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Decomposition of Total Factor Productivity (TFP) of Indian software industry

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Abstract

Objectives: To decompose the total factor productivity of Indian Software industry into efficiency change (catch up) and technical change (innovation).
Methodology: The study is entirely based on secondary sources of data. The data is obtained from various sources, which includes World Bank, Reserve Bank of India (RBI), National Association of Software and Services Companies (NASSCOM), CMIE Prowess, and Indian Brand Equity Foundation (IBEF). The study has used the Malmquist Productivity Index in order to carry out the analyses for decomposition of total factor productivity into innovation and catch up.
Findings: The results show that during the study period, the TFP has increased by an average rate of 3 percent. The study found that out of 100 firms, 45 firms have increased total factor productivity. Most firms are trying to catch up their peers rather than surpassing them. It is clearly supported by the analysis that out of 100 firms 82 have shown an increase in efficiency change (Catch up) while as only 8 firms have shown growth in technical change (innovative).
Improvements/Applications: Indian IT sector is required to follow new directions. In order to survive in the long run with the same zeal, the industry demands to consolidate its strengths and move up the value chain if it has to maintain its head start on the competition. Most importantly, it will have to invest substantially in research and development and create linkages to encourage career prospects for researchers in engineering. As a matter of necessity, the companies in the industry should focus on the path-breaking technology rather than following the linear process.
Keywords: Software industry, Total Factor Productivity, Technical Efficiency change, Technical change, Research and Development.

1. Introduction

Tertiary sector has been playing an important role in the growth of the world economy, although it was invisible till the sectoral classification by Coin Clark [1]. The global services Gross Domestic Product (GDP) was estimated at US$ 52.33 trillion in 2016 and constituting the share of 69 percent approximately in world GDP [2]. Like many other emerging economies, services sector in India is also the largest and fastest growing sector and has been the key driver of growth of the economy for the past decade, with the average annual economic growth of over 7% [3]. According to The World Bank (2017), the contribution of the sector has increased from 47% in 2005 to 54% in 2016.

Usually, economies are likely to follow a linear evolution of development that takes them away from the dependence on the primary sector, to the development of the manufacturing sector and lastly to the service based phenomenon. But, the Indian journey of following the path is different, missing the stage of industrialization. Services sector was receiving the treatment like Cinderella, but with the dramatic cost reduction, speed, and reliability in the transportation and the communication of information has led the sector for international trade and competition [4]. Technological changes have extensively changed the scenario of the service sector globally [5]. For economies at large, these have brought good opportunities [6]. One of such exemplar is India, which has recognized her potential by developing the world-class Information Technology (IT) industry. The success of the Indian IT industry has led to the postulations of imitation by other countries; over and above it has created the competitive challenges to developed countries [7].

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The rapid growth of the information and communication technology industry has been an important factor in worldwide economic development. In addition to export earnings, it has been a key driver in the transformation of the domestic economy and its international interface for several Asian economies. In the past decades, East Asian countries have been successful in capturing a large share of the global sourcing of IT hardware and India have emerged as a major centre for offshoring of IT industry related services [8]. The rise of an IT industry and as well as the software industry is one of the most spectacular achievements of the Indian economy [9]. Indian IT industry, with the high-visible success, has impressed the industry observers and researchers alike. The increasing importance of IT industry in the Indian economy can be seen in terms of contribution to GDP, employment generation, and foreign exchange reserve earnings. Over the period the contribution has increased significantly and in 2016, the revenue generated by the Industry was the US$ 143 billion, out of which 75% is generated through exports and creating millions of jobs [10]. The Indian software industry is mainly driven by exports, which have shown phenomenal growth over the period [9]. The industry is also attracting a good amount of foreign investment due to her competitiveness [11]. However, the growing scarcity of talent, the rising wage costs, and emerging competition from the other low-cost countries are significant challenges. Moreover, the slowdown in general and particularly from the US has a negative impact on the growth estimates of the information technology industry.

India is the world's largest outsourcing destination for the information technology industry, accounting for approximately 67% of the world demand. The industry provides indirect employment to around 10 million people in 2016 [3]. One of the strikingfeatures of the industry is that it has changed the perception of the world regarding the Indian economy, which was considered mainly an exporter of agricultural goods. Among various factors, it is a cost advantage, which has led the industry in such a unique selling position around the globe. Various global IT firms have set up their innovation centres in India, implicitly reflecting the presence of skilled human capital at a low cost.

