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Total Factor Productivity – Its Decomposition and Determinants

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Total Factor Productivity
– Its Decomposition and Determinants

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Sammanfattning

Syftet med föreliggande produktivitetsprojektet har varit att undersöka möjligheterna att studera produktivitet med hjälp av något mer moderna och kompletta metoder, jämfört med det som vanligtvis används. Arbetet presenteras i två rapporter där föreliggande rapport är del 2. Vår slutsats är att produktivitet låter sig mätas med moderna metoder varför studier som syftar till att mäta produktivitet mycket väl kan använda dessa metoder och index. Att använda partiella mått eller andra förenklingar kan få konsekvenser för de policyrekommendationer som riktas.

I den första rapporten (Unikrishnan & Månsson, 2023) var utgångspunkten en replikering av Färe et al. (1994). Motivet var att få ett riktmärke för vilken modell som används för att mäta produktivitet, vilka input(s) och output(s) som kan användas samt vilken datakälla som kan användas. Syftet var att med utgångspunkt från replikeringen utöka analysen till att omfatta en längre tidsperiod. I Unikrishnan & Månsson (2023) drogs slutsatsen att datakällan som användes i Färe et al. (1994), Penn Wold Table, var för volatil mellan versioner för att kunna användas i en studie av produktivitet som sträckte sig över flera år. Bland annat visade en korrelationsanalys av mellan version 5 och version 10 avseende inputs på en låg och negativ korrelation. Detta faktum har även observerats av andra (se exempelvis Johnson et al., 2013). Därför rekommenderade vi en alternativ databas, iSTAN-databasen från OECD. Våra resultat och slutsatser avseende några av nyckelfrågorna i första rapporten, och således utgångspunkten för denna rapport, var att:

a) Samma modellspecifikation som i Färe et al. (1994) används

b) Datakällan utgörs av iSTAN-data från OECD

c) För att mäta produktivitet kan Bjurek – Hicks – Moorsteens (BHM) produktivitetsindex användas. Det produktivitetsindex som används har alla positiva egenskaper som Malmquist-indexet, vilket används i Färe et al. (1994), men det bygger på färre antaganden, det vill säga icke-testbara förutsättningar.

I denna rapport tar vi det empiriska arbetet vidare och presenterar Sveriges totala faktorproduktivitet (TFP) jämfört med grupper länder.

• Sverige jämfört med olika ländergrupper

I rapporten konstrueras tre ländergrupper, Small Advanced Open Economies (SAOE), Major Advanced Open Economies (MAOEs) samt Advanced Open Economies (AOEs). Ett resultat är att det föga förvånande är stora skillnader i de slutsatser och potentiella rekommendationer som kommer från de olika jämförelserna. När Sverige jämförs med SOAE-länderna, vilka är definierade på basis av att de är lika Sverige i en rad dimensioner, framstår Sverige som det land som har den högsta produktivitetsutvecklingen. Jämfört med MAOE-länderna tenderar Sverige att släpa efter vilket även är fallet i jämförelse med AOE-länderna. En första slutsats är därför att om policy ska bygga på länder jämförelser så är det viktigt att de länder som används som måttstock åtminstone likar Sverige i centrala egenskaper. I rapportens resultatredovisning har huvudfokus varit jämförelsen med de små öppna avancerade ekonomierna.

Uppdelning av totalfaktorproduktivitet

TFP beräknade med BHM-indexet kan, till skillnad från de traditionella tillvägagångssätt där TFP ofta behandlas som ett enda aggregerat mått, delas upp i minst två komponenter: teknisk förändring (TC) och effektivitetsförändring (EC). Detta gör det möjligt att få en mer nyanserad kunskap om de faktorer som driver produktiviteten. Uppdelningen i TC och EC hjälper oss att identifiera potentiella bidrag från tekniska framsteg som görs i de länder som jämförs, och som även kan dra med sig svensk produktivitet, och särskilja dem från bättre resursutnyttjande.

Uppdelningen i TC och EC indikerar att Sverige, sett till teknisk förändring, sticker ut. Något som skiljer Sverige från jämförelseländerna är Sveriges investeringar i teknik och FoU, vilket sannolikt ligger bakom resultaten. Det finns dock en eftersläpning mellan teknisk förändring och effektivitetsförändring. Efterfrågefluktuationer och kriser kan bromsa införandet och implementeringen av ny teknik, vilket kan försena effektivitetsvinster. Resultaten visar på ett mönster där effektivitetsvinster kommer något efter de förändringar vi kan se i den komponenten som visar på tekniska framsteg. i hur företag tar till sig ny teknik, där vissa är "tidiga användare" och andra "eftersläpande". Tidiga användare utnyttjar effektivt teknisk utveckling, medan eftersläntrarna ligger kvar med ”gammal” teknik, vilket leder till olika effekter på produktiviteten.

De sektoriella analyserna visar på att det finns en heterogenitet. Medan tillverkningsindustrin uppvisar en hög produktivitetsutveckling i relation till andra små avancerade öppna ekonomier visar resultaten det motsatta för servicesektorn.

