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TOTAL FACTOR PRODUCTIVITY GROWTH IN THE US STEEL MANUFACTURING INDUSTRY: 1958-2005

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Submitted to the Economics Faculty
in partial fulfillment of the requirements for degree of
Bachelor of Science in Business Administration

December 2011

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Prior research regarding total factor productivity growth uses aggregated data to examine productivity growth over time. This method does not provide an accurate examination of total factor productivity growth for specific industries.

This paper addresses this shortcoming by examining only the US steel manufacturing industry and decomposing total factor productivity growth into scale and technical change to study productivity growth from 1958-2005. I conclude that the steel industry extracts scale efficiencies over technological progress to fuel total factor productivity growth over time.

JEL classifications: O14, O33, O47

Key words: technical change, scale effect, total factor productivity, productivity growth, steel manufacturing

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I. Introduction/Motivation

Despite the recent economic downturn, manufacturing remains a crucial part of the United States economy. In fact, durable goods manufacturing was among the leading contributors to an increase in economic growth in 2010. Additionally, manufacturing value added, a common measure of a certain industry's contribution to GDP, rose 5.8 percent in 2010. More specifically, durable goods increased 9.9 percent, while nondurable goods rose 0.8 percent in 2010 according to the Bureau of Economic Analysis.

This large increase in the manufacturing industry's impact on GDP raises a number of questions about what factors contributed to this sudden increase. To examine this more closely, this paper will study total factor productivity in a detailed level industry group to examine the scale effect and technical change components of the productivity growth. The industry that is to be examined is the steel manufacturing industry. Steel manufacturing is important to study because it is a very competitive global industry. Many nations are now producing quality, low cost steel. For the United States to maintain an advantage within the industry, it must be able to maximize its productivity to maintain a low cost. This industry is also useful to study because it is one which is globally competitive and has seen technological change throughout its history.

The U.S. steel manufacturing industry has increased productivity while lowering the number of work hours needed to produce one ton of steel by nearly 90% over the last twenty years, according to the Bureau of Labor Statistics. One of the reasons for this is due to an improvement in technology. The steel industry is also projected to see a large increase in demand caused by the global clean energy movement. According to the Bureau of Labor Statistics, as the world demands more clean energy sources such as wind turbines and nuclear plants, the demand for steel to construct buildings to house them will also increase.

Additionally, with growing economic expansion in many countries such as China and India, the demand for steel to construct housing and infrastructure will likely sharply increase. These areas of economic expansion also provide large markets for small inexpensive vehicles. With two of the world's most populous countries, China and India, having increasing standards of living, a large number of individuals are now able to purchase automobiles. This vast new market for both private and public transportation poses as a large market for the steel industry. To be competitive with other nations' steel industries, it is imperative to study productivity growth in the United States in order to more fully understand production growth patterns in our domestic steel manufacturing industry. Total factor productivity (TFP) refers to the portion of output not explained by the amount of inputs used in production.

This paper will build upon previous literature by looking at detailed industry level data in United States steel manufacturing plants from 1958 to 2005 to examine the trends in productivity growth. Much of the previous literature examines only the aggregated manufacturing industry data. While this provides good information on sectors as a whole, it often hides growth trends in many detailed level industries which may not follow the same trends as the overall sector. To better analyze productivity growth patterns, it is more beneficial to examine detailed industry level data. To examine TFP growth, the production function will be decomposed into its growth components: scale effect and technical change. Scale effect is the productivity growth caused by the way in which a firm organizes its inputs, and technical change in this paper is exogenous and is how productivity growth is changed due to new technology through time.

II. Literature Review

Solow (1957) examined variations in output per head due to changes in availability of capital per head. He examined data from 1909-1949, and found that technical change was neutral over the period. Additionally, he found that there was an upward shift in the production function of 1% over the first half of the period, and 2% for the second half. Over the course of the time studied, gross output per man doubled. The study also derived what is known as the Solow residual which is the part of growth that can't be explained through capital or labor accumulation.

Baily (1986) studies the use of a value added production function to see if it introduces a bias. To do this, he examines the algebraic relationships among five alternative measures of productivity growth. He found that U.S. manufacturers have economized on purchased intermediate goods, and there may be a bias in value added based productivity measures as a result. Additionally, he found that a slowdown in productivity growth is not created by a particular production function assumption.

Alexander (1992) builds upon classical and post Keynesian economic theory to explore resource diversion on post war manufacturing. The study examines data from 1951 to 1972 to explore the misallocation of productivity expanding resources that deprived many manufactures of labor and capital needed to increase productivity. The study found that managerial decisions and market competition did not induce innovation required to maintain a high level or productivity growth in the United States.

Gullickson (1995) discusses the measurement of multifactor productivity for manufacturing and analyzes growth trends within the sector. He examines multifactor productivity growth trends for nineteen two digit SIC manufacturing subsectors from 1949 to 1992. Gullickson finds that an analysis of productivity for industries cannot be restricted to only capital and labor inputs. In the manufacturing industry, energy, non-energy materials and business services comprise a large portion of the cost structure. Excluding these intermediate inputs makes mismeasurement of growth trends more likely.

Ryan (2000) examines panel data from the NBER Manufacturing Productivity Database covering 450 industries from 1958-1991 to determine the year-by-year fluctuations in total factor productivity growth rates, and the utilization of nonmaterial inputs. The study found that utilization was procyclical, and that demand shocks can explain half of the procyclicality of production growth rates.

Gold et al (2001) assess the rates at which production comes to be dominated by new processes and facilities. To do so, they focus on the steel industry and examine the diffusion of new technology in relation to the percentage of industries which utilize this technology in their production process. Additionally, the study looks at how long it took for industries to diffuse new technology into their manufacturing process. The measure used is the proportion of total output accounted for by innovation. The study examined 14 major innovations in the iron and steel industry, and found there to be a significant increase in diffusion rates in more recent decades compared to that of earlier decades.

Saal (2001) performs a disaggregated industry level analysis of the productivity effects associated with the U.S. government's defense procurement policies. He examines data from 1973 to 1986 gathered from the National Bureau of Economic Research (NBER). The study finds that industries which are defense dependent have substantially greater total factor productivity growth than other manufacturing industries because of process driven procurement driven technological change.