The government institutional measures like Software Technological Parks of India (STPI) and other liberalization policies were in line with the development of the industry [12]. It is the highly subsidized education in India because of which many engineering professionals from Indian Institute of Technology are produced annually. The Indian economy is not in a position to absorb the excess educated technical and professional manpower created by our education system. The Silicon Valley of United States absorbs and demands skilled human capital of India due to efficiency and relative low-costly. Then the return of those Non-Residents of India (NRIs) powered with money, networking ability, prestige and technology start their units here. Further, the liberalization process, establishment of STPI and the IT policy made them excel along with the multinational companies (MNCs) [13]. The industry is of a different nature, composed of products and services and hence requires thevarying quality of human capital. The industry is usually divided into four segments which include IT services, Business Process Management (BPM), software products and engineering services, and hardware. The segments differ with each other in respect of skills needed and hence demand a different set of human capital requirement. Generally, the industry has created the demand for educated youth and particularly for engineers [14]. The study is divided into four sections. In the first section, a brief introduction of the IT industry is discussed. The second section includes the data and methodology used in the study. In the third section the results are discussed and in the final section, the study is concluded with appropriate policy measures.

2. Data and Methodology

One of the main concerns of any industry in general and firm in particular is to enhance the efficiency or to sustain the same level of efficiency. There are various models which are dealing with macro-level growth sustainability and the models based on the Schumpeterian idea that innovation by firms is the force that drives the growth process is of micro-level growth sustainability, which assists to spring sustainability conditions of the industry. Here profits are viewed as the vehicle by which successful innovators grow relative to other firms. Businesses compete with one another, other than price on similar products based on their monopoly position with a particular differentiated product and service. Technology is seen as a distinguished, endogenous factor explaining productivity growth in the economy [15, 16]. Users of new technologies seem to pay a price to cover the cost of new technology and in return, they receive an exclusive monopoly right to its use.

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Thus, technological progress is at least partly relevant, at the same time, new technologies also argument the existing pool of knowledge and in the process facilitate new technological developments. Thus the incentive to innovate due to the suitableness of technological progress and the positive externality from this process are the two elements, a combination of which allows growth to go on [17]. Growth hence relies positively on the availability of resources, especially human capital and investment in research & development for the development of new technologies. Along with traditional factors of production, namely capital and labour, human capital and knowledge, therefore, appears to be the main factors in the production process. Accompanying with knowledge, innovation, imperfect competition and technological progress are the conditions for the long run sustainable industrial growth [18].

For organizations in almost every industry and for individuals working in almost every organizational function innovation has become a slogan. Large companies are appointing innovation managers and leading universities are setting up centres for innovation research. In the software development industry, the rate of technological change brings up a specific logic of imperativeness for the need to innovate is very high. This forces to have strategies, which promote innovations, as innovation is the lifeline for the software development organizations [19]. Globalization, standardization, and industrialization are demanding software development firms to become increasingly dependent on their innovation skills [20].

Fluctuations in the economic activities in domestic and particularly in the world economy are imposing greater risks and challenges to the IT industry of India. In this respect, continuously monitoring and improving the performance of individual software companies and setting standards for relatively inefficient ones become crucial for growth and maintaining the growth of this industry. So, to examine the relative efficiency of individual IT firms and set the best-practice target for the underperforming firms is of importance. For this purpose, productivities of individual IT firms have been measured through the MalmquistProductivity Index based on Data Envelopment Analysis(DEA). The data has been collected on both cross-sectional as well as time series from the Centre for Monitoring Indian Economy (CMIE) Prowess database. Since DEA measures the relative efficiency of individual firms, so the firms having consistent data under output variables are taken. With the help of CMIE Prowess database, the study has selected top 100 Indian software firms on the uniformity of data on sales and exports during the time period. Sales and Exports of the firm are treated as the output variables in the analysis, where the former refers to the gross revenue received by a software company and the latter refers to the gross revenue earned from selling the products and services abroad. Total cost, number of employees and the number of years in the business are used as the input variables. The firms are selected from the prowess database on the uniformity of data.

