© INNOVATIVE RESEARCH THOUGHTS
Refereed | Peer Reviewed | Indexed
ISSN : 2454 – 308X | Volume : 09 , Issue : 04 | July - September 2023
DOI : https://doi.org/10.36676/irt.2023-v9i4-018

Recession and Technological Change: Does Technological Change contribute to Recessions

Aastik Madan
Department of Commerce, Hansraj College
Email: aastik.madan23@gmail.com

Abstract

This research paper analyses the role of technological change in the occurrence of recessions or periods of strained economic growth. Economists and industry professionals have provided us with various possibilities and causes that lead to the existence of a recession. Even though most economists believe causes such as inflation and unemployment to be the main contributing factors towards the occurrence of recessions, there are some economists, from an alternate school of thought, who attribute the occurrence of recessions to gradual technological change and process innovations. Over the years, there have been multiple research papers published that have tried to establish a correlation between economic growth and technological change. This paper aims to build on this existing research and provide a better and more conclusive explanation for the influence of technological change on the global economy and periods of recession through a detailed analysis of R&D spending, innovations, and employee compositions. The paper will trace the development of the listed aspects through periods of strained economic growth such as the recessions of 2007-2009 and 1991-92 to establish an effective line of reasoning.

Introduction

A recession is a significant economic business cycle that is characterized by a widespread contraction in global economic activity. Generally, a contraction in economic activity persistent over consecutive quarters is regarded to constitute a situation of an economic recession. Recessions often lead to difficulties and hardships for companies, individuals, and households often leaving a long-lasting imprint on the society, country, and the world as a whole. Even though the global economy can keep showing signs of a slowdown and weakening months before a recession begins, it often requires a significant time to determine the time period of the recession. Therefore, it has always proven tricky for economists and researchers to dig deep into the specifics and causal factors underlying a recession.

The phenomenon of a recession has been analyzed by numerous economists over the years. Initially, early-age economists were of the view that recessions are majorly caused due to a result of external factors such as war or weather beyond human control. They began to believe that recessions are a natural occurrence in the global economy. However, with further analysis of the system of business cycles, various factors have been discovered to be responsible for the occurrence of recessions.

The causal factors of recessions can be categorized into economic, financial, and psychological. From an economic perspective, a major change or shift in elements like consumer prices and industry structure can lead to increased costs in the economy, thereby giving rise to a recession. From a financial point of view, factors such as credit growth and money supply need to be kept in check to avoid a recessionary situation. Moreover, from the psychological perspective, factors such as a lack of investor confidence and a pessimistic outlook contribute to economic slowdown. A factor, however, that is grossly overlooked is the gradual change in technology around the time of a recession. Technological change is an aspect that not only influences a recession but in turn, is also influenced in the aftermath of a recession.

© INNOVATIVE RESEARCH THOUGHTS
Refereed | Peer Reviewed | Indexed
ISSN : 2454 – 308X | Volume : 09 , Issue : 04 | July - September 2023
DOI : https://doi.org/10.36676/irt.2023-v9i4-018

Technology has played a vital role in accelerating economic growth over the course of human history. Beginning with the industrial revolution that saw production increasing to unbelievable levels, to the growth of the IT industry and technologies like Generative AI, technology has come a long way in the past 2 centuries. However, it is an accepted fact of life that every innovation carries a host of disadvantages along with the benefits it provides. Technology helps automate and enhance business processes, however, at the same time it leads to unemployment, lack of creativity, and environmental concerns. It has also emerged as a contributing factor to the existence of recessions in modern economies. Looking back at the early example of the Great Depression of 1929, rapid economic output growth and productivity growth through techniques of mass production and assembly lines led to excess productive capacity and a decrease in wages and working time of workers. This alarming rise in productivity over the past decades leading to 1929 resulted in an economic slowdown. Several economists today are concerned that the elimination of entire job categories by AI and robotics could trigger recessions.

There have been various research papers published depicting the correlation between recession occurrences and inflation, unemployment, etc. through detailed empirical analysis. Through this paper, we provide a detailed explanation of how economies are affected as a result of substantial technological change and the consequent situations which lead to a recession. The world has seen various recessions in the past that have slowed down the growth of the world economy by a significant pace. Notable examples include the recessions of 1975, 1982, 1991, and 2009. We will trace the level of technology changes during these periods and take a look at the transition that took place in or around this time interval. We will try to establish a relationship between technological change and economic slowdown to provide a better basis for technology as a cause of a recession.