Variationer i totalfaktorproduktivitet

Även om dekomponeringen ger en beskrivning av hur utvecklingen skett så finns det faktorer som ligger utanför själva produktionen som påverkar densamma. I detta sammanhang talar vi om tre olika grupper av faktorer. Den första gruppen av faktorer utgörs av ledningens förmåga att fatta rätt beslut. Denna grupp av faktorer kräver att vi vet vilken/a som utgör företagsledning och den informationen saknas på den aggregeringsnivå vi har data. Den andra gruppen av faktorer utgör sådana som exogena för produktionen och som ledningen inte kan påverka. Ett exempel på dessa är väder vilket påverkar exempelvis jordbruks, byggnads och turismsektorerna. En tredje uppsättning av faktorer är sådana som är exogena för produktionen, men där ledningen kan välja att agera eller inte agera, kan agera snabbt eller långsamt etc.. På den aggregeringsnivå denna studie görs är det främst faktorer av det andra och tredje slaget som har inkluderats i regressionsanalyserna.

Variablerna i regressionsanalyserna har delats in i makroekonomiska faktorer, innovationer och FOU, arbetskraftens sammansättning, institutionella förhållanden samt chocker. I regressionerna har vi även inkluderat landets samlade värde av materiella och immateriella tillgångar.

Av de makroekonomiska faktorerna är det bara variabeln som indikerar hur öppet ett land är för utbyte med andra länder. Denna är positiv och signifikant, vilket indikerar att öppnare länder i regel har en högre produktivitet.

Både för variablerna materiella och immateriella tillgångar visar resultaten på en fördröjning innan investeringar ger produktivitetsvinster. FoU-utgifter uppvisar på samma sätt en eftersläpande positiv inverkan på TFP, vilket indikerar att det tar tid för att omvandla innovationer till produktivitetsförbättringar och därigenom ökad konkurrenskraft. Ingen av de institutionella variabler var inte signifikanta, vilket med stor sannolikhet beror på de länderna som studeras här är lika i många av de institutionella dimensionerna som mäts, vilket innebär mycket liten variation mellan länderna. När det gäller de chocker som inträffat under perioden så är det främst Eurozonkrisen som påverkade. Enligt resultaten sjönk produktiviteten med ca. 1.2% under perioden 2008 till följd av global finanskris.

När det gäller de sektoriella analyserna är en första iakttagelse att det är relativt stor skillnad mellan tillverkning- och servicesektorerna. Resultaten visar att det är snarare importvolymen som är viktig för tillväxten i tillverkningssektorn medan växelkursen är viktig för servicesektorn. Som förväntat är tillgångar och FoU viktigare för utvecklingen och konkurrenskraften hos tillverkningsindustrin än för servicesektorn. Av de chocker som kontrolleras för visar resultaten att Covid hade en svag positiv påverkan på produktiviteten för båda sektorerna.

Som inledningsvis nämndes så har utgångspunkten för hela produktivitetsprojektet varit att undersöka möjligheterna att studera produktivitet med hjälp av något mer moderna och kompletta metoder, jämfört med det som vanligtvis används. Vår slutsats är att produktivitet låter sig mätas med moderna metoder varför studier som syftar till att mäta produktivitet mycket väl kan använda dessa metoder och index. Att använda partiella mått eller andra förenklingar kan få konsekvenser för de policyrekommendationer som riktas. Vidare går det genom att använda mer moderna metoder att få fram mer information om vad som driver produktivitetsutvecklingen, varför bättre underlag för exempelvis industri och tillväxtpolitik fås.

Även om arbetet har svarat på en del frågor så har även nya frågor och områden identifierats. En av slutsatserna av detta arbete är, föga överraskande, att vid länder jämförelser så är valet av jämförelseländer av stor betydelse. I studien har vårt val av SAOE-länder baserats på att de uppvisar likheter med Sverige i ett antal observerbara dimensioner, vilket vi anser löser lite av problematiken av att välja jämförelseländer. Det behövs dock ytterligare forskning hur en jämförbar landsgrupp kan konstrueras. Ytterligare ett område, där det pågår ett utvecklingsarbete, är att bygga produktivitetsindexen utifrån aggregerade sektoranalyser snarare än att beräkna produktivitet på redan aggregerade data. Detta kräver dock tillgång till mikrodata. Likaså finns det fler grupper av förklaringsvariabler som inte funnits, eller kommer att finnas, tillgängliga på aggregerad nivå. Exempelvis utbildning och erfarenheter hos företagsledningen. Även dessa analyser kräver mikrodata.

Summary

The starting point for the entire productivity project has been investigating the possibilities of studying total factor productivity (TFP) by employing somewhat more modern and complete methods compared to what is usually used. The work is presented in two reports, of which the present report is the second part. Our conclusion is that productivity and productivity changes can be measured using modern methods, which is why studies aimed at measuring TFP can use these methods and indices. Using partial measures or other simplifications may have implications for the policy recommendations that are targeted.

In the first report (Unnikrishnan & Månsson, 2023), the starting point was a replication of Färe et al. (1994). The motive was to get a benchmark for which model is used to measure productivity development, which input(s) and output(s) can be employed, and which data source can be utilized. The aim was to expand the analysis to cover a longer period of time based on the replication. The report concluded that the data source used in Färe et al. (1994), the Penn World Table, was too volatile between versions to be used in a study spanning several years. Among other things, a correlation analysis between version 5 and version 10 regarding inputs showed a low and negative correlation. This has also been observed by others (see, for example, Johnson et al., 2013). Therefore, we recommended an alternative database, the iSTAN database from the OECD. Furthermore, in recent years there has been criticism of the Malmquist index, namely, the productivity index used in Färe et al. (1994). To partly deal with this criticism, a slightly more general index was chosen. Our findings and conclusions regarding some of the key issues in the first report, and, thus, the starting point for this report, were as follows:

- The same model specification as in Färe et al. (1994) is used.
- The data source is iSTAN data from the OECD.
- To measure productivity, the Bjurek-Hicks-Moorsteen (BHM) productivity index can be used. The productivity index used has all the positive attributes of the Malmquist index utilized in Färe et al. (1994), but it is based on fewer assumptions, that is, non-testable assumptions.