1. Total factor productivity growth

According to Fare, Grosskopf, & Margaritis [21] the Overall Technical efficiency is composed of two components Scale and Technical efficiencies and are estimated in comparison to the efficient firm(s) in a given year. Thus, these efficiency measures are static in nature and the dynamic changes, which occur over time, are not incorporated. Due to dynamic changes, there is a shift in the production frontier over the time period. The while measuring the efficiency approach of total factor productivity (TFP) measurement includes both static as well as dynamic changes. It thusincludes technical and scale efficiencies and incorporates the shifting factors of the production frontier. It has become indispensable for every firm to improve her TFP, as the scarcity of resources leads to having alternative uses. The TFP is constituted by two main components, as mentioned above by technical efficiency change and technical change, and these two components are also called catch up and innovation respectively [22]. A study of these two components is of importance to examine which component is driving the TFP [23]. Considering these aspects, the study will examine the growth of TFP and its origin in the IT industry. For this purpose, 100 software firms are selected and data has been collected for the period 2005 to 2015 (11 years) from the CMIE PROWESS on the different variables. The Malmquist Productivity Index (MPI) is used in the estimation of the TFP growth trends, technological change and technical efficiency change in the software companies.

1.1. The malmquist productivity index model

The Data Envelopment Analysis (DEA) based Malmquist Productivity Index (MPI) is one of the prominent indices for measuring the relative productivity change of the producing units in multiple time periods [23]. Actually, Caves, Christensen and Diewert (1982) developed the MPI for measuring productivity [24].

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Since the 1990s the index was applied in a number of studies, including Fare, Grosskopf, and Li (1992) [25] for measuring the productivity of Swedish pharmacies, Fare, Grosskopf, Norris and Zhing (1994) [22] for calculating the productivity of Swedish hospitals, Grifell-Tatje and Lovell (1996) [26] used for estimating the efficiency of Spanish banks, Ray and Desli (1997) [27] applied the index for measuring the productivity and technical progress of Industrial countries.

Fare, Grosskopf, & Margaritis, (2011) [22] provided an overview of static as well as dynamic MPI based on DEA. As the MPI is formed on the distance functions, which allows us to construct multiple input-output production technologies without any requirement to identify a behavioural objective, such as cost minimization or profit maximization [23]. Distance functions may be terms of output and input, the distance functions are constructed. An output distance function tries to maximize the output vector, given the input vector; while as the input function tries to minimize the input vector, given the output vector. According toFare et al., (1992)[25], the Malmquist TFP change index between period t (the base period) and period t+1 is given by:

$$M_0^{t+1}(Y^{t+1},X^{t+1},Y^t,X^t) = [\frac{D_0^t(Y^{t+1},X^{t+1})}{D_0^t(Y^t,X^t)} * \frac{D_0^{t+1}(Y^{t+1},X^{t+1})}{D_0^{t+1}(Y^t,X^t)}]^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots.(1)$$

The equation above is the geometric mean of the technical efficiency change (catch up) and technical change (innovation). The first index (technical efficiency change) is estimated with respect to period t technology and second index (technical change) with respect to period t+1technology. Assuming that $D_0^t(Y^t,X^t)$ and$D_0^t(Y^{t+1},X^{t+1})$, both from equation (1) ≤ 1, and can be rewritten as according to [25]:

$$M_0^{t+1}(Y^{t+1},X^{t+1},Y^t,X^t) = \frac{D_0^{t+1}(Y^{t+1},X^{t+1})}{D_0^t(Y^t,X^t)}[\frac{D_0^t(Y^{t+1},X^{t+1})}{D_0^{t+1}(Y^{t+1},X^{t+1})} * \frac{D_0^t(Y^t,X^t)}{D_0^{t+1}(Y^t,X^t)}]^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The term outside the square brackets of equation (2) represents EFFCH and the expression in the square brackets indicates TECHCH. Thus, in this way, MPI is decomposed into EFFCH (catching up) and TECHCH (technical progress) as:

$$\text{EFFCH} = \frac{D_0^{t+1}(Y^{t+1},X^{t+1})}{D_0^t(Y^t,X^t)} \ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

$$\text{TECHCH} = [\frac{D_0^t(Y^{t+1},X^{t+1})}{D_0^{t+1}(Y^{t+1},X^{t+1})} * \frac{D_0^t(Y^t,X^t)}{D_0^{t+1}(Y^t,X^t)}]^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(4)$$

EFFCH measures the change in technical efficiency between the time period t and t+1 in terms of production possibilities available in each period while as TECHCH is the geometric mean of the shifts in frontier at the factor ratios of period t and t+1 respectively. The value of the MPI greater than or less than 1 represents productivity growth and regress in productivity respectively, and the value equal to 1 represents that there is no change in TFP index [26]. In the same manner, the value above, below or equal to 1 is representable for the components of the MPI.