Gamponia and Brown (2001) study the impact of the depletion of natural resources used in the steel manufacturing industry and input substitution on economic growth. They use time series data gathered from the NBER from 1947 to 1971 on total costs, input shares of capital, labor, and energy. They find that the steel manufacturing sector is capable of substituting capital and labor for other inputs because of high elasticity in the industry.

Cobet and Wilson (2002) examine the overall trend in manufacturing production from 1950 to 2000. To do this, they review panel data from the Bureau of Labor Statistics to study the trends of America and other G-7 countries, which includes Canada, Japan, France, Germany, Italy, and the United Kingdom. They break the data into 3 sub periods (1950-1973, 1973-1990, 1990-2000). The study finds there are substantial differences in each period due to a number of political and economic factors that impact each sub sector. Most notably, the study found a decline in total factor productivity in all sectors.

Kumbhakar (2003) decomposes total factor productivity growth into input specific components, measures input specific productivity/efficiency growth, and tests the neutrality hypothesis in technical change. He uses a panel data set of 450 U.S. manufacturing industries for the period of 1959-1992. He found that technical change increased productivity of capital by 6.6% where productivity of labor and material caused a decline of 5.10% and .4% respectively.

Berstein et al (2004) examine the impact of new inputs on technical efficiency levels for U.S. manufacturing. The study uses data from 1958-1998 on intermediate inputs in the manufacturing industry. It found that there was a gap between efficiency adjusted and measured productivity growth rates caused by a decline in efficiency adjusted material costs shares and comparatively high material input growth rate. Additionally, the study found that intermediate inputs exhibit higher rates of efficiency growth than do labor and capital.

Nakamura and Ohashi (2008) examine the impact of new technology on plant level productivity in the Japanese steel industry during the 1950's and 1960's. To do this, they control for omitted variable bias in the construction of total factor productivity, deal with possible selection bias, and allow for spillovers between new and old technology. The study decomposes the industry productivity down to the plant level, and examines 33 plants and 17 steel firms during the period of 1957-1968. They find that the adoption of new technology during this time period accounted for the industry's initial slowdown, then sudden spike in productivity growth during this period.

Petrin et al (2010) build up from plant level data and examine the aggregated Solow residual by estimating every U.S. manufacturing plant's contribution to the change in aggregate final demand of 459 different productive technologies for each four digit SIC code between 1976 and 1996. To do this, Petrin decomposed the contributions of imperfect competition into plant-level resource allocation and plant level technical change. The study found that there was an average productivity growth of 2.2% during periods of declining U.S. GDP.

Hammond and Thompson (2011) analyze manufacturing growth and decline across metropolitan and non-metropolitan regions during 1972-2002. To do this, they decompose real value added growth across local labor market areas in the lower 48 states into contributions from labor and capital to find total factor productivity. They find that increased productivity increases the growth of labor and capital, and that there is a positive correlation between labor and capital stock growth. Furthermore, they find that human capital investment encourages productivity growth, while unionization strongly discourages productivity growth.

III. Data and the Empirical Model

III.I Data

To estimate the total factor productivity and its components, annual detailed industry group data from 1958 to 2005 is used. The data is taken from the NBER U.S. Census Beureau's Center for Economic Studies (CES) Manufacturing Industry Productivity Database. The data set has the detailed information on manufacturing industries (six digit code) based on the 1997 North American Industry Classification System (NAICS). This coding system is beneficial because it allows industries to be compared to the United States' NAFTA trading partners, relevant due to its increased number of economy sectors compared to SIC, and consistent because it classifies industries by how it produces items, not only what items it produces. The numbers in the coding system represent various levels starting with industry sector and continue toward the most detailed industry group data available for public use. The NBER manufacturing database contains annual industry level data on output, employment, payroll and other input costs, investment, capital stocks and various industry specific price indexes. Table 1 lists the detailed level industries and their respective codes that are used in this study.

Table 1. NAICS Code and Industry Name

NAICS Code	Industry Name
331111	Iron and Steel Mills
331112	Alloy Product Manufacturing
331210	Steel Pipe & Tube Manufacturing from Purchased Steel
331221	Rolled Steel Shape Manufacturing
331222	Steel Wire Drawing
331511	Iron/Steel Foundries
331512	Steel Investment Foundries
331513	Steel Foundries
332111	Iron and Steel Forging
332212	Steel Hand Tool Manufacturing
332312	Fabricated Structural Steel
332323	Architectural Steel Manufacturing
332431	Steel Can Manufacturing
332992	Steel Small Arms Manufacturing
332996	Steel Pipe and Tubing
332999	Miscellaneous Fabricated Steel Product Manufacturing
333511	Industrial Steel Mold Manufacturing
333514	Dies, Steel Rule, Metal Cutting Manufacturing

To examine the total factor productivity growth, an econometric estimation of the production function is used. This was chosen because of the availability of data. To do this, a transcendental logarithmic, commonly referred to as the translog production function, is specified as follows:

$$\ln Q = \beta_0 + \beta_1 \ln K + \beta_2 \ln L + \beta_3 \ln M + \beta_4 \ln E + \beta_5 \ln T + \frac{1}{2}\beta_6 (\ln K)^2 \quad (1)$$

$$\frac{1}{2}\beta_7(\ln L)^2 + \frac{1}{2}\beta_8(\ln M)^2 + \frac{1}{2}\beta_9(\ln E)^2 + \frac{1}{2}\beta_{10}T^2 + \beta_{11}(\ln K) * (\ln L) +$$

$$\beta_{12}(\ln K) * (\ln M) + \beta_{13}(\ln K) * (\ln E) + \beta_{14}(\ln L) * (\ln M) + \beta_{15}(\ln L) *$$

$$(\ln E) + \beta_{16}(\ln M) * (\ln E) + \beta_{17}(\ln K) * T + \beta_{18}(\ln L) * T + \beta_{19}(\ln M) * T +$$

$$\beta_{20}(\ln E) * T$$

where: *Q* denotes output adjusted for inventory and real values, *K* equals capital stock, *L* is equal to labor, and *E* and *M* respectively. Both energy and materials are adjusted for real values.

The output is measured as total value of shipments. The gross value of shipments is the total value of shipments plus inventory change and then deflated by the price index of shipments (Bartelsman, Backer and Gray Industry 2005). The NAICS database contains information on the cost of materials as well as fuel costs and electricity costs for each detailed level industry. Thus, total value of shipments, material costs, and energy costs are deflated by the Bartelsman Backer and Gray's index of material and energy respectively. The labor variable represents the total number of man hours worked per year for each detail level industry. The capital stock variable is taken directly from the NAICS database.