This paper will look to establish a cause-and-effect relationship between technological change and recession by the use of two alternative approaches. Through the first approach, we will look to quantify the level of technological change as a measure of the R&D spending efforts undertaken by countries during times of recession. While through the second approach, we will trace the changes in occupational and employment structures of prominent countries to understand if there was a substantial shift in jobs from routine/less-skilled to high-skilled jobs as a result of technological change. We will closely analyze data published by organizations such as International Labour Organization (ILO), Organization for Economic Co-operation and Development (OECD), and World Intellectual Property Organization (WIPO) to establish a valid hypothesis. The rest of this paper proceeds as follows. Section 2 presents the literature review which constitutes previous findings on the topic, while section 3 explains our research objective and methodology. Section 4 provides data to support our initial notion and a detailed analysis of those facts and figures. The conclusion and recommendations of the research are listed under Section 6 of this paper.

Literature Review

Recession as an economic term came to be widely used by the start of the 20th century. With global trade being largely scattered and differentiated throughout the 19th and early 20th centuries, the world was privy to the concept of recessions and economic slowdowns. However, with the arrival of the Great Depression of 1929, the global economy experienced a sudden shock. What followed was a flurry of recessions spread throughout the 20th century and the early 21st century. This pushed economists to establish models and frameworks to explain the causes and factors behind the occurrence of a recession. It all started with the British Economist John Maynard Keynes who proposed the “General Theory of Employment, Interest and Money” to provide a theoretical framework to explain the reasons behind the occurrence of the Great Depression in the 1930s. Through this theory, he necessitated the importance

ISSN : 2454 – 308X | Volume : 09 , Issue : 04 | July - September 2023
DOI : https://doi.org/10.36676/irt.2023-v9i4-018

of government intervention in the grand scheme of things. He advocated that governments can employ tools such as taxes and public expenditure to encourage demand and avoid the existence of recessions. He overthrew the then-prevailing notion that the free market automatically corrects itself in the long run through self-balancing mechanisms.

With further developments in economics, a new theory of Monetarism emerged in the 1970s that sought to challenge the ideas of Keynesian Economics. The theory highlighted the importance of money supply in the global economy. They advocated the increased effectiveness of monetary policy in comparison to the fiscal policy provided by Keynesian economics. This theory came under criticism by Keynesian economists mainly due to the belief that even though monetary policy could help regulate nominal elements like the prices of commodities and wages, it couldn't possibly effect a change in the elements of output and employment. With the arrival of the Great Recession of 2007-08, the principles and concepts of Keynesian Economics played a vital role in helping the government to get the economy back on track. However, the 2007–2008 financial crisis also demonstrated that Keynesian theory needed to better take into account the financial system's function. By combining the real and financial sectors of the economy, Keynesian economists are attempting to fix that gap.

Economic growth is an essential tool for the measurement of the degree of advancement and progress in countries throughout the world, and technological change has emerged as one of the major factors affecting economic growth and continues to contribute to the upgradation and advancement of modern production methods. Hence, technological change is considered the main catalyst for economic growth and societal progress. Spending on the development of new technologies, research, and process automation thus, improves the level of competition in the industry and leads to further progress. This ensures that economic growth is achieved in a sustainable and planned manner. Moreover, it ensures economic growth without the expense of large depletion of natural resources for the sake of future generations.

With various economists and researchers trying to identify other causes or reasons for the occurrence of recessions, a number of research papers have been published. In line with the objective of this research paper, several papers have been published trying to explain the relationship between technological change and economic growth.

The paper titled "Technological innovation and the demand for labor by firms in expansion and recession" by Javier Ortiz and Vicente Salas Fumas (2019) analyzed the scale of product and process innovations in Spain with reference to the demand for labor during the period 2003-2014 with a key focus on the recession of 2007-2009. It found that the number of product and process innovations witnessed a steady decline in the aftermath of the financial crises, i.e., from 2009 to 2014. The firms undertook these innovations during the period of expansion till 2008 and stopped innovating further after the financial recession period.

The research paper titled "The Impact of Technology on Economic Growth: Some New Ideas and Empirical Considerations" by Ivo de Loo and Luc Soete (1999), has tried to provide possible explanations for the productivity paradox associated with technical change and economic growth through the use of R&D models. They provided the explanation that while R&D efforts have significantly increased across various countries, they have been aimed more toward product differentiation rather than ground-breaking innovations which have only made a limited effect on the economic growth.

In another paper titled "Did Technology Shocks Cause the 1990-1991 Recession?" by Gary D. Hansen and Edward C. Prescott (1993) under the American Economic Review, the researchers produced a model economy by introducing various parameters. They concluded that the model economy adjusted more quickly to technological shocks than the actual economy during that time period indicating that

© INNOVATIVE RESEARCH THOUGHTS
Refereed | Peer Reviewed | Indexed
ISSN : 2454 – 308X | Volume : 09 , Issue : 04 | July - September 2023
DOI : https://doi.org/10.36676/irt.2023-v9i4-018

technological shocks were not the sole responsible factor for the recession. They reckoned that various factors other than technical change contributed to the slow recovery of the actual economy in the aftermath of the recession.