2. Results and Discussions

This section will analyze the results obtained through the Malmquist productivity Index. Before analyzing the results, it would be better to define some key concepts. The Overall Technical Efficiency (OTE) refers to the ability of a firm to produce the optimum level of output, given the combination of inputs and state of technology. The OTE, in DEA,is measured by the variation between the observed quantities of a firm's output(s) to input(s) and the ratio is compared with the best practice firms that are used as a point of reference to measure its efficiency. It is, therefore, a relative technical efficiency, and oscillates between zero and one. If the OTE for a firm is equal to one, it means that the firm is on the production frontier and does not have any input or output slack. OTE is composed of two components i.e. Pure Technical Efficiency (PTE) and Scale Efficiency (SE), where the former refers to the proportion of OTE which is ascribed to the efficient transformation of inputs into output(s), capturing the pure resource-conversion efficiency, regardless of returns to scale.

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The SE refers to efficiency due to the size of the firm. The value of PTE also oscillates between zero and one and may be greater than or equal to OTE score. The value of SE is obtained by dividing the OTE value by the PTE score for a firm. The value of SE score also lies between one and zero because the PTE score is either equal to one or zero. If the value on both fronts i.e. PTE and SE are equal to one for a firm, then it is said to be working on the most productive scale size (MPSS). Thus, the inefficiency in any firm may be either due to its technical incompetence or of the inappropriate size under which it is operating or of both.

1. Trends in OTE, PTE and SE

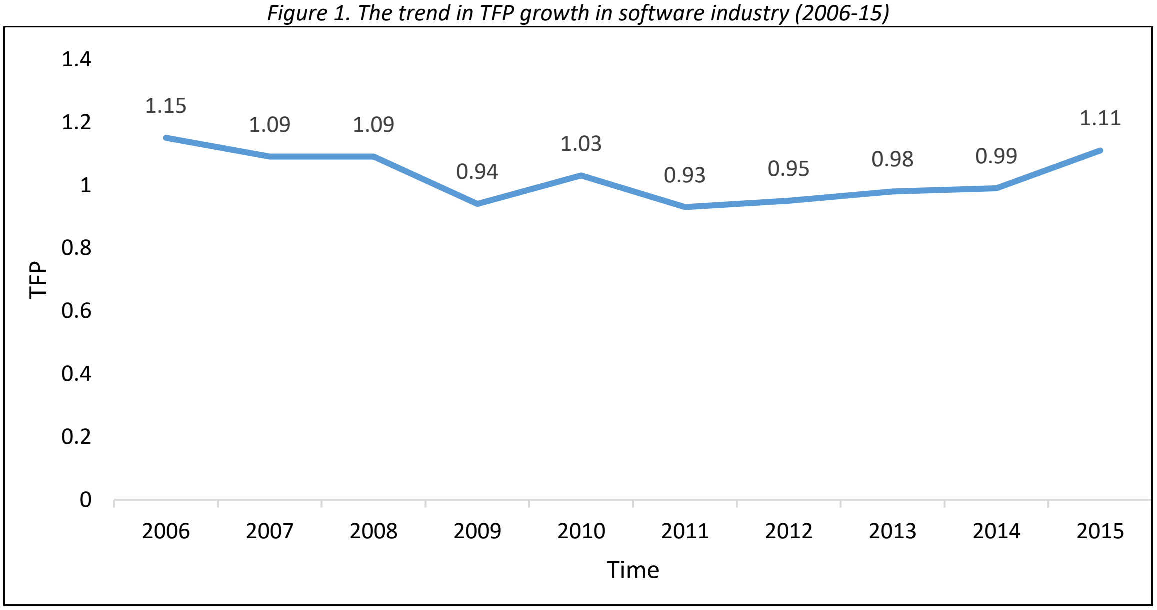
During the study period, the number of firms having OTE equal to 1 has increased by 200percent to 18 by 2015 and were operating on the production possibility frontier. Most of the firms during the study have enhanced the scale efficiency rather than their technical efficiency. In 2005, 12 and 10 firms were technical and scaleefficient but in 2012 there were 25 and 35 respectively.

It is clear from the above that most of the firms are operating below the production possibility frontier showing their inefficiency and hence the possibility to enhance the efficiency. In 2005, out of 6 efficient firms 3 were robust as their peer count was more than 30 means these were used more than 30 times as a benchmark for other firms and in 2015 there were again only 3 firms which were of peer count of 30 and most were of less robust because their peer counts were less than 10. The DEA analysis reveals that most of the firms are driven by the SE, rather than by PTE [28].