In this report, we take the empirical work further and present Sweden's total factor productivity (TFP) compared to groups of countries.

Sweden Compared to Different Country Groups

The report constructs three country groups, namely, small advanced open economies (SAOEs), major advanced open economies (MAOEs), and advanced open economies (AOEs), with the first group being constructed so that they are similar in a number of characteristics to Sweden. One result is that, unsurprisingly, there are large differences in the conclusions and recommendations that come from the various comparisons. When Sweden is compared with the SAOE countries, it appears to be the country with the highest TFP development. Compared with the MAOE countries, Sweden tends to lag behind, which is also the case in comparison with the AOE countries. A first conclusion to be drawn is therefore that if policy is to be based on country comparisons, it is important that the countries used as a yardstick are at least like Sweden in terms of key characteristics. In the report, the main focus has been the comparison with SOAEs.

Total Factor Productivity Breakdown

TFP calculated with the BHM index, unlike the traditional approaches where TFP is often treated as a single aggregated measure, can be broken down into at least two components: technological/technical/technology change (TC) and efficiency change (EC). This makes it possible to gain more detailed knowledge of the factors that drive productivity over time. The division into TC and EC helps us to identify specific potential contributions of technological changes, such as the introduction of new technologies and innovation (captured by TC), and distinguish them from better use of resources, which can result from both adaptive innovation and environmental factors or managerial characteristics (captured by EC).

The breakdown into technological and efficiency changes indicates that Sweden, in terms of technological progress, stands out in all groups. Something that distinguishes Sweden from the comparison countries is its larger investments in technology and research and development (R&D), which probably lies behind the results. As for the second component, efficiency changes, the relative efficiency changes are relatively low in Sweden compared to peer groups. However, there is a lagged effect between technological change and efficiency change. Demand fluctuations and crises can slow down the adoption and implementation of new technologies, which can delay efficiency gains. Additionally, there is a pattern in how companies adopt new technologies, with some being "early adopters" and others "lagging behind." Early adopters are effectively taking advantage of technological advancements, while laggards are left with "old" technology, leading to various effects on productivity development.

Variations in Total Factor Productivity

Although the decomposition gives a description of how development has taken place, there are factors that are outside the production itself that affect it. In this context, we are talking about three different groups of factors. The first is the management's ability to make the right decisions. This group of factors requires us to know which people make up management, and that information is missing at the level of aggregation at which we have data. The second group of factors is those that are exogenous to production and that management cannot influence. An example of these is weather, which affects, for example, the agriculture, construction, and tourism sectors. The third set of factors is those that are exogenous to production but where management can choose to act or not act, can act quickly or slowly, and so on. At the aggregation level of this study, it is mainly factors of the third kind that have been included in the regression analyses.

The variables in the regression analyses have been divided into macroeconomic factors, innovations and R&D, labor force composition, institutional conditions, and shocks. In the regressions, we have also included the country's total value of tangible and intangible assets.

Of the macroeconomic factors, only the trade openness variable indicates how open a country is to exchange with other countries. This is positive and significant, which indicates that more open countries generally have higher productivity.

For both the tangible and intangible assets variables, the results show a delay before investments yield productivity gains. R&D expenditure similarly shows a lagging positive impact on TFP, indicating that it takes time to turn innovations into productivity improvements and, thus, increased competitiveness. None of the institutional variables were significant; in all likelihood, this is due to the fact that the countries studied here are similar in many of the institutional dimensions measured, which means there is very little variation between countries. When it comes to the shocks that have occurred during the period, it is mainly the Eurozone crisis that had an impact. According to the results, productivity growth fell by approximately 1.2% as a result of the Eurozone crisis.

A first observation in the sectoral analyses is that there is a relatively large difference between the manufacturing and service sectors. For example, the results show that the volume of imports is important for the manufacturing sector, while the exchange rate is of primary importance for the service sector. Furthermore, the results show that assets and R&D are more important for the manufacturing industry than for the service sector. Of the shocks controlled for, the results show, somewhat surprisingly, that Covid had a slight positive impact on productivity development for both sectors.

As mentioned at the beginning, the starting point for the entire productivity project at the Swedish Entrepreneurship Forum has been investigating the possibilities of studying productivity using somewhat more modern and complete methods compared to what is usually used. Our conclusion is that productivity can be measured with modern methods, which is why studies that aim to measure productivity can use these methods and indices rather than using partial measures or other simplifications that may have implications for the policy recommendations that are targeted. Furthermore, by using more modern methods, it is possible to obtain more information about what drives productivity development, which is why better data for growth policy, for example, is obtained. Although this work has answered some questions, new questions and areas have also been identified. One of the conclusions of this work is, not surprisingly, that in country comparisons, the choice of comparison countries is of great importance. In the study, our choice of SAOE countries has been based on the fact that they show similarities to Sweden in a number of observable dimensions, which we believe solves some of the problems of choosing comparison countries. However, further research is needed on how a comparable country group can be constructed. Another area where development work is underway is building productivity indices based on aggregated sector analyses rather than calculating productivity based on already aggregated data. However, this requires access to microdata. Finally, there are more groups of explanatory variables that have not been available, or will not exist, at the aggregate level – for example, the training and experience of a company’s management. These analyses require microdata, and some research on how a comparable country group can be constructed is also inevitable.