Research Methodology

The purpose of this research is to arrive at an efficient metric to estimate the level of technological change prior to the occurrence of recessions and establish a reasonable explanation for the role of this technological change in the contraction of the economy.

In this paper, we'll be taking the help of two different frameworks to see the level of technological change through the periods of recession. By the way of the first framework, we will be looking at the R&D spending statistics of Organization for Economic Co-operation and Development (OECD) countries from 1991 to 2015. OECD is an intergovernmental organization comprising 38 member countries which together hold a 42.8% share of the global GDP as of 2017. The data pertaining to gross R&D spending for time periods before 1991 couldn't be obtained due to the unavailability of data. The reason behind choosing R&D statistics as a way of estimating technological change is simply because it depicts the amount a country is investing in innovation. It is one of the leading indicators of investment in technologies of the future.

However, R&D can be incurred for equivalent or non-equivalent innovations. Equivalent innovations simply can refer to the advancement of current technology or processes. Concepts such as product differentiation would be covered under the ambit of equivalent innovations since it is merely an expansion of current technology practices. Non-equivalent innovations, on the other hand, would refer to the creation of new technological processes and products completely different from existing technologies. These include newer and better ways of doing things through advanced technology like Artificial Intelligence, Machine Learning, etc. Our objective would be to trace the developments in non-equivalent innovations as they have the potential to induce substantial technological change.

In order to trace non-equivalent innovations, we will need to obtain sufficient data on the number of patents granted during the same time period as non-equivalent innovations are patented more often than equivalent innovations. This is due to the fact that non-equivalent innovations require a significant amount of expenditure and effort and hence are granted patents to ensure unilateral benefits for the researcher or organization involved in its development for a specific time frame.

For the purpose of our research, we will obtain data on total patent grants around the world from 1991 to 2015 from the database of the World Intellectual Property Organization (WIPO). WIPO compiles data on global patent research from the major patent offices in the world, including but not limited to the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO), and the Japan Patent Office (JPO). The ratio of the number of patents granted from 1991 to 2015 to the gross spend on R&D will provide us with an appropriate estimate of the proportion of R&D spending that went towards the development of non-equivalent innovations, i.e., advanced technologies and processes.

The second framework looks to quantify technological change by tracing the change in the occupational/employment structure of countries during a recession. It is a common notion that technological change brings with itself, a reduction in the number of low-skilled or routine jobs prevalent in the economy. A dramatic or gradual reduction in the number of low-skilled and routine jobs can signal a change toward automation and jobs requiring high skill. Technological change is viewed as a job-destroying innovation because its main goal is to increase business productivity, i.e., to reduce the resources, including labor, required to produce a given level of output. The resulting job

© INNOVATIVE RESEARCH THOUGHTS
Refereed | Peer Reviewed | Indexed
ISSN : 2454 – 308X | Volume : 09 , Issue : 04 | July - September 2023
DOI : https://doi.org/10.36676/irt.2023-v9i4-018

losses can lead to an uptick in unemployment and affect whole sectors of the economy risking an economic slowdown in the short term.

Continuing on this line of reasoning, we will, by obtaining data on the employment mix of G-7 countries from the International Labor Organization (ILO) database, try to analyze the proportionate increase/decrease in the number of jobs of different skill levels from the beginning of 2007 to the end of 2010, a period representative of the Great Recession. G-7 countries act as a strong indicator of the state of the world economy since they constitute roughly 30.7% of the global GDP as of 2021. Along with that, most of the G-7 countries were generating a majority of their gross domestic product from the services and industrial sectors thereby acting as an effective indicator of technology change's influence on the world economy.

A decrease in the number of low-skilled jobs in these countries during the period in consideration will help us make a point for technological change's influence on the economy during the great recession of 2007-2009. For the purpose of this research, we will make use of various tools, i.e., charts and graphs including line charts, bar charts, and waterfall charts to effectively represent the data required and conduct further analysis. The 2 frameworks will enable us to develop sufficient reasoning for the economic influence of technological change.

Data Analysis and Discussion

R&D Spending and Patent Model

Under the R&D spending and patent model, we have obtained the data of OECD countries and will look closely at the periods closely following the recessions of 1991-92 and 2007-09. A normal assumption would be that consumer spending would increase in times of economic expansion and would decrease during slowdowns. This further means that R&D spending would contract during times of recession because companies will be more cautious and aware that consumers won't be looking for any new products or services due to low demand and high savings.