The translog production function is a flexible functional form to estimate productivity, and it is beneficial to use for a number of reasons. First, this production function circumvents the problem of over restriction. The translog production function is neither bound by the assumption of perfect competition on the production factor markets, nor the assumption of smooth substitution of inputs. Other functions, such as the Cobb-Douglas, do not allow for these assumptions. This function also allows for varying returns to scale. Because this is a four factor analysis, the translog production function is a suitable production function specification.

III.II Total Factor Productivity Growth and Its Components

The total factor productivity growth (TFP) decomposition starts with specifying an industry production function, as follows:

$$Q_{it} = F_i(X_{i1}, \ldots\ldots, X_{in}, t) \tag{2}$$

where t refers to the time period, Q_{it} denotes the output of an industry i in period t, and X_{ij} refers to the level of inputs j of industry $i, j=1,\ldots,n$.

Following the well-known previous approach of decomposing TFP (e.g. Bartelsman and Dhrymes (1998), Geylani and Stefanou (2010)), equation (2) is totally differentiated, and the subscripts i and t are dropped for ease of presentation. This decomposition then yields:

$$dQ = \sum_{j=1}^{n} F_{X_j} dX_j + F_t dt \tag{3}$$

Dividing equation 3 through Q as well as dt yields:

$$\frac{dQ_t}{dt}\frac{1}{Q_t} = \frac{d\ln Q_t}{dt} = \sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} \frac{d\ln X_j}{dt} + \frac{F_t}{Q} \tag{4}$$

Which can be rewritten as:

$$\hat{Q} = \sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} \hat{X}_j + \hat{A} \tag{5}$$

Where ^ indicates proportional growth rates and $\hat{A}$ denotes the proportional shift in the firm specific production function caused by exogenous technical change. Next, multiplying and dividing equation (4) into $\sum_{j=1}^{n} F_{X_j} X_j$ yields:

$$\hat{Q} = \sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} \left[\sum_{j=1}^{n} \frac{F_{X_j} X_j}{\sum_{j=1}^{n} F_{X_j} X_j} \hat{X} \right] + \hat{A} \tag{6}$$

Additionally, the elasticity of scale is defined as $\varepsilon = \sum_{j=1}^{n} \varepsilon_j$, where $\varepsilon_j = \frac{F_{X_j} X_j}{Q}$.

The aggregate input growth term can be expressed as:

$$\hat{F} = \sum_{j=1}^{n} \frac{F_{X_j} X_j}{\sum_{j=1}^{n} F_{X_j} X_j} \hat{X}_j \tag{7}$$

Therefore, using equations 7 in equation 6, the proportional actual output growth is:

$$\hat{Q} = \sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} \hat{F} + \hat{A} \tag{8}$$

Where $\sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} \hat{F}$ is the scale effect (input growth) and $\hat{A}$ is the technological change effect.

Total factor productivity, which is defined as the residual growth in output not accounted by the growth in inputs, can be defined as:

$$T\hat{F}P = \hat{Q} - \hat{F} \tag{9}$$

Then, substituting equation 6 into equation 8 yields:

$$T\hat{F}P = (\varepsilon - 1)\hat{F} + \hat{A} = \left(\sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} - 1 \right) \sum_{j=1}^{n} \frac{F_{X_j} X_j}{\sum_{i=1}^{n} F_{X_j} X_j} \hat{X} + \hat{A} \tag{10}$$

IV. Results

We calculate total factor productivity growth and its components, scale and technical change effects for each detail level industry using the coefficients from the production function estimation. Table 2 presents the results of this estimation.

Table 2. Translog production function estimation using fixed effects regression with time controls

Regressor	Estimate	Standard Error	P-Value
Constant	2.4984	0.972	0.010
ln(E)	0.3351	0.089	0.000
ln(K)	0.6179	0.188	0.001
ln(M)	0.5718	0.187	0.002
ln(L)	-0.6199	0.214	0.004
T	0.0133	0.006	0.042
$[(\ln(E)]^2$	0.0123	0.003	0.001
$[(\ln(K)]^2$	-0.0119	0.004	0.008
$[(\ln(M)]^2$	0.0177	0.005	0.001
$[(\ln(L)]^2$	-0.0501	0.016	0.003
T^2	-0.0001	0.000	0.252
ln(K)*ln(L)	0.0157	0.032	0.63
ln(K)*ln(M)	-0.0807	0.028	0.005
ln(K)*ln(E)	-0.0052	0.014	0.716
ln(L)*ln(M)	0.1128	0.019	0.000
ln(L)*ln(E)	0.0394	0.011	0.001
ln(M)*ln(E)	-0.0511	0.018	0.005
ln(K)*T	-0.0061	0.001	0.000
ln(L)*T	0.001	0.001	0.25
ln(M)*T	0.0055	0.001	0.000
ln(E)*T	0.0001	0.000	0.119
R-squared	0.8986	F-Statistic p-Value	0.000

Notes: The regression controlled for time effects. 1958 is the base year for the regression. 864 observations 1958-2005

Average total factor productivity growth over the time period examined is positive in nine of the industries examined (see Table A-1 in the appendix). TFP growth is positive in iron and steel mills, alloy product manufacturing, steel pipe and tube manufacturing from purchased steel, rolled steel shape manufacturing, steel wire drawing, iron/steel foundries, steel foundries, iron and steel forging, and steel can manufacturing. For example, in the iron and steel mills industry, the average TFP growth is 0.6% throughout the time period. Conversely, TFP growth is negative in nine of these industries. These include steel investment foundries, steel hand tool manufacturing, fabricated structural metal manufacturing, architectural steel manufacturing, steel small arms manufacturing, steel pipe tubing, miscellaneous fabricated steel product manufacturing, industrial steel mold manufacturing, steel rule metal cutting manufacturing. For example, in the steel investment foundries, the average productivity growth is -0.49% throughout the time period

Additionally, when comparing average scale and technical change effects across each specific detailed level industry, it is apparent that mean scale effect contributes more to total factor productivity than technical change. Figure A-7 (in the appendix) shows the effect of scale, technical change, and total factor productivity growth for each specific industry. This study shows that impact of technical change is negligible. This can be attributed to the fact that this study only captures exogenous technical change due to data restrictions.