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1. Introduction

The dynamics in business are about changes in labor and capital and their development. New technology can cause capital to become more important during a period, while using more qualified labor ("skill substitution") can have a countervailing consequence. These go hand in hand and are not something static that can be reduced to either partial measures or a time-independent basic model. Since 1989, there has been a large development of modern ways of measuring total factor productivity (TFP). The goal of these modern measures is not only to measure productivity changes but also to connect them to why there is a change in productivity, for instance, technological development, efficiency changes, scale effects, or the production environment, and in quantitative terms to measure how these different elements affect TFP. Notwithstanding, labor productivity and other simplified versions of computing TFP are used to form policy. Thus, the overall motivation for this project is to present a thorough analysis based on recent methods for computing TFP and to suggest an enhanced measure of TFP changes. This enhanced measure aims to offer a more nuanced perspective on TFP development by integrating the impacts of technological development, efficiency changes, and exogenous factors, thereby assisting policymakers in making informed decisions.

Accordingly, in this report, we measure TFP development by applying the Bjurek-Hicks-Moorsteen (BHM)[1] index to analyze productivity development. In the report, Sweden's performance is compared with that of other small advanced open economies (SAOEs). TFP changes are decomposed into two components: technology changes (TC) and efficiency changes (EC). Moreover, we analyze the correlation between TFP changes and some exogenous variables identified in the literature.

Thus, with this report, we try to answer the following questions:

- How does Sweden's productivity development, measured using the BHM index, compare to that of other SAOEs?
- What is the impact of technology and efficiency change on TFP?
- What exogenous factors contribute to the variations in TFP?

The remainder of the paper is structured as follows. Section 2 presents and discusses different ways used to measure productivity and compare the results. Our finding is that partial measures, like labor productivity, are not as well suited to capturing productivity, especially when the study covers several years. In Section 3, we present the logic of modern TFP indexes, which can be decomposed into at least two components: technology change and efficiency change. In this section, we also discuss factors that can cause TFP to change but are exogenous to production. In Section 4, we define groups of countries with which Sweden is compared. The groups used are SAOEs, advanced open economies (AOEs), and major advanced open economies (MAOEs). In Sections 5 and 6, the results are presented. In Section 5, TFP, technology change, and efficiency change are compared between Sweden and SAOE countries, and we also present the results of a second-stage analysis where TFP changes are regressed against exogenous factors that are identified in the literature as drivers of productivity. In Section 6, we present the results when disaggregated data for the manufacturing and service sectors is used. In an extensive appendix, results for sector-wise comparisons are presented in graphs. Finally, in Section 7, conclusions are drawn, and concluding remarks are presented.

[1] In much of the literature, the index is referred to as the Hicks-Moorsteen index. However, it was Hans Bjurek at Gothenburg University who first applied it in 1996. To give credit to this development, we refer to it as the Bjurek-Hicks-Moorsteen index.

2. Measuring Productivity

Productivity is well defined in economic theory as the ratio between what is produced (output) and the factors used in the production process (inputs). Often, the measures used to describe productivity development, both in applied research and in investigations, are based on several simplified assumptions. An example of such a measure is labor productivity, that is, output over labor. For example, this is used to study productivity in Sweden in relation to the rest of the world in Persson et al. (2024). Likewise, the same measure is used in Tillväxtanalys (2021), just to give a few examples. In the remainder of this section, we will discuss different measures of productivity that are commonly used to assess productivity.

2.1. Different Ways of Measuring Productivity

2.1.1. Average Product of Labor as a Measure of Productivity

As referenced above, many authority reports and scientific studies use some kind of partial measure where only a part of the inputs is included in the denominator. This could be the average product of capital as well as the average product of labor or, in farming, the average product of land. The most common, however, is to use some measure of labor in the denominator. The average product of labor, or labor productivity, is defined as the output divided by the amount of labor. That labor productivity in general provides an imperfect description of what is meant by productivity was already noticed by Farrell (1957), who writes:

> "[labor productivity] is so obviously unsatisfactory that one would not waste space discussing it, were it not for the danger that its popularity with the general public." (Farrell, 1957, p. 263)

In a discussion of how policies can be designed to increase productivity, O'Donnell (2022) writes in a memo to the Australian Productivity Commission:

> "First, unless inputs of capital, energy, materials and services are worthless, then any interest in labour productivity is misplaced." (O'Donnell, 2022, p. 11)

In Unnikrishnan and Månsson (2023), this is nuanced a little:

> "But a partial measure, such as labour productivity, is only a true description of productivity when there is only one input – labour, or when there is a perfect correlation (perfect substitutes) between labour and other factors of production. This is naturally problematic." (Unnikrishnan & Månsson, 2023, p. 4, translated from Swedish)

As is common in economic sciences, models used should mimic the reality studied. To set up these models, simplifications and assumptions need to be made. In the best cases, and despite the simplifications and assumptions, the models still manage to produce a realistic picture of what is intended to be studied. However, sometimes, the models used are hard to interpret due to their complexity. Therefore, further assumptions are made to facilitate interpretation. We believe that the use of partial measures, such as labor productivity, is a result of making something that is quite complex, such as TFP, accessible to a non-trained audience. Unfortunately, as will be further elaborated in Section 2.5, using labor productivity as a substitute for TFP results in a rather poor description of what is intended to be measured, which will especially be the case if productivity is studied over a longer time.

