115
4	Mining	211, 212, 213
5	Utilities	221
6	Construction	236, 237, 238
7	Food, Beverage and Tobacco Product Manufacturing	311, 312
8	Textile, Apparel, Leather and Allied Product Manufacturing	313, 314, 315, 316
9	Wood Product Manufacturing	321
10	Paper Manufacturing	322
11	Printing and Related Support Activities	323
12	Petroleum and Coal Products Manufacturing	324
13	Chemical Manufacturing	325
14	Plastics and Rubber Products Manufacturing	326
15	Nonmetallic Mineral Product Manufacturing	327
16	Primary Metal Manufacturing	331
17	Fabricated Metal Product Manufacturing	332
18	Machinery Manufacturing	333
19	Computer and Electronic Product Manufacturing	334
20	Electrical Equipment, Appliance, and Component Manufacturing	335
21	Transportation Equipment Manufacturing	336
22	Furniture and Related Product Manufacturing	337
23	Miscellaneous Manufacturing	339
24	Wholesale trade	423, 424, 425
25	Transportation and warehousing	481, 482, 483, 484, 485, 486, 487, 488, 491, 492, 493
26	Retail Trade	441, 442, 443, 444, 445, 446, 447, 448, 451, 452, 453, 454
27	Information	511, 512, 515, 517, 518, 519
28	Finance and Insurance	521, 522, 523, 524, 525,
29	Real Estate and Rental and Leasing	531, 532, 533
30	Professional, Scientific, and Technical Services	541
31	Management of Companies and Enterprises	551
32	Administrative and Support and Waste Management and Remediation	561, 562
33	Educational Services	611
34	Health Care and Social Assistance	621, 622, 623, 624
35	Arts, Entertainment, and Recreation	711, 712, 713
36	Accommodation and Food Services	721, 722
37	Other Services (except Public Administration)	811, 812, 813, 814
38	Public Administration	921, 922, 923, 924, 925, 926, 927, 928

Table A2. Main growth indicators of Indiana sectors, 2001 and 2006 (at constant 2001 prices).

	Industry Output Index	Employ-ment Index	Import Ratio (%)		Domestic Export Ratio (%)		Foreign Export Ratio (%)		Induced Output by Exports (%)		Power of Disper-sion (Output Mul-tiplier)	
	2001= 100	2001= 100	2001	2006	2001	2006	2001	2006	2001	2006	2001	2006
All sectors	120.15	99.95	37.53	42.25	28.39	32.01	7.20	7.07	49.39	52.42	--	--
Mfg 7-23	136.21	92.86	59.34	66.62	51.53	56.79	14.96	13.70	79.11	80.54	--	--
Serv 27-37	113.80	105.00	35.93	37.51	18.75	19.37	1.41	1.21	35.60	37.89	--	--
1	98.61	75.90	76.20	79.22	54.93	46.62	25.81	37.91	91.82	91.96	1.40	1.27
2	88.05	118.03	27.29	28.39	41.46	32.44	2.50	2.61	77.60	74.35	1.55	1.45
3	173.75	116.09	66.80	62.26	24.28	34.30	3.35	2.41	84.12	81.37	1.25	1.26
4	101.16	100.08	85.43	87.61	57.36	53.36	7.16	9.22	82.70	87.55	1.28	1.27
5	93.56	106.54	24.04	21.25	8.44	0.00	0.18	0.34	34.22	30.36	1.21	1.10
6	95.88	93.63	6.41	0.66	3.98	4.41	0.01	0.01	6.75	7.36	1.41	1.39
7	136.78	99.86	59.64	60.99	50.39	55.34	7.81	5.92	64.71	67.78	1.53	1.54
8	128.13	102.92	92.68	89.22	50.42	35.98	12.22	13.46	68.71	55.64	1.28	1.25
9	102.65	96.25	60.08	60.62	51.54	50.82	3.37	3.45	71.95	72.60	1.45	1.41
10	128.40	87.45	89.62	98.21	77.83	91.31	7.16	6.36	94.47	98.84	1.30	1.27
11	78.93	91.28	55.70	62.23	48.56	66.20	8.06	2.20	73.86	81.98	1.30	1.15
12	138.45	102.77	25.37	19.01	7.13	10.74	4.23	4.57	39.64	47.25	1.36	1.37
13	159.65	104.71	53.16	50.83	47.69	47.79	16.11	13.49	76.44	78.38	1.40	1.52
14	102.75	91.20	33.38	39.59	49.31	50.63	10.34	11.20	80.67	83.10	1.38	1.26
15	117.09	90.27	76.88	78.41	69.95	73.44	9.17	6.68	90.09	90.96	1.34	1.34
16	109.39	75.66	81.06	89.10	79.24	81.68	9.28	10.85	98.22	99.01	1.37	1.46
17	102.94	93.78	69.24	83.23	64.91	75.79	8.83	8.64	91.47	95.42	1.31	1.26
18	144.19	91.10	54.73	61.59	38.36	46.38	29.17	26.49	76.47	81.43	1.37	1.29
19	252.42	81.72	65.41	65.33	15.02	18.33	31.44	17.61	67.35	47.87	1.41	1.33
20	81.80	63.05	70.32	88.66	46.56	65.87	25.29	20.71	81.38	92.54	1.41	1.28
21	152.12	99.67	51.46	75.66	52.12	67.05	18.59	16.36	82.96	89.45	1.50	1.29
22	143.55	93.78	26.84	26.41	27.58	31.32	4.79	3.00	37.66	37.95	1.37	1.28
23	135.04	107.62	59.16	55.65	45.62	41.28	20.19	20.59	69.69	67.43	1.32	1.29
24	104.10	102.06	32.11	32.11	0.45	3.81	9.66	5.69	50.97	50.76	1.24	1.26
25	119.71	95.01	9.19	11.06	10.02	5.91	0.00	0.00	13.71	9.15	1.31	1.25
26	95.55	106.52	31.84	27.78	26.64	20.45	8.23	6.96	65.05	66.29	1.42	1.35
27	153.17	92.71	60.47	60.40	22.96	31.77	2.39	1.63	44.98	54.98	1.27	1.34
28	105.26	96.85	46.51	46.04	27.42	22.00	2.45	1.84	44.83	42.76	1.29	1.33
29	114.82	111.42	35.13	32.11	1.50	5.31	2.68	2.85	28.97	32.80	1.20	1.26
30	170.21	111.40	51.94	50.05	14.58	21.36	1.88	1.12	42.13	54.29	1.16	1.32
31	134.82	103.50	43.51	48.51	0.27	-	11.46	5.96	62.36	65.11	1.20	1.35
32	134.26	120.62	47.34	47.46	31.36	41.91	0.40	0.76	52.62	62.35	1.21	1.27
33	147.66	137.99	30.91	24.39	31.16	20.81	0.19	0.16	41.40	24.81	1.28	1.37
34	105.48	109.89	8.79	9.49	20.23	14.19	0.00	0.00	20.32	14.32	1.35	1.32
35	84.11	97.80	30.27	28.39	51.57	38.17	0.04	0.03	56.00	46.64	1.25	1.28
36	109.86	95.07	18.61	22.86	14.28	14.24	0.09	0.07	21.39	23.69	1.42	1.41
37	70.45	93.13	22.87	25.35	10.24	18.78	0.03	0.50	35.68	34.21	1.39	1.34
38	111.21	99.28	4.19	3.35	0.34	0.05	0.06	0.07	2.10	2.91	1.03	1.05