To analyze the average TFP growth more closely during this time period, Table A-7 and A-8 in the appendix presents ten year averages for TFP growth, scale effect and technical change for each industry. By examining the ten year averages, growth trends are more easily recognized within each industry. In each ten year period examined technical change is positive, however, its impact on TFP is extremely small. Throughout much of the period studied, the steel industry was combating significant overseas competition and a dramatic reduction in domestic steel production. This large reduction in steel production, and a loss of thousands of jobs, caused the steel industry to slow in technological progression.

The period in which this dramatic reduction took place is captured in the table, and can be seen in the periods 1968-1977 and 1978-1987. Across nearly all industries TFP growth is negative in this ten year period. In this same period, scale effect was also negative in most industries. This is expected because of the large contribution scale effect has on TFP growth in every ten year period examined. During this time period of reduction, the allocation and organization of resources lead to negative TFP growth.

Conversely, in the 1988-1997 period, when the United States economy was experiencing a general expansion, TFP growth is positive in most industries examined. In this same period, it is interesting to note that scale effect is positive in nearly industries. This indicates that in periods of economic expansion, the industries examined focused more on the organization and reallocation of inputs to improve TFP. A similar relationship can be seen in the period of 1958-1967 across all industries. This time period most likely shows positive TFP growth because foreign competition had not yet negatively impacted the United States steel industry. Again, this time period shows negative scale effect across all detailed level industries examined.

Figures A-1 through A-6 show TFP growth for each industry from 1958-2005. In each industry, there is a dramatic decline in TFP growth in the 1970's, followed by a substantial increase in TFP growth in the early 1980's. The decline can be attributed to the collapse of the steel industry in the 1970's; however, the sharp increase in TFP which follows this decline is most interesting. Tables A-2 and A-3 show a large scale effect contribution in the period 1978-1987 over all industries. This increase is expected because industries which wanted to survive the collapse of the industry had to find ways to remain competitive. To do so, they allocated resources more effectively to increase TFP. This had a substantial impact on the growth across all industries studied during this time period.

Finally, the minimal impact technological change had on TFP throughout the time period could also be attributed to the increase in new types of steel that were developed over this period. Because of this, inputs were organized and allocated differently in order to create new products such as corrosion resistant steel and high strength alloys. These new products did not always utilize new technology. Instead, old technology was used in new ways. Because of this scale effect has a much larger impact on TFP over the course of the study compared to exogenous technological change. Additionally, this study only examines exogenous technical change which is measured by using time. The dataset used does not have detailed product and process innovation data; therefore, this study does not capture this effect on productivity growth.

V. Conclusions

This paper has analyzed detailed level industry dynamics in productivity growth for the United States steel industry over a period of 1958-2005. After performing an analysis, this study has resulted in the following findings.

The scale effect accounts for the most significant contribution to the TFP growth measurement for all of the detailed level industries in the study. This suggests that these industries extract scale efficiencies over technological progress to fuel TFP growth over the period studied. This result indicates that organizing input allocation of resources plays a more important role than an increase in technology. The contribution of scale effect to TFP also suggests that the movement along the production curve has a larger impact on TFP compared to the much smaller shift upwards of the production curve caused by technical change.

In all of the industries examined, technical change played a small yet positive role on TFP. In every industry, technical change was found to be positive. This positive impact suggests that all of the industries studied do benefit from the implementation of more technology, yet this impact was considerably less dramatic than that caused by the scale effect.

VI. Future Research

In the future, this research could be expanded to cover similar detailed level industries in other countries to see if they differ with regards to scale effect and technical change depending on the country. This research is important because it would allow for the comparison between the United States steel industry and the industries of other countries to see how productivity growth differs by nation. It would also reveal growth patterns of competitors' industries, which may allow the United States' industry to become more competitive in the world market. Furthermore, this paper could be expanded by utilizing a more detailed dataset that captures specific product and process innovation within the industry to better capture technical change. Finally, it could also be expanded to different industries in the United States to examine how the impact of scale and technical changes the productivity growth other sectors.

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APPENDIX

Table A-1. Mean technical change, scale effect, and total factor productivity 1958-2005

NAICS Code	Mean Scale Effect	Mean Technical Change	Mean TFP
331111	0.0060	$1.026x10^{-7}$	0.0060
331112	0.0132	$3.914x10^{-6}$	0.0132
331210	0.0003	$2.098x10^{-6}$	0.0003
331221	0.0006	$2.378x10^{-6}$	0.0006
331222	0.0001	$3.222x10^{-6}$	0.0001
331511	0.0021	$6.142x10^{-7}$	0.0021
331512	-0.0049	$4.303x10^{-6}$	-0.0049
331513	0.0014	$1.671x10^{-6}$	0.0014
332111	0.0018	$1.647x10^{-6}$	0.0018
332212	-0.0010	$1.730x10^{-6}$	-0.0010
332312	-0.0006	$1.054x10^{-6}$	-0.0006
332323	-0.0035	$6.488x10^{-6}$	-0.0035
332431	0.0092	$1.085x10^{-6}$	0.0092
332992	-0.0000	$8.778x10^{-6}$	-0.0000
332996	-0.0024	$3.969x10^{-6}$	-0.0024
332999	-0.0048	$1.812x10^{-6}$	-0.0048
333511	-0.0035	$2.323x10^{-6}$	-0.0035
333514	-0.0020	$1.497x10^{-6}$	-0.0020

Figure A-1. TFP growth for Iron and Steel Mills (331111), Alloy Product Manufacturing (331112), and Steel Pipe and Tube Manufacturing from Purchased Steel (331210)