2.1.2. Growth Accounting Model

Another common way to measure productivity is to rely on the recommendations made/used by the OECD, the IMF, the EU Commission, and other researchers (see, e.g., OECD, 2024).[2] In these measurements, a rather simple and inflexible functional form is used (Cobb–Douglas = geometric mean), and the fixed weight on labor is set to 0.7 and the weight on capital to 0.3 (see, e.g., Eklund & Thulin, 2020; Pilat, 1996). Although this is less restrictive than labor productivity, it is still a simplification that builds on very restrictive assumptions. For example, by using fixed weights, there is an implicit assumption that there is no substitution between capital and labor over time, which means that we assume away labor-saving inventions, such as digitalization and robotization. Neither can efficiency gains or changes in optimal scale/size be distinguished.

Moreover, the Cobb-Douglas aggregate production function suggests that productivity depends on the capital-to-labor ratio, influenced by both physical capital accumulation and TFP. While capital accumulation and TFP are crucial factors affecting labor productivity, the interpretation of TFP is complex. The Cobb-Douglas function's assumption of constant returns to scale is highly restrictive, yet studies based on this function and Solow residuals consistently link significant gross domestic product (GDP) growth to TFP growth. However, some research views TFP not merely as a residual (e.g., Benkovskis et al., 2012; Färe et al., 1994; Koop et al., 1999). Criticism of growth studies relying on the aggregate production function is notable (Felipe & McCombi, 2014; Osiewalski et al., 2020; Shaikh, 1974; Simon, 1979; Temple, 2006). Osiewalski et al. (2020) argue that while production functions effectively describe individual producers' technologies at a microeconomic level, aggregating physical capital, labor, and production at the macro level is problematic. Theoretical contradictions (Fisher, 1969) and specific assumptions (Growiec, 2008, 2013; Jones, 2005) further challenge these models.

2.1.3. Total Factor Productivity Indexes

Total factor productivity indexes are a family of indexes that relate total volumes of output(s) to total volumes of input use.[3] The weights attached to outputs and inputs need to reflect different measures of economic importance. In the literature and among indexes, several such weights have been proposed:

- Prices can be used to construct the Laspeyres, Paasche, Fisher, chained Fisher, Elteto-Koves-Szulc (EKS), and Lowe indexes.
- Value shares can be used to construct the Törnqvist, chained Törnqvist, Caves-Christensen-Diewert (CCD), and geometric Young indexes.
- Marginal rates of technical substitution and transformation can be used to construct the Malmquist, Bjurek-Hicks-Moorsteen, and Färe-Primont indexes. These indexes build on distance functions (Shephard, 1953, 1970).
- Estimated shadow prices and shadow value shares can be used to construct additive and multiplicative indexes when no market price or value share data is observed.

However, the most common of these indexes in applied research today is the Malmquist index, used in, for example, Färe et al. (1994).[4]

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[2] For a Swedish example see, for example, Milicevic (2023).

[3] Since it is impossible to be sure that all inputs have been captured or measured – for example, unpaid working hours – even what is labelled TFP is sometimes referred to as multi-factor productivity index (MFP). We will use TFP throughout the text, which is in line with how the wording is used in most scientific papers.

[4] It should be noted that there is ongoing development around productivity indexes based on axioms of productivity indexes. In some of the literature, even so-called "distance function-based indexes" such as the Malmquist and the BHM index are questioned based on the fact that they do not fulfil all axioms that can be

2.2. *Comparing the Different Measures*

In this section, we will compare and discuss the simplified methods for computing productivity to the BHM index.

2.2.1. Labor Productivity as a Proxy for TFP

Figure 1 measures yearly changes in the growth of TFP starting in 1995 and compares three productivity measures: (a) labor productivity measured as the GDP per worker; (b) labor productivity measured as the value added per worker; and (c) the Bjurek-Hicks-Moorsteen index as the TFP measure. The figure reflects fluctuations in the growth of productivity. It can be observed from Figure 1 that both measures of labor productivity are highly sensitive to business cycles. During economic booms, these measures may provide artificially inflated estimates due to increased output without a proportional increase in the input. Labor productivity as a performance measure ignores capital as an input of production, focusing solely on one input: labor. Moreover, labor productivity cannot, other than indirectly, capture the impact of technological progress and advancements that, essentially, lead to better utilization of resources. It is also crucial to choose an appropriate and comprehensive measure while analyzing sectoral shifts in productivity. For example, the service sector is more labor intensive than the manufacturing sector. Thus, using labor productivity to compare the productivity in these sectors may lead to misleading implications. It should be noted that the correlation between the BHM index and the labor productivity measures is around 0.5, so there is a correlation as expected, but not as high as sometimes claimed.[5] Moreover, it is worth emphasizing that while the trends of the three productivity measures are broadly similar, indicating consistent patterns of productivity change over time, the levels of these measures differ. Specifically, the BHM index consistently shows lower levels than labor productivity measures based on the GDP per worker and the value added per worker. This difference in levels highlights the distinct aspects of productivity changes captured by TFP compared with labor productivity metrics, which might reflect the different contributions of inputs, technological changes, and efficiency changes over time.