Note: Employment is the total of full-time and part-time.

Table A3. Demand side's factors of growth, 2001-2006.

	Increase in Output ($million)	Contribution by factors of growth (%)								
		HH	FED	SLG	CAP	INV	ED	EF	ISFD	ISID & TC
All sectors	75,427	30	2	(1)	5	1	67	9	(0)	(13)
Mfg 7-23	51,603	11	2	0	8	1	81	12	(3)	(12)
Serv 27-37	15,465	43	1	(0)	(0)	1	52	3	(3)	4
1	(50)	52	5	4	(0)	66	(553)	842	2	(519)
2	(250)	28	3	2	0	7	(37)	(0)	(6)	(97)
3	214	10	0	(1)	(0)	1	57	5	5	24
4	24	25	(11)	(27)	10	36	(30)	254	31	(187)
5	(413)	53	2	(32)	4	2	(52)	12	22	(111)
6	(869)	12	(3)	(159)	(71)	0	18	1	143	(40)
7	4,157	20	3	1	0	1	74	1	(2)	0
8	237	24	2	1	0	1	(9)	19	59	3
9	78	45	(1)	(49)	(14)	6	154	17	67	(125)
10	801	1	0	0	0	0	140	4	(1)	(44)
11	(563)	1	(0)	2	1	0	30	(30)	(1)	(104)
12	1,852	2	(5)	(4)	(1)	8	37	9	14	41
13	8,620	13	1	1	0	2	59	11	(2)	16
14	238	42	8	(8)	15	20	295	66	5	(343)
15	511	3	0	(1)	(0)	2	113	(6)	3	(15)
16	1,559	1	0	(0)	1	3	123	30	(1)	(56)
17	287	9	5	(2)	10	8	550	17	(22)	(474)
18	4,676	1	1	(1)	9	3	72	22	(6)	(1)
19	7,387	31	7	3	22	0	27	10	2	(1)
20	(735)	5	0	(0)	(8)	0	46	(45)	(50)	(49)
21	19,629	3	1	0	6	0	102	13	(6)	(19)
22	1,246	11	(1)	(6)	42	2	43	(1)	4	6
23	1,623	12	3	(1)	13	2	31	23	3	14
24	662	98	(45)	(15)	150	19	329	(57)	(5)	(374)
25	3,791	138	0	(2)	(5)	0	(11)	0	(6)	(15)
26	(718)	(40)	5	(2)	(14)	8	(9)	(18)	52	(82)
27	3,856	18	(0)	3	2	0	65	1	(2)	13
28	997	66	2	(2)	4	1	(39)	(5)	10	63
29	2,002	46	0	(3)	(7)	1	61	8	(4)	(1)
30	6,677	7	2	(1)	(1)	0	49	2	2	40
31	1,068	22	1	(0)	5	1	54	(3)	(2)	22
32	2,205	8	4	(3)	1	0	88	3	0	(2)
33	916	129	0	0	0	0	2	0	(1)	(31)
34	1,354	198	3	(1)	(0)	0	(97)	(0)	(11)	7
35	(701)	6	(15)	1	0	0	(117)	1	5	20
36	918	63	(0)	1	1	0	36	2	(17)	13
37	(3,828)	(26)	0	1	0	0	18	2	(6)	(90)
38	2,251	16	35	26	0	0	2	1	6	14