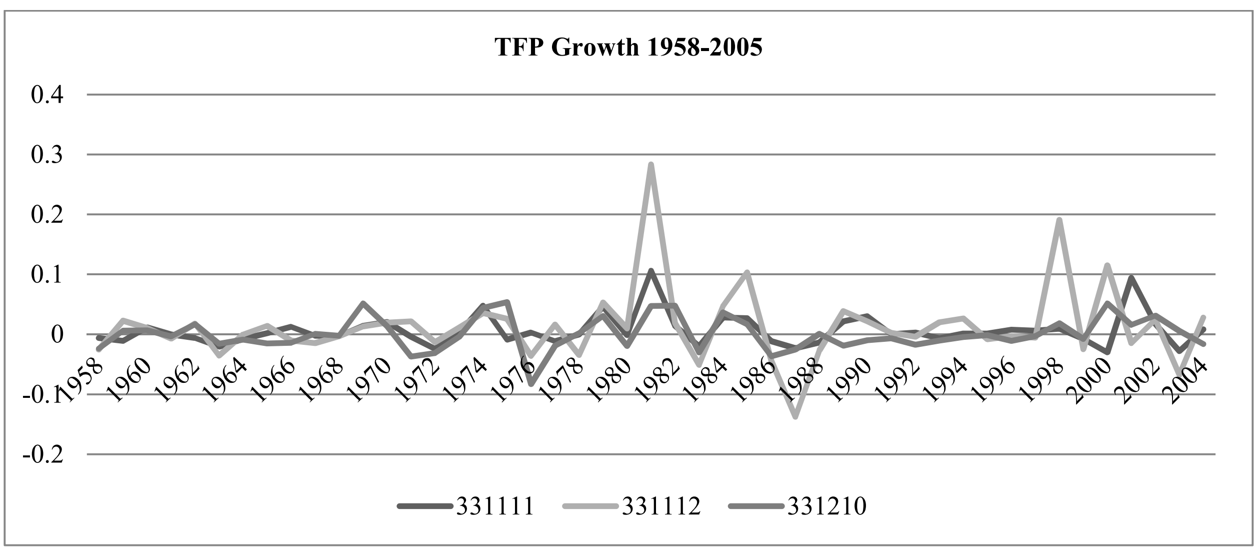


Figure A-2. TFP growth for Rolled Steel Pipe Manufacturing (331221), Steel Wire Drawing (331222), and Iron/Steel Foundries (331511)

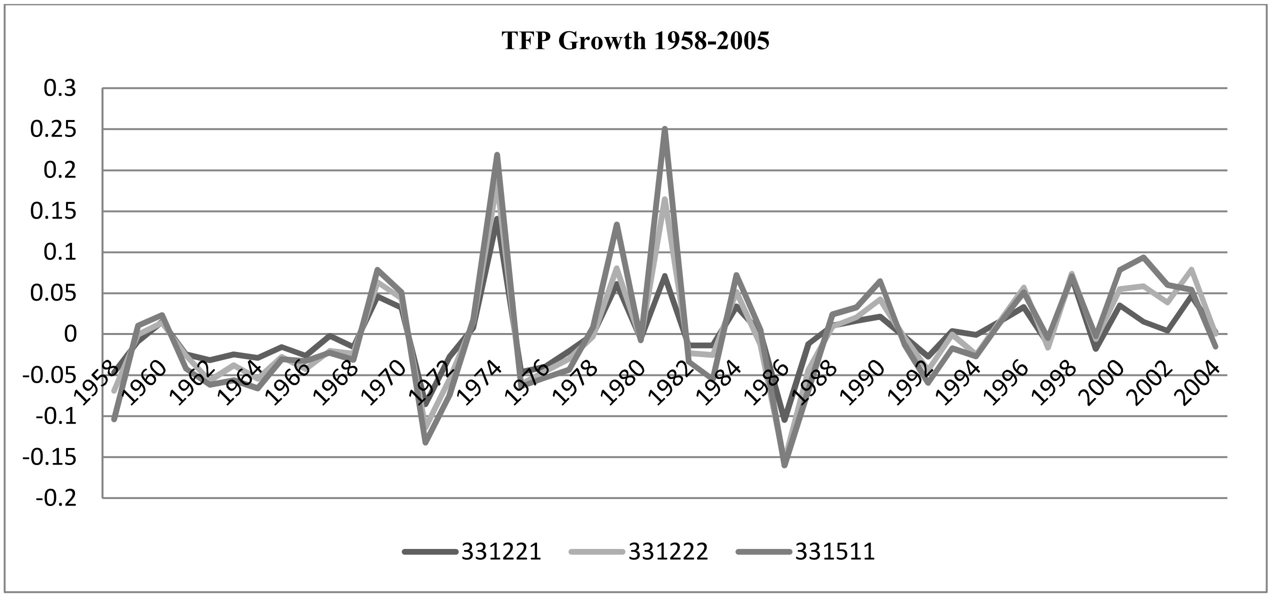


Figure A-3 TFP growth for Steel Investment Foundries (331512), Steel Foundries (331513), Iron and Steel Forging (332111)

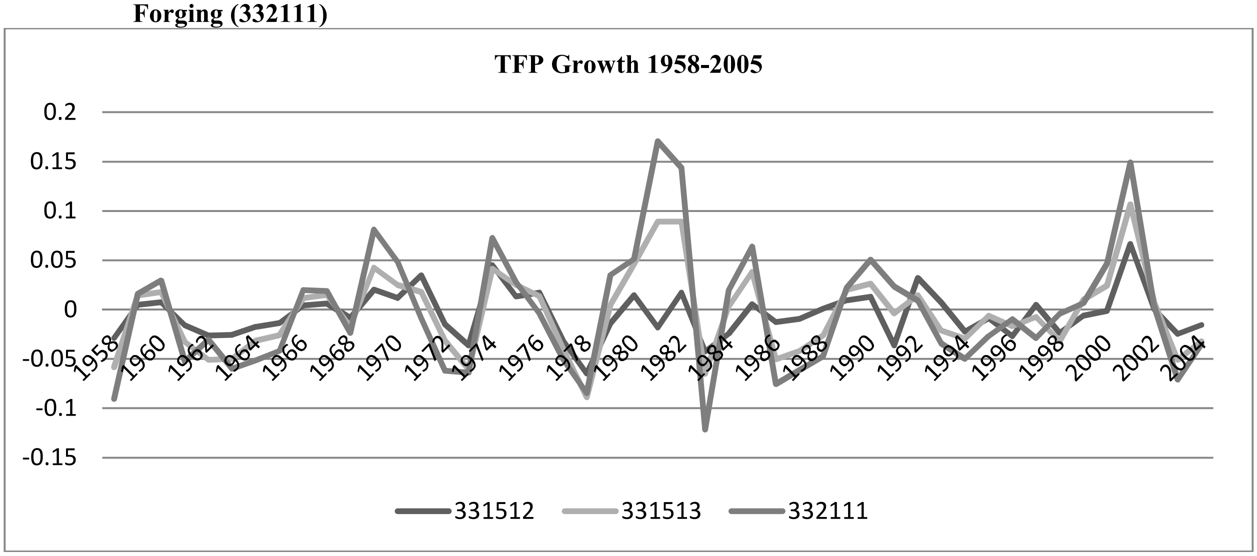


Figure A-4. TFP growth for Steel Hand Tool Manufacturing (332212), Fabricated Structural Steel Manufacturing (332312), Architectural Steel Manufacturing (332323)