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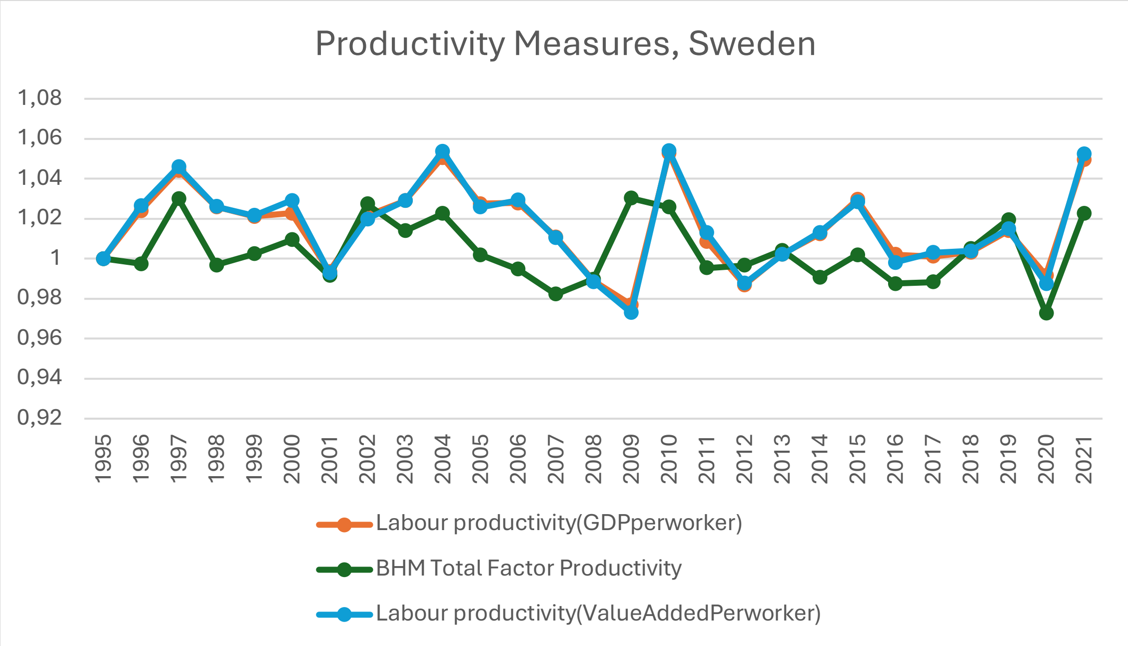
expected (see O'Donnell, 2016 for details). Our choice of index is more related to an evidence-based choice – that is, it is commonly used in the scientific literature. When writing this report in 2024, we recognized that there is ongoing development around productivity indexes, considering alternatives to mainstream TFP indexes such as Malmquist and BHM indexes, which addresses the theoretical shortcomings of mainstream indexes (see, e.g., O'Donnell, 2014).

[5] For example, Persson et al. (2024) claim that there is a high correlation between labor productivity and the TFP measure and use this as an argument for using labor productivity.

Figure 1. *Comparing yearly labor productivity and TFP changes (BHM index), Sweden 1995–2021*



2.3. Summary

In this section, we have discussed and problematized ways of measuring productivity and productivity changes. The conclusion is that many of the studies that claim to measure the growth and level of productivity are only doing so in a partial and, in our opinion, rather poor way. It is especially hazardous when we try to understand development relating to productivity since the regressor only accounts for a portion of the inputs involved in the production process. These partial measures can lead to inaccurate assessments and misguided policy recommendations. Thus, if productivity itself, variation in productivity, or productivity as a regressor is on the agenda of a study, we recommend that productivity be measured as TFP using one of the available indexes that have been developed since the mid-1990s.

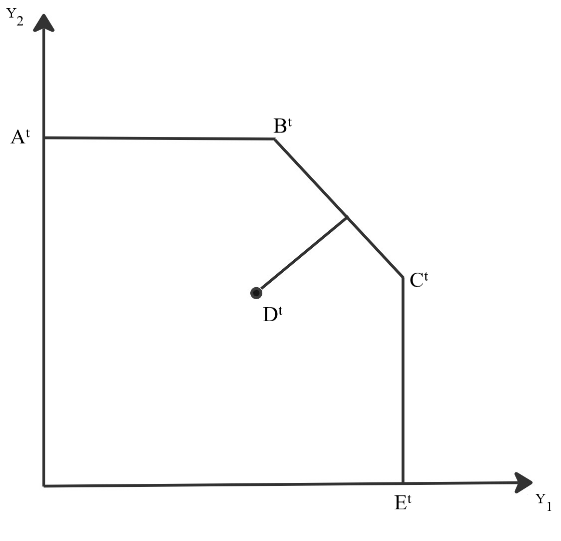
It is also important to note that we would be using aggregate data due to its availability, consistency, and relevance for cross-country comparison and longitudinal analysis. Even though aggregate data captures the broader trends in productivity, it inevitably lacks the granularity that microdata offers. This would imply that aggregate data cannot capture firm-specific behavior, trends, and micro-level factors such as skill substitution.[6] Although microdata could yield a more detailed analysis, using microdata is beyond the scope of this study. Consequently, even though aggregate data may not give the most granular insights, it remains the most appropriate/effective/available method for this cross-country study.