Keeping the above-mentioned assumption in mind, we will take a look at the figures relating to R&D spending and try to form a logical argument based on the analysis. Figure 1 contains the data on gross R&D spending undertaken by OECD countries during the time period 1991 to 2015. The data provide compiled information on R&D spending by the highly affluent and developed nations of Europe including the United Kingdom, France, Germany, Spain, and Italy.

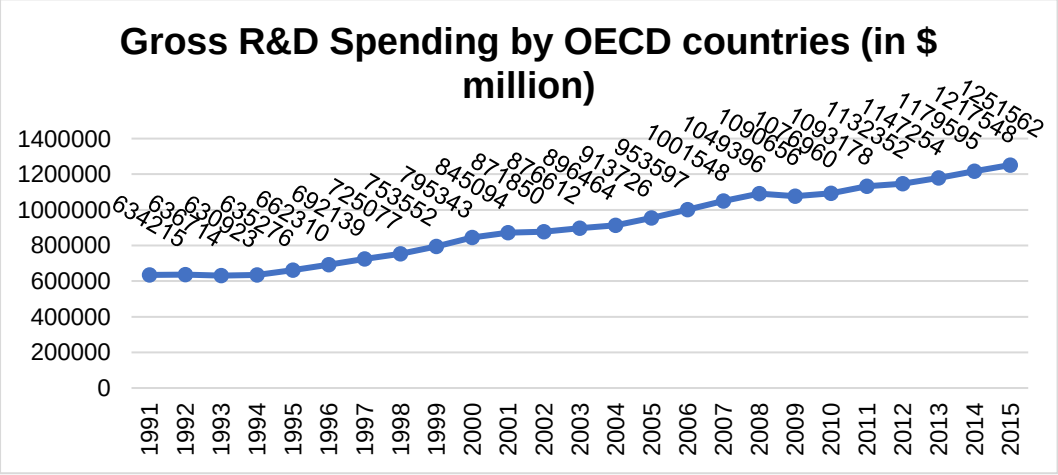

Figure 1

© INNOVATIVE RESEARCH THOUGHTS
Refereed | Peer Reviewed | Indexed
ISSN : 2454 – 308X | Volume : 09 , Issue : 04 | July - September 2023
DOI : https://doi.org/10.36676/irt.2023-v9i4-018

The above figure shows that gross R&D spending has taken the form of a rising curve depicting an upward trend. Looking at the period of 1991-92 and 2007-09 in isolation, we can observe that R&D spending remained strained from 1991 to 1994 with only a $1000 million increase owing to the 1991 recession. While R&D spending decreased for the first-time year-on-year in 2010 since 1992 in the follow-up of the Great Recession of 2009. The data, therefore, seems to be in line with the normal assumption.

However, looking at the trend of R&D spending alone only provides us with an estimate of the level of money pooled into technological development by countries. To find out the share of R&D spending that is incurred on the development of non-equivalent innovations, there is a need to correlate it with the number of patents filed during the same period. Patents represent a significant innovation different and unique from the existing and prevailing technologies available in the market.

Therefore, our next objective is to identify the amount of R&D spending that has been done toward non-equivalent innovations. For that purpose, we have generated a detailed line graph as shown in Figure 2 depicting the total amount of patents granted all over the world from the time period in consideration, i.e., 1991 to 2015. The data has been collected from WIPO's database on total patent grants.