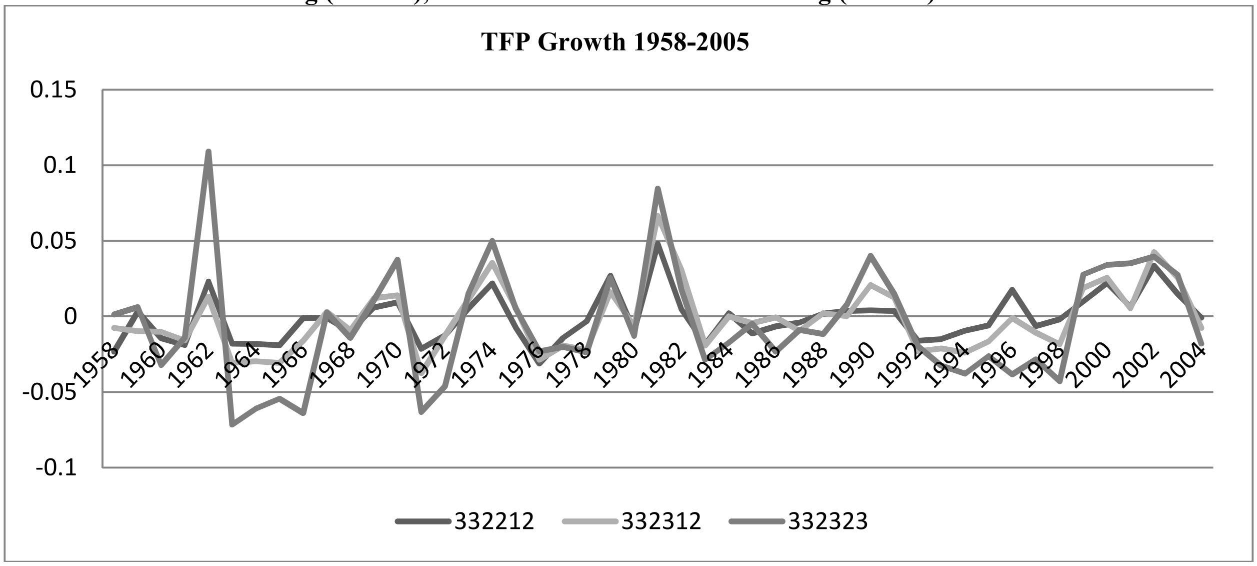


Figure A-5. TFP growth for Steel Can Manufacturing (332431), Steel Small Arms Manufacturing (332992), Steel Pipe and Tubing (332996)

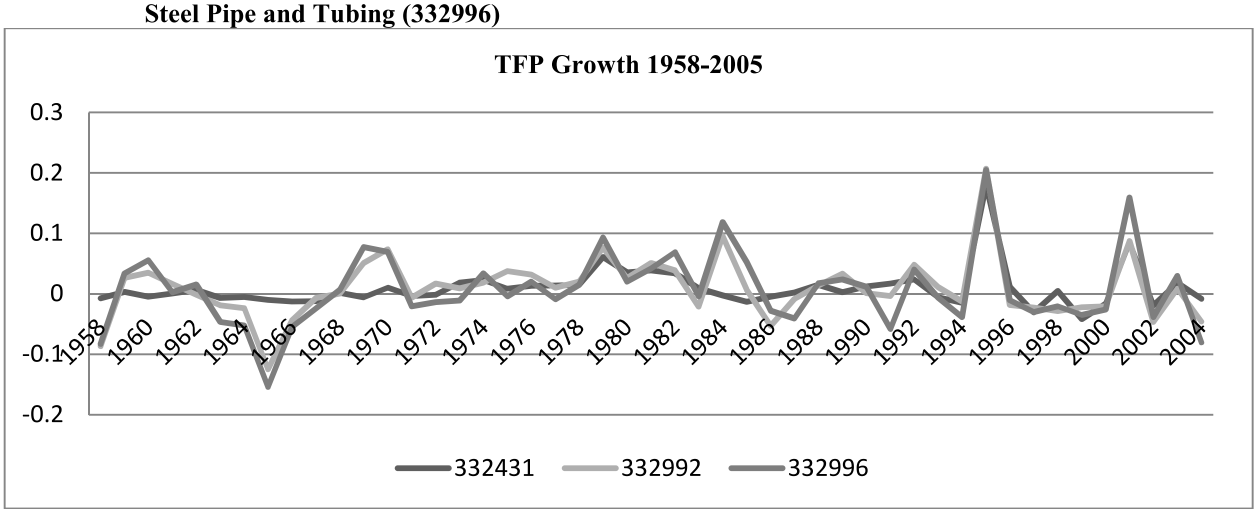


Figure A-6. TFP growth Miscellaneous Fabricated Steel Products (332999), Industrial Steel Mold Manufacturing (333511), Dies, Steel Rule, Metal Cutting Manufacturing (333514)