[6] During the writing of this report and the presentation of the results, several suggestions emerged on multiple occasions as alternatives to PWT. One suggestion to overcome the aggregation level in the data we use was to use CompNet, where Microdata is collected and reported for a number of EU countries. However, Sweden is not one of them. See https://www.comp-net.org/fileadmin/_compnet/user_upload/CompNet_Productivity_Report_-_July_2023.pdf.

3. Productivity indexes and their components

In empirical production economics, we study the consequences of decisions made by the entity under study. It could be, inter alia, firms, countries, organizations, or authorities. What is common, regardless of the type of organization studied, is that they make the decision. We therefore use the term "decision-making unit" (DMU)[7] to represent all types of organizations. Inputs are defined as physical quantities of factors of production that can be influenced by management, and outputs are physical quantities of production delivered. It is assumed that these DMUs have one of two objectives related to production: the objective is either to minimize resource use (inputs) to produce a given level or target of production/output (input-oriented model) or to maximize the production given their resources (output-oriented model). For simplicity, we will in the following limit the presentation to the output-oriented model—that is, DMUs have the objective of maximizing production (Y_1 and Y_2 in Figure 2) given their resources. In this illustration, the sample consists of three counties (B, C, and D), and A and E are points that limit the production possibility set. T indicates that this is measured in time period t. In this sample, B and C are producing at the frontier (i.e., maximum production given resources), and D is not producing the maximum output. Thus, D is inefficient in period t.

Figure 2. *Illustration of the production possibility set and frontier*

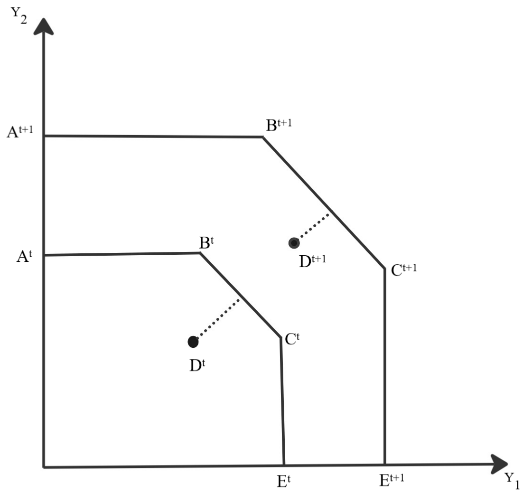


In Figure 2, Y_1 and Y_2 represent the two outputs that are produced. The amounts of Y_1 and Y_2 that are produced are measured along the horizontal and vertical axes. Assume that there are three DMUs at times t, B^t, C^t, and D^t. The line passing through A^t, B^t, C^t, and E^t represents the maximum observed production given the inputs. This is called the "frontier." In fact, all combinations of Y_1 and Y_2 limited by the area 0-A^t, B^t, C^t, and E^t can be produced given the resources. It is obvious that DMU B^t and C^t are producing more than D^t with the same amount of resources, which makes DMU D^t inefficient compared to B^t and C^t. The degree of inefficiency is illustrated by the distance to the frontier. The shortest distance from D^t to the

[7] In the context of this study, the DMUs are countries and country groups. However, it is important to note that a country's productivity, as measured by TFP, inherently reflects the aggregated performance of the firms within its industries. Therefore, when referring to a country or country group, TFP encompasses the productivity contributions of the firms and industries that comprise it. The terms "country" and "firms" are used interchangeably to represent this aggregation throughout the study.

frontier (such as from D^t to B^t) measures the immediate technical inefficiency. The potential area above and to the right of D^t (encompassing the area up to the frontier) represents possible improvements that could be made. Note that since B^t and C^t are efficient, they are used to construct the frontier. In Figure 3, a hypothetical situation at year *t+1* is illustrated.

Figure 3. *Illustration of the production possibility set and frontier at year t+1*



The situation illustrated in Figure 3 shows two things that have happened. Firstly, the frontier has moved outwards. This means that there has been a positive technology change (TC) indicated by TC>1. That is, those that fulfill the objective of producing the maximum amount of output given their resources can now produce a larger amount of Y_1 and Y_2 compared to year *t*. Secondly, if the DMU D^t, now illustrated by D^{t+1}, has moved closer to the frontier compared to year t, it means that there has also been an efficiency improvement, indicated by a positive efficiency change (EC>1). It is obvious that the output at D^{t+1} is greater than the output at D^t, meaning that TFP has increased, and this is partly due to technology change (TC>1) and efficiency change (EC>1).[8]

Examples and elaborations

Now consider a situation where DMU *D*'s inefficiency (distance to the frontier) is the same in both year t and year t+1. Since the output at D^{t+1} > the output at D^t, this means that TFP has increased (TFP change >1). However, in this case, there is no efficiency improvement, which means that the EC component is equal to 1. Thus, the whole observed TFP change for DMU *D* is because there has been technological progress and DMU *D* has managed to adopt this. In this case, TFP = TC*1 as there is no efficiency improvement, meaning that the EC component is equal to 1. In this example, it is DMU *B* and *C* that are on the frontier in both periods. Since it is DMU *B* and *C* that are driving the outward movement of frontier, it is these two countries that have adopted, invented, or adjusted the technology to enable them to produce more than in period t (i.e., increase productivity). Thus, when referring to technological change, it is a frontier movement that is driven by DMUs in the sample for the study.