2. Total factor productivity growth in software industry

The growth in TFP and its origin is analyzed through the MPI. First, the trend of the TFP is constructed on the mean growth rate calculated for the 100 software firms for the period of 11 years (2005-2015). Since the MPI does not provide TFP change for the first year because it is considered as a base for the current year. The figure below shows the trend in the average TFP growth in the industry. In order to calculate the TFP growth rate one is being deducted from the TFPCH index and to express the growth rate in percentage, the value is multiplied by 100. A value of TFPCH index above than 1 indicates positive growth in TFP, while a value of less than 1 implies regress [26]. On an average TFPCH index for the industry during the study period is 1.026, reflecting the average growth of 3 percent from 2005-2015. But the Figure 1 depicts that during some years the productivity growth rate has regressed. In 2009 the productivity growth rate turned negative first time in the study period followed by in 2011-2014 continuously, but from 2011-14 there is an increase in productivity growth and in 2015, it again turned into positive. One of the reasons, for the regress in productivity growth, is the declining growth of the Indian information technology industry.

Figure 1. The trend in TFP growth in software industry (2006-15)



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The Figure 1 shows that the TFP growth rate of the software industry varies across years. In 2006 there was the highest growth rate compared to other years. The TFP grows at the rate of 15% in 2006. Over the period of time from 2006-2008 TFP of software industry remained positive. For the year2009, the TFP of the industry turned negative due to the financial crisis. As the Indian software exports are concentrated mainly to the USA, so the crisis of the USA has a significant impact on the efficiency of the software industry. For the next year, TFP of the Industry was positive, but for the next four years 2011 to 2014 it declined again. European Crisis may be the one the reasons. Figure 1 demonstrates that there is no particular pattern in TFP growth as some years are with regress in productivity so explicitly there is no trend in the TFP growth rate is observed. The results show that during the study period, the TFP has increased by an average rate of 3%.
The year wise analysis of TFPCH indices of software firms at the individual level shows that during the study period 45 out of total 100 firms on average have achieved positive growth and remaining 55 firms realized regressed growth in the TFP index.

Table 1 demonstrates that the number of firms achieving positive growth rates varies across years. The number of firms with positive growth rates is observed highest in 2012, followed by 2015, and 2008. It is found lowest in 2009, followed by 2006, 2011 and 2013. The Table 1 also shows that the number of firms having realised no change in the TFP index is almost negligible.

Table 1. Year-wise distribution of software firms in the TFPCH index

Status of Firm	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average
Progress	49	37	49	31	47	45	58	45	47	48	45
Regress	51	63	51	69	52	55	42	55	52	51	55
No Ch.	0	0	0	0	1	0	0	0	1	1	0

Source: Author's Calculations

Note: Progress means that TFPCH is positive in comparison to the previous year. Regress means that TFPCH is negative in comparison to a previous year and No Change (No Ch.) Means the same TFP

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The firm-wise indices of TFPCH, TECHCH and EFFCH over the period are shown in Table A in the Appendix. It indicates that in case of most software firms, the TFPCH index is less than 1 thus showing regress in TFP over the period of 11 years. There are only 45 firms which have made progress from 2005-15 and one firm maintained the score equal to 1 means no change. The growth of Indian software companies is driven by the export demand. Thus the performance of the software industry is more sensitive to the fluctuations in the world demand for software product and services. On an average, during the 11 years, the software companies have shown poor performance in terms of TFPCH. Thus, the software firms did not provide any evidence of a trend in the TFPCH during the period. From Table 2, it is evident that most of the firms in the Indian software industry are not innovative, only 8 firms out of 100 have TECHCH positive. In case of EFFCH (catch up) most of the software firms registered growth, only 6 firms regressed and 2 firms neutral.

Table 2. Distribution of TFPCH, TECHCH and EFFCH (2005-15)

Change	Progress	Regress	Neutral
TFPCH	45	54	1
TECHCH	8	91	1
EFFCH	82	6	2

Source: Author's Calculations

One more striking thing from the above analysis is that the more the firm is big in size; there are more chances of her being technical efficient. It is clear from the table that most of the progressive firms are driven by EFFCH (efficiency change) rather than by TECHCH (technical change), indicating that the firms are trying to catch the most efficient firms rather than trying to surpass them.

3. Conclusions

In concluding remarks, it is clear from the above analysis that most Indian software firms are scale efficient rather than pure technical efficient. The number of overall technically efficient firms has increased during the study period.

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In the case of total factor productivity more than half of the firms have regressed. Out of 100 firms, 45 firms have increased total factor productivity. Most firms are trying to catch up their peers rather than surpassing them. It is clearly supported by the analysis that out of 100 firms 82 have shown an increase in efficiency change (Catch up) while as only 8 firms have shown growth in technical change (innovative).