Notes: HH = Household Demand, FED = Federal Government Demand, SLG = State and Local Government Demand, CAP = Capital Demand, INV = Inventory Additions/Deletions, ED = Domestic Export, EF = Foreign Export, ISFD = Import Substitution of Domestic Final Demand, ISID = Import Substitution of Intermediate Demand, TC = Technological Change.

*See Appendix Table A1 for corresponding sectors and numbers.

Table A4. Share of each sector in each factor of growth, 2001-2006.

	Share of Each Sector (%)									
	Output	HH	FED	SLG	CAP	INV	ED	EF	ISFD	ISID & TC
All sectors*	100	100	100	100	100	100	100	100	100	100
Mfg 7-23	68	24	57	(12)	97	72	82	92	580	60
Serv 27-37	21	29	11	2	(0)	10	16	6	176	(6)
1	(0)	0	0	(0)	(0)	3	(1)	6	(0)	3
2	(0)	0	0	(1)	0	2	(0)	(0)	6	2
3	0	0	0	0	(0)	0	0	0	(4)	(1)
4	0	0	(0)	1	0	1	(0)	1	(3)	0
5	(1)	1	0	13	0	1	(0)	1	(37)	5
6	(1)	0	(2)	136	(15)	0	0	0	(510)	3
7	6	4	9	(6)	0	5	6	1	34	(0)
8	0	0	0	(0)	0	0	(0)	1	(57)	(0)
9	0	0	(0)	4	(0)	0	0	0	(22)	1
10	1	0	0	(0)	0	0	2	0	3	4
11	(1)	0	(0)	(1)	0	0	0	(3)	2	6
12	2	0	(6)	8	(0)	13	1	2	(107)	(8)
13	11	5	7	(8)	0	14	10	15	79	(14)
14	0	0	1	2	1	5	1	2	(5)	8
15	1	0	0	1	(0)	1	1	(0)	(5)	1
16	2	0	0	0	0	4	4	7	7	9
17	0	0	1	1	1	2	3	1	26	14
18	6	0	2	3	11	12	7	16	115	1
19	10	10	31	(22)	40	2	4	11	(57)	1
20	(1)	0	0	0	(1)	0	1	(5)	152	4
21	26	2	9	(0)	27	8	40	39	459	37
22	2	1	(1)	7	13	2	1	(0)	(23)	(1)
23	2	1	3	1	5	3	1	6	(22)	(2)
24	1	3	(18)	10	25	12	4	(6)	13	25
25	5	23	1	9	(4)	0	(1)	0	91	6
26	(1)	(1)	2	1	(3)	5	(0)	(2)	(155)	6
27	5	3	(1)	(10)	2	2	5	1	31	(5)
28	1	3	1	2	1	1	(1)	(1)	(41)	(6)
29	3	4	0	6	(3)	2	2	2	33	0
30	9	2	9	3	(2)	2	6	2	(63)	(26)
31	1	1	1	0	1	1	1	(0)	10	(2)
32	3	1	5	5	0	1	4	1	(4)	0
33	1	5	0	(0)	0	0	0	0	4	3
34	2	12	2	1	(0)	0	(3)	(0)	59	(1)
35	(1)	0	(6)	(1)	0	0	(2)	0	(14)	(1)
36	1	3	(0)	(1)	0	0	1	0	65	(1)
37	(5)	(4)	0	(3)	0	0	1	1	95	34
38	3	2	48	(59)	0	0	0	0	(56)	(3)

Notes: HH = Household Demand, FED = Federal Government Demand, SLG = State and Local Government Demand, CAP = Capital Demand, INV = Inventory Additions/Deletions, ED = Domestic Export, EF = Foreign Export, ISFD = Import Substitution of Domestic Final Demand, ISID = Import Substitution of Intermediate Demand, TC = Technological Change.

*See Appendix Table A1 for corresponding sectors and numbers.