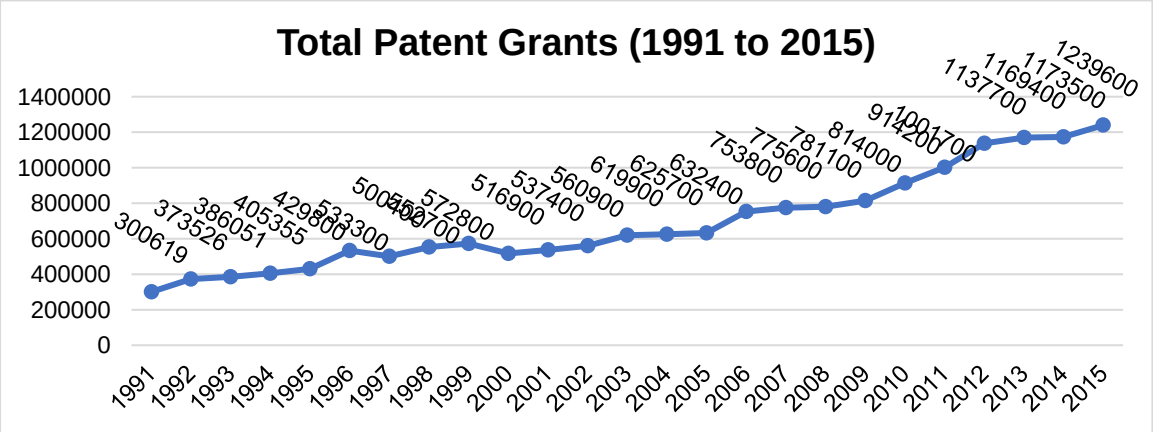

Figure 2

Figure 2 again shows that the number of patent grants all over the world have seen a significant rise owing to better R&D infrastructure expansion. At the same time, looking at the patent data points for the period of 2007-09 in isolation, we can see that patent grants saw a significant rise in the years of expansion prior to 2007 with a record increase of 19.2% in patent grants in 2006 from 2005.

Now looking at patent grants data and R&D spending in isolation wouldn't be beneficial to formulate a conclusion for technological change's impact on recessionary situations so we will prepare another line chart representing that ratio of patents granted to the R&D spending to get an estimate of the increase/decrease in non-equivalent innovations for the periods in consideration.

Figure 3 represents the ratio of the number of patents granted all over the world to R&D spending undertaken by OECD countries providing us with an adequate metric for tracing the level of technological change in the past 30 years as it entirely represents the investment in non-equivalent innovations with wide applications for the economy.

© INNOVATIVE RESEARCH THOUGHTS
Refereed | Peer Reviewed | Indexed
ISSN : 2454 – 308X | Volume : 09 , Issue : 04 | July - September 2023
DOI : https://doi.org/10.36676/irt.2023-v9i4-018

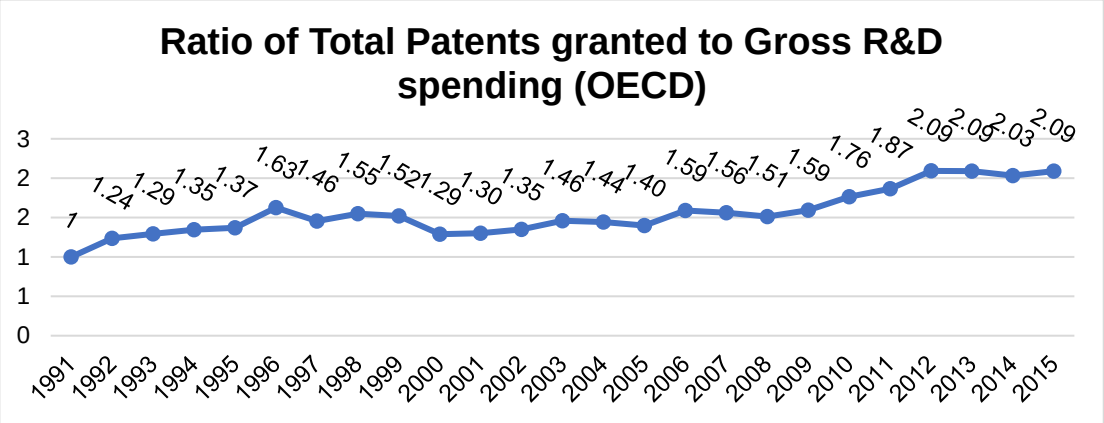

Figure 3

The above figure effectively depicts the ratio of patents granted to Gross R&D spending with 1991 taken as the base year. The ratio has varied through the years but it does not show a definite pattern leading to the periods of recession. As per the normal assumption, for technological change to lead to recessions, there should have been a rise in investment for non-equivalent innovations for the period leading up to the 2007-09 recession. It can be observed that the ratio in the period of expansion leading up to the recession, i.e. from 2002 to 2006 averaged around 1.5 with no major increase or decline.

This framework doesn't help us to conclusively prove that technological change saw a major uptick leading to the periods of recession and explain how it could have triggered a recession. It has provided us with an inconsistent trend of information proving inadequate to reach a conclusion.

Occupational Change/Labor Model

Under this framework, we operate under the assumption that technological change reduces the amount of low-skilled or routine jobs in the economy by developing advanced technologies for automation and workload reduction. We have obtained the data for the employment composition in G-7 countries across the years 2007 to 2010 categorized on the basis of different skill levels. The data has been obtained from the ILO's database and categorizes the skill levels of jobs into 4 different levels: Skill Level 1 which represents jobs with the lowest skills in the economy, Skill Level 2 which represents jobs requiring a medium level of skills, and Skill Level 3 & 4 which represent the high skilled jobs in the economy. The objective of this framework is to quantify the level of technological change through a reduction in routine jobs and a subsequent increase in high-skilled jobs during the period of the 2007-2009 recession.