"Indian IT sector is required to follow new directions". In order to survive in the long run with the same zeal, the industry demands to consolidate its strengths and move up the value chain if it has to maintain its head start on the competition. Most importantly, it will have to invest substantially in research and development and create linkages to encourage career prospects for researchers in engineering. As a matter of necessity, the companies in the industry should focus on the path-breaking technology rather than following the linear process.

4. Appendix

Table A. Firm wise TFPCH, TECHCH and EFFCH (2005-15)

Firm	EFFCH	TECHCH	TFPCH	Firm	EFFCH	TECHCH	TFPCH
F1	1	1.049	1.049	F51	1.155	0.942	1.088
F2	1.038	1.024	1.064	F52	1.045	0.98	1.024
F3	1	1.027	1.027	F53	1.06	0.941	0.997
F4	1.009	1.1	1.109	F54	1.118	0.988	1.105
F5	1.059	1.066	1.129	F55	1.108	0.973	1.078
F6	1.259	0.99	1.247	F56	1.152	0.982	1.131
F7	1.015	0.917	0.931	F57	1.097	0.955	1.048
F8	0.994	0.889	0.884	F58	1.005	0.931	0.935
F9	1.236	0.917	1.134	F59	1.012	0.847	0.857
F10	1.009	0.979	0.988	F60	1.014	0.945	0.959
F11	1.022	0.958	0.979	F61	1.036	0.937	0.971
F12	1.042	0.937	0.976	F62	1.122	0.959	1.076
F13	1.09	0.975	1.063	F63	1.083	0.88	0.953
F14	1.05	0.935	0.982	F64	1.015	0.943	0.957
F15	0.995	0.992	0.987	F65	1.233	0.929	1.145
F16	0.992	0.971	0.964	F66	1.252	0.902	1.129
F17	1.038	0.863	0.896	F67	1.083	0.891	0.965
F18	0.988	0.935	0.923	F68	1.064	0.909	0.967
F19	0.994	0.971	0.965	F69	1.182	0.957	1.131
F20	1.049	0.975	1.023	F70	1.103	0.813	0.897
F21	1.066	1.000	1.066	F71	1.119	0.966	1.081
F22	1.024	0.941	0.963	F72	1.107	0.933	1.033
F23	1.009	0.923	0.931	F73	1.053	0.939	0.988
F24	1.085	0.893	0.969	F74	1.048	0.914	0.958
F25	0.989	1.011	1.000	F75	1.419	0.84	1.192
F26	0.982	0.966	0.949	F76	1.028	0.874	0.898
F27	0.993	0.993	0.986	F77	1.013	0.851	0.862
F28	1.047	0.993	1.041	F78	1.174	0.913	1.072
F29	1.019	0.995	1.013	F79	1.084	0.92	0.997
F30	1.127	0.996	1.122	F80	1.301	0.867	1.129
F31	1.107	0.95	1.051	F81	1.042	0.905	0.943
F32	1.254	0.966	1.211	F82	1.161	0.846	0.982
F33	1.015	0.948	0.962	F83	1.184	0.884	1.046
F34	1.025	0.987	1.012	F84	1.191	0.846	1.007
F35	0.989	0.97	0.96	F85	1.211	0.829	1.004
F36	1.019	0.96	0.978	F86	1.35	0.869	1.173

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F37	1.032	1.031	1.064	F87	1.048	0.859	0.901
F38	1.015	0.924	0.938	F88	1.11	0.814	0.904
F39	0.985	0.985	0.971	F89	1.138	0.908	1.034
F40	0.992	0.98	0.997	F90	1.631	0.834	1.36
F41	1.018	0.975	1.129	F91	1.311	0.925	1.212
F42	1.078	0.995	0.943	F92	1.023	0.847	0.866
F43	1.027	0.941	0.982	F93	1.166	0.911	1.062
F44	1.006	0.93	1.046	F94	1.014	0.926	0.939
F45	1.136	0.982	1.007	F95	0.977	0.867	0.847
F46	1.108	0.949	1.004	F96	1.066	0.879	0.938
F47	1.026	0.97	1.173	F97	0.936	0.879	0.822
F48	0.986	0.83	0.901	F98	1.191	0.904	1.077
F49	1.009	0.951	0.904	F99	0.965	0.855	0.825
F50	1.081	0.945	1.034	F100	0.919	0.895	0.823

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