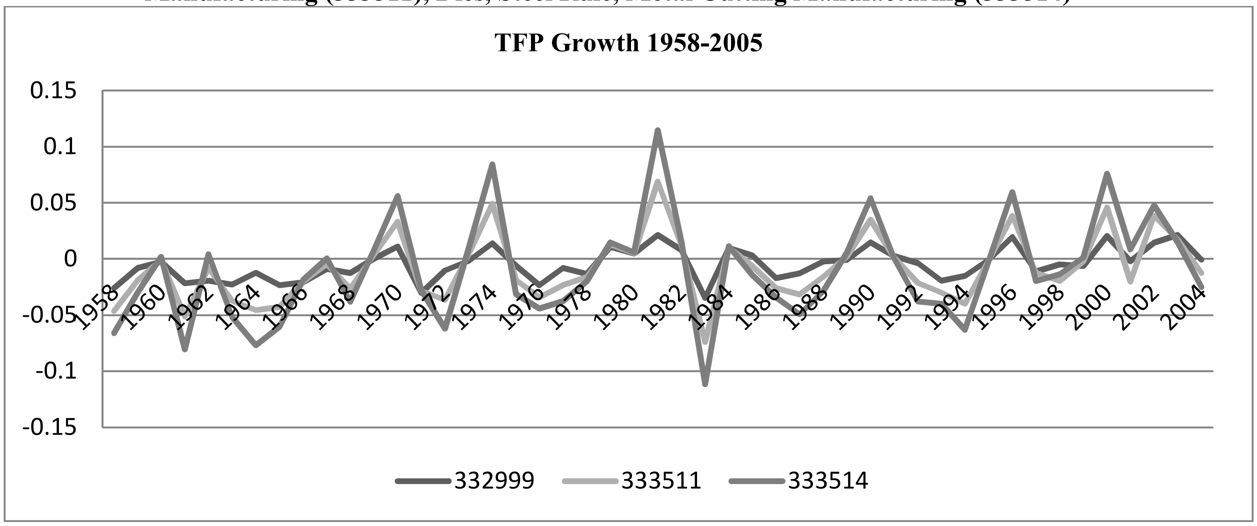
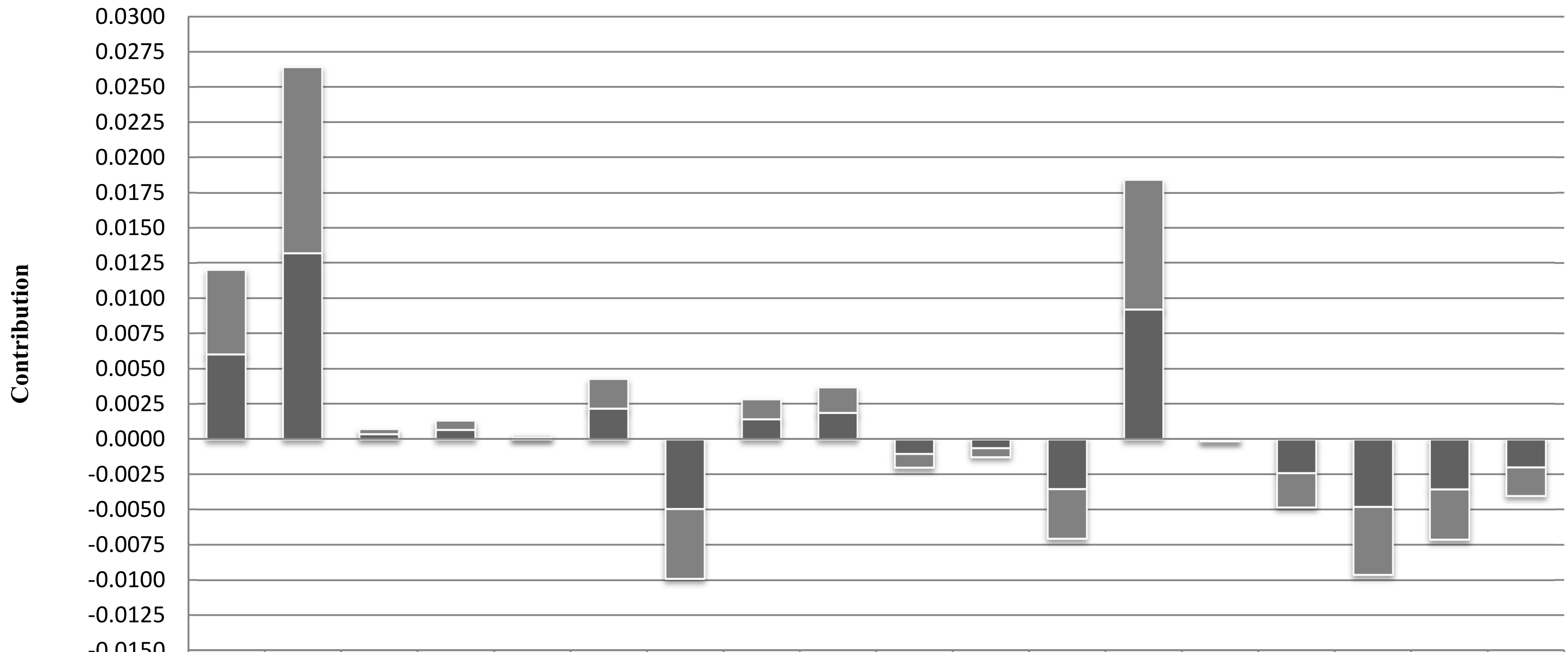


Figure A-7. Average TFP, Scale, and Technical Change Effects for each detailed level Industry



	331111	331112	331210	331221	331222	331511	331512	331513	332111	332212	332312	332323	332431	332992	332996	332999	333511	333514
Mean TFP	0.0060	0.0132	0.0004	0.0007	0.0002	0.0021	-0.0050	0.0014	0.0018	-0.0010	-0.0006	-0.0035	0.0092	-0.0001	-0.0024	-0.0048	-0.0036	-0.0020
Technical Change	1.0E-07	3.9E-06	2.1E-06	2.4E-06	3.2E-06	6.1E-07	4.3E-06	1.7E-06	1.6E-06	1.7E-06	1.1E-06	6.5E-06	1.1E-06	8.8E-06	4.0E-06	1.8E-06	2.3E-06	1.5E-06
Scale Effect	0.0060	0.0132	0.0004	0.0007	0.0002	0.0021	-0.0050	0.0014	0.0018	-0.0010	-0.0006	-0.0035	0.0092	-0.0001	-0.0024	-0.0048	-0.0036	-0.0020