Table 1: Employment by Occupation in G7 Countries (Skill Level 1 - Low) (in thousands)					
Countries	2007	2008	2009	2010	% change
Canada	1395.9	1374.1	1270	1294	-7.30%
France	2443.867	2486.894	2460.317	2471.645	1.14%
Germany	3185.803	3260.401	3169.418	3101.804	-2.64%
United Kingdom	3119.449	3101.394	2968.863	2956.99	-5.21%
Japan	20060.95	19574.9	18568.19	18324.12	-8.66%
United States	12772.96	12624.2	11766.94	11707.49	-8.34%
Italy	2065.507	2163.181	2251.011	2354.426	13.99%

© INNOVATIVE RESEARCH THOUGHTS
Refereed | Peer Reviewed | Indexed
ISSN : 2454 – 308X | Volume : 09 , Issue : 04 | July - September 2023
DOI : https://doi.org/10.36676/irt.2023-v9i4-018

Table 1 shows the number of people employed in low-skilled jobs in G-7 countries from 2007 to 2010. We'll take a look at each of the G-7 nations one by one to see if there has been a change in absolute employment in low-skilled jobs. It can be observed that most of the G-7 nations barring France and Italy have experienced a major decline in the low-skilled job sector with the decline being as high as 8.66% for Japan by the end of 2010. It goes on to show the reduced dependence of the largest economies of the world on low-skilled jobs. Italy being the only outlier in this data experienced a growth of 13.99% in low-skilled jobs in 2010 in comparison to 2007.

Table 2: Employment by Occupation (Skill Level 2 - Medium) (in thousands)					
Countries	2007	2008	2009	2010	% change
Canada	8413.1	8463.7	8216.9	8249.9	-1.94%
France	12585.81	12499.64	12289.09	12150.8	-3.46%
Germany	18489.38	18597.89	18311.13	17879.5	-3.30%
United Kingdom	13704.39	13683.71	13359.1	13305.19	-2.91%
Japan	31674.79	31821.3	31803.63	31653.47	-0.07%
United States	68141.36	67163.42	63405.2	63310.33	-7.09%
Italy	11347.67	11505.79	11384.55	11326.21	-0.19%

Table 2 shows the number of people employed in skill level 2, i.e. medium-skilled jobs in G-7 countries from 2007 to 2010. It depicts a consistently falling trend across all the G-7 nations in the medium-skilled jobs category. United Kingdom, France, Germany, and the United States turned out to be the biggest losers in this case with falls of 3.46%, 3.3%, 2.91%, and 7.09% respectively in the skill level 2 category.

Table 3: Employment by Occupation (Skill Level 3 & 4 - High) (in thousands)					
Countries	2007	2008	2009	2010	% change
Canada	7026.8	7258.9	7237.8	7419.6	5.59%
France	10151.42	10561.12	10589.97	10772.26	6.12%
Germany	15627.47	16021.27	16319.03	16340.49	4.56%
United Kingdom	12275.34	12558.7	12564.02	12670.03	3.22%
Japan	11072.8	11142.9	11338.31	11399.12	2.95%
United States	65132.2	65574.77	64705.32	64046.14	-1.67%
Italy	9231.91	9178.707	8814.495	8587.749	-6.98%

Table 3 depicts the number of people employed in skill level 3 & 4 jobs, i.e. the high-skilled jobs in the G-7 countries from 2007 to 2010. Contrary to low-skilled and medium-skilled jobs, high-skilled jobs have observed an increase in the number of people employed in the high-skilled sector in most of the G-7 economies during the time period. Canada, France, Germany, the UK, and Japan observed a substantial increase in high-skilled jobs with percentage growths north of 3% for all of them. The United States and Italy were the outliers as they saw decreases of 1.67% and 7% respectively in the high-skilled job category.

To formulate an effective conclusion, we will need to look at the data across all the 3 categories in consolidation. Figure 4 shows a cumulative view of the percentage increase and decrease for all the G-7 countries for the time period in consideration as shown below.

© INNOVATIVE RESEARCH THOUGHTS
Refereed | Peer Reviewed | Indexed
ISSN : 2454 – 308X | Volume : 09 , Issue : 04 | July - September 2023
DOI : https://doi.org/10.36676/irt.2023-v9i4-018