Table A-2. Average Scale, Technical and TFP growth per ten year period

Industry	Time Period	Average Scale Effect	Average Technical Change	Average TFP Growth
(331111) Iron and Steel Mills	1958-1967	0.004	$9.788x10^{-8}$	0.003
	1968-1977	0.016	$9.505x10^{-8}$	0.004
	1978-1987	0.016	$9.505x10^{-8}$	0.016
	1988-1997	0.005	$1.055x10^{-7}$	0.005
	1998-2005	0.009	$9.710x10^{-8}$	0.009
(331112) Alloy Product Manufacture	1958-1967	-0.003	$5.452x10^{-6}$	-0.003
	1968-1977	-0.002	$2.319x10^{-6}$	-0.002
	1978-1987	0.025	$2.584x10^{-6}$	0.025
	1988-1997	0.006	$4.101x10^{-6}$	0.006
	1997-2005	0.036	$3.576x10^{-6}$	0.036
(331210) Steel Pipe & Tube Man.	1958-1967	-0.005	$2.992x10^{-6}$	-0.005
	1968-1977	-0.001	$2.452x10^{-6}$	-0.001
	1978-1987	0.002	$2.375x10^{-6}$	0.002
	1988-1997	0.006	$1.788x10^{-6}$	0.006
	1998-2005	0.022	$1.609x10^{-6}$	0.022
(331221) Rolled Steel Shape	1958-1967	-0.019	$3.435x10^{-6}$	-0.019
	1968-1977	-0.001	$2.452x10^{-6}$	-0.001
	1978-1987	0.002	$2.375x10^{-6}$	0.002
	1988-1997	0.006	$1.788x10^{-6}$	0.006
	1998-2005	0.022	$1.609x10^{-6}$	0.022
(331222) Steel Wire Drawing	1958-1967	-0.013	$5.387x10^{-6}$	-0.013
	1968-1977	-0.001	$3.322x10^{-6}$	-0.001
	1978-1987	0.001	$2.889x10^{-6}$	0.001
	1988-1997	0.000	$2.212x10^{-6}$	0.000
	1998-2005	0.020	$1.907x10^{-6}$	0.020
(331511) Iron/Steel Foundries	1958-1967	-0.006	$1.092x10^{-6}$	-0.006
	1968-1977	-0.001	$6.486x10^{-7}$	-0.001
	1978-1987	0.012	$4.481x10^{-7}$	0.012
	1988-1997	0.001	$4.487x10^{-7}$	0.001
	1998-2005	0.006	$3.570x10^{-7}$	0.006
(331512) Steel Investment Foundries	1958-1967	-0.010	$6.264x10^{-6}$	-0.010
	1968-1977	0.005	$4.370x10^{-6}$	0.005
	1978-1987	-0.015	$4.048x10^{-6}$	-0.015
	1988-1997	-0.003	$3.625x10^{-6}$	-0.003
	1998-2005	-0.001	$2.743x10^{-6}$	-0.001
(331513) Steel Foundries	1958-1967	-0.009	$2.370x10^{-6}$	-0.009
	1968-1977	-0.003	$1.628x10^{-6}$	-0.003
	1978-1987	0.017	$1.116x10^{-6}$	0.017
	1988-1997	-0.002	$1.566x10^{-6}$	-0.002
	1998-2005	0.005	$1.676x10^{-6}$	0.005
(332111) Iron/Steel Forging	1958-1967	-0.005	$2.084x10^{-6}$	-0.005
	1968-1977	0.000	$1.795x10^{-6}$	0.000
	1978-1987	0.012	$1.553x10^{-6}$	0.012
	1988-1997	-0.004	$1.425x10^{-6}$	-0.004

Table A-3. Average Scale, Technical and TFP growth per ten year period

Industry	Time Period	Average Scale Effectct	Average Technical Change	Average TFP Growth
(332212) Steel & Hand Tools	1958-1967	-0.009	$2.720x10^{-6}$	-0.009
	1968-1977	-0.005	$1.801x10^{-6}$	-0.005
	1978-1987	0.003	$1.429x10^{-6}$	0.003
	1988-1997	-0.002	$1.406x10^{-6}$	-0.002
	1998-2005	0.012	$1.106x10^{-6}$	0.012
(332312) Fabricated Structural Steel	1958-1967	-0.005	$1.520x10^{-6}$	-0.005
	1968-1977	0.003	$1.077x10^{-6}$	0.003
	1978-1987	0.002	$9.505x10^{-7}$	0.002
	1988-1997	-0.004	$9.190x10^{-7}$	-0.004
	1997-2005	0.001	$6.993x10^{-7}$	0.001
(332323) Architectual Steel	1958-1967	-0.004	$1.309x10^{-5}$	-0.004
	1968-1977	-0.002	$7.627x10^{-6}$	-0.002
	1978-1987	-0.004	$4.575x10^{-06}$	-0.004
	1988-1997	-0.007	$3.456x10^{-6}$	-0.007
	1998-2005	0.002	$2.495x10^{-6}$	0.002
(332431) Steel Cans	1958-1967	-0.005	$1.644x10^{-6}$	-0.005
	1968-1977	0.008	$1.052x10^{-6}$	0.008
	1978-1987	0.017	$9.744x10^{-7}$	0.017
	1988-1997	0.021	$8.878x10^{-7}$	0.021
	1998-2005	0.003	$7.730x10^{-7}$	0.003
(332992) Steel Small Arms	1958-1967	-0.018	$1.420x10^{-5}$	-0.018
	1968-1977	0.016	$9.841x10^{-6}$	0.017
	1978-1987	0.006	$6.796x10^{-6}$	0.006
	1988-1997	0.005	$6.425x10^{-6}$	0.005
	1998-2005	-0.013	$5.709x10^{-6}$	-0.013
(332996) Steel Pipe and Tubing	1958-1967	-0.008	$6.972x10^{-6}$	-0.008
	1968-1977	-0.009	$4.269x10^{-6}$	-0.009
	1978-1987	0.011	$2.953x10^{-6}$	0.011
	1988-1997	-0.010	$2.912x10^{-6}$	-0.010
	1998-2005	0.008	$2.213x10^{-6}$	0.008
(332999) Misc Fabricated Steel Product	1958-1967	-0.017	$3.599x10^{-6}$	-0.017
	1968-1977	-0.007	$1.837x10^{-6}$	-0.007
	1978-1987	-0.002	$1.402x10^{-6}$	-0.002
	1988-1997	-0.002	$1.136x10^{-6}$	-0.002
	1998-2005	0.006	$7.736x10^{-7}$	0.006
(333511) Industrial Steel Mold	1958-1967	-0.011	$3.944x10^{-6}$	-0.011
	1968-1977	-0.001	$2.620x10^{-6}$	-0.001
	1978-1987	-0.003	$2.026x10^{-6}$	-0.003
	1988-1997	-0.003	$1.575x10^{-6}$	-0.003
	1998-2005	0.001	$1.077x10^{-6}$	0.001
(333514) Steel Rule, Metal Cutting	1958-1967	-0.010	$2.508x10^{-6}$	-0.010
	1968-1977	-0.001	$1.673x10^{-6}$	-0.001
	1978-1987	-0.003	$1.323x10^{-6}$	-0.003
	1988-1997	-0.003	$1.012x10^{-6}$	-0.003
	1998-2005	0.009	$7.738x10^{-7}$	0.009