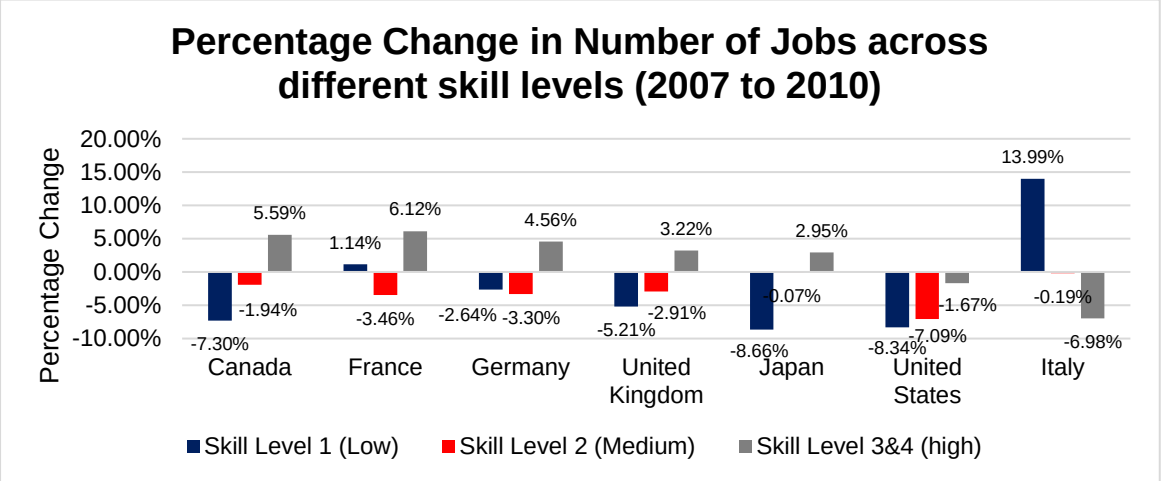

Figure 4

Figure 4 clearly shows a similar trend, i.e., a heavy decline in Skill Level 1: Low-Skilled jobs and Level 2: medium-skill jobs and a subsequent increase in the amount of Skill Level 3 & 4: High-skilled jobs across most of the G-7 countries. The United States being the worst-hit country during the Great Recession of 2007-09, suffered a decline across all the job categories with low-skilled jobs and medium-skilled jobs leading the way. Italy is the only country out of the G-7 group that has experienced a contrasting effect in its employment mix with larger growth in low-skilled jobs followed by a decline in the number of high-skilled jobs.

The above data analysis, therefore, makes a great case for technological change leading to significant alterations in the employment mixes of G-7 countries and having a huge impact on the occurrence of recessions. However, even though it can be deduced that technological change played an important part in the decrease in low and medium-skilled jobs, we cannot say with certainty that it is the only reason. Alternative explanations include efficient upskilling projects introduced in the country, a greater shift to the services sector from the primary and industrial sectors, and a change in labor supply composition.

Conclusion and Recommendations

The R&D framework has been inefficient in proving the relevance of technological change for the recessionary years of 1991-92 and 2007-09. It has provided us with a great way to quantify substantial technological change through non-equivalent innovations. At the same time, it has produced contradictory results to the initial hypothesis. In an ideal situation, for technological change to have played a significant growth in economic contraction, there should have been a rapid increase in the ratio of patenting and R&D spending by countries through the expansionary period preceding the recession. Nevertheless, the data shows that the ratio remained constant averaging around 1.5 from 2002 to 2006 in case of the great recession of 2007-09, and grew rapidly during the period of recession. Similarly, the 1991-92 recession also experienced higher growth in technological change during the recession.

The R&D framework also suffers from a few limitations. Through the use of patents, we tried to distinguish non-equivalent from equivalent innovations, however, it is not a perfect estimate as R&D spending could also have been done for equivalent innovations during the same time period. Also, even if the scale of non-equivalent innovations had increased, it was difficult to attribute it directly to the change in business processes, unemployment, and contraction of output.

The Labour/Employment mix framework on the other hand has provided us with favorable results that seem to be in line with the initial hypothesis. The framework has shown a consistent trend of decline in

the number of people employed in low-skilled and medium-skilled jobs with a subsequent increase in high-skilled job workers in most of the G-7 countries during the period of the recession of 2007-09. It goes on to show that technological change has led to a loss in jobs requiring lesser skills in the economy due to improvement in business processes and activities during that period. However, this framework also suffers from major limitations. First of all, it seems to present an incomplete explanation as it is not sufficient to develop a direct correlation between technological change and economic slowdown. Along with that, a change in the employment mix from low-skilled to high-skilled could also be due to high literacy rates, involvement of more women in the workforce, upskilling initiatives, higher growth in the services sector, and changes in labor supply.

Future Research should focus on further refinement of R&D spending and patent model along with the Labor Model. This involves tracing the purpose of each patent filed during the time period in consideration and establishing a clear distinction in the number of equivalent and non-equivalent innovations. It would help us get rid of the assumption that patents are attributed to non-equivalent innovations. However, due to a lack of sufficient secondary data and time constraints, it is difficult to achieve this objective. Moreover, concerning the Labor Model, further emphasis can be laid on the establishment of an empirical approach to understanding how the economy responds to the change in the labor mix and the underlying role of technological change in the process.

Attempts to quantify technological change always seem to be challenging as it is a dynamic concept that can be experienced but is always difficult to measure. Through the existence of such R&D and employment mix frameworks, a researcher can only add to further speculations and arrive at insufficient solutions but cannot conclusively depict the effect of technological change on the economy.

References

1. Anghel, B., De La Rica, S., & Lacuesta, A. (2014), *The impact of the great recession on employment polarization in Spain*, SERIEs, 5(2–3), 143–171. https://doi.org/10.1007/s13209-014-0105-y

2. Autor D, Levy F, Murnane R (2003), *The skill content of recent technological change: an empirical investigation.*
3. Baumann, J., and A. Kritikos. (2016), *"The Link Between R&D, Innovation and Productivity: Are Micro Firms Different?"*, Research Policy 45
4. Brynjolfsson, E., and A. McAfee. (2011), *Race Against the Machine. How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy*, Lexington, MA: Digital Frontier Press.
5. Buerger, M., T. Broekel, and A. Coad. (2012), *"Regional Dynamics of Innovation: Investigating the Co-Evolution of Patents Research and Development (R&D), and Employment."*, Regional Studies 46: 565–582.
6. Çalışkan, H. K. (2015), *Technological Change and Economic Growth*, Procedia - Social and Behavioral Sciences, 195, 649–654. https://doi.org/10.1016/j.sbspro.2015.06.174
7. Conlisk, J., (1967), *'A Modified Neoclassical Growth Model with Endogenous Technical Change'*, The Southern Economic Journal 34
8. Freeman, C., (1989), *"New Technology and Catching Up"*, The European Journal of Development Research, June 1989, No. 1.
9. Goos M, Manning A, Salomons A (2010), *Explaining job polarization in Europe: the roles of technology, globalization and institutions*, CEP Discussion Paper No 1026, November
10. Greenan, N., and D. Guellec. (2000), *"Technological Innovation and Employment Reallocation."*, Labour 14 (4): 547–590.

ISSN : 2454 – 308X | Volume : 09 , Issue : 04 | July - September 2023
DOI : https://doi.org/10.36676/irt.2023-v9i4-018

11. Grossman, G.M. and Helpman, E., (1991), *Innovation and Growth in the Global Economy*, MIT Press, Cambridge
12. Hansen, G. D., & Prescott, E. C. (1993), *Did Technology Shocks Cause the 1990-1991 Recession*, The American Economic Review, 83(2), 280–286. http://www.jstor.org/stable/2117678
13. Hershbein, B., & Kahn, L. (2016), *Do Recessions Accelerate Routine-Biased Technological Change? Evidence from Vacancy Postings*, National Bureau of Economic Research. https://doi.org/10.3386/w22762
14. Loo, Ivo & Ivo, & Soete, Luc & Luc,. (1999), *The Impact of Technology on Economic Growth: Some New Ideas and Empirical Considerations*.
15. Ortiz, J. U., & Salas-Fumás, V. (2020), *Technological innovation and the demand for labor by firms in expansion and recession*, Economics of Innovation and New Technology. https://doi.org/10.1080/10438599.2019.1629535
16. Rodeck, D. (2022, July 12). *What Is a Recession?* Forbes Advisor. https://www.forbes.com/advisor/investing/what-is-a-recession/
17. Thompson, C. (1988). *High-Technology Development and Recession: The Local Experience in the United States, 1980-1982*, Economic Development Quarterly, 2(2), 153–167. https://doi.org/10.1177/089124248800200205
18. ILO Department of Statistics. (n.d.). Statistics on employment. ILOSTAT. https://ilostat.ilo.org/topics/employment/?
19. ILO Department of Statistics. (n.d.-a). International Standard Classification of Occupations (ISCO). ILOSTAT. https://ilostat.ilo.org/resources/concepts-and-definitions/classification-occupation/
20. Research and development (R&D) - Gross domestic spending on R&D - OECD Data. (n.d.). theOECD. https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm
21. WIPO - Search International and National Patent Collections. (n.d.). https://patentscope.wipo.int/search/en/search.jsf
22. What is a recession? (2022, December 12). McKinsey & Company. https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-a-recession
23. The Editors of Encyclopaedia Britannica. (2006, June 9). Keynesian economics | Definition, Theory, Examples, & Facts. Encyclopedia Britannica. https://www.britannica.com/topic/Keynesian-economics
24. What Is Keynesian Economics? - Back to Basics - Finance & Development, September 2014. (n.d.). https://www.imf.org/external/pubs/ft/fandd/2014/09/basics.htm