Consider the situation where the frontier for both periods is unchanged, that is, frontier period *t* = frontier period *t*+1. Without any frontier movements, the TC component will equal 1, so

[8] It is worth noting that the importance of decomposing TFP into technological change and efficiency change was observed by the Swedish Productivity Delegation (SOU, 1991, p. 82), following the development work done by Färe et al. (1989).

TFP = 1 * EC. Thus, if we observe a positive TFP change (TFP>1), it is due to the fact that DMU *D* has moved closer to the frontier. So, when talking about efficiency change, it is a movement towards/away from the frontier that is made up of efficient units in the sample that is referred to.

Consider a situation where the frontier has moved outwards (TC>1) but the DMU evaluated has done nothing, that is, $Y_{1,t} = Y_{1,t+1}; Y_{2,t} = Y_{2,t+1}$. At the given input level, this means that TFP is unchanged (TFP=1). However, since the DMU in period *t*+1 is further away from the frontier, efficiency has been reduced, as indicated by EC<1. Then, since TFP=1, the decrease in efficiency has to be totally offset by an increase in TC in such a way that EC*TC=1. For example, if TFP=1 (no change in productivity) and the efficiency change is 0.95 (further away from the frontier), then TC (movement of the frontier) needs to be 1.05 to satisfy the equation TFP=EC*TC. Thus, in order to say something about what is driving TFP, we need to start with what we know about TFP. For example, if observed TFP = 1.03 and observed EC=0.95, then TC needs to be 1.08. That is a 5% reduction in efficiency, but an 8% increase related to technological progress. Thus, TFP has increased, and it is driven by the TC component.

3.1. What Causes the Frontier to Move and DMUs to Become More/Less Efficient?[9]

3.1.1. Factors of Production

As discussed above, TFP can change over time in a positive way (TFP change > 1) or a negative way (TFP change <1), and this is due to the fact that the frontier has moved and the DMU has not done so to the same degree (i.e., inefficiency has become higher or lower). There are several reasons for this related to the actual production. A DMU becomes more efficient by organizing its production in a better way; it could be that the DMU has replaced its capital by adopting/inventing new ways to produce, for instance. Thus, improved efficiency (EC>1) can be driven by adopting new and better technology but could also be related to other and better management decisions within the DMU.

In some situations, a DMU can adopt new technology, optimize its organization, or upskill staff in a way that they can produce more in year *t*+1 than what was possible in year *t*. With "not possible," we mean that the DMU produces production volumes in period *t*+1 that are larger than frontier DMUs' production in period *t*. The only way this could happen is that a new technology has been adopted or invented that allows more production at a given resource level. In this case, model wise, the frontier for the used sample has moved outwards, and the part that makes up the TC for an individual DMU is the difference between what was possible in period t if the DMU was on the frontier and the actual production *t*+1 (which was not possible in period *t*).

A question that relates to innovation studies is how sure one can be that the frontier movement actually relates to innovations. If a DMU is on the frontier in both period t and period *t*+1, it is obvious that the EC component equals one since no efficiency improvements have been done

[9] The term "technological regress" is widely used in the literature for inward movements of the frontier; however, we do not condone this usage. While it is true that skills and technologies, once learned, are not typically "unlearned," there is dire need to properly explain why a technological frontier might appear to move inward. We argue that this inward shift is often driven by external factors that impact production. Thus, what is often perceived as technological regress is, in reality, the result of exogenous factors affecting the use and deployment of existing technologies and resources.

or were possible. The only way that TFP can improve in this situation is if new technology (representing innovation) that did not exist in period t is introduced. The argument for attributing the frontier's movement to innovation lies in the assumption that an outward shift of the frontier reflects advancements in production capabilities, which are typically the result of technological innovation, process improvements, or new methods. Without such innovations, the production frontier would remain static, and no TFP improvements would be observed for DMUs already operating efficiently. Therefore, if the frontier expands and a DMU remains on it, this strongly suggests that the shift is due to the adoption or implementation of innovations.

3.1.2. Exogenous Factors Within the Control of Management

Other factors exogenous to production (i.e., not inputs or outputs) influence the choices made by managers. For example, during some of the shocks (financial crisis, Eurozone crisis, COVID-19), the demand went down. How to respond to this demand reduction is a management decision, and the results vary. Some DMU managers directly cut staff, while others thought that the shocks were short-lived and retained all staff. As a consequence, those who were producing the most (i.e., determined the frontier) produced less than the year before. This is shown in the model as the frontier moves inwards. Using regression analysis, as is done in 5 and 6, makes it possible to get some information about the exogenous factors influencing productivity.

3.1.3. Factors Outside the Control of Management

A second reason for frontier movement is related to exogenous factors outside the control of management.[10] For example, in the agriculture sector, exogenous factors like weather, temperature, or natural disasters are factors that most likely influence the output and input but cannot be changed by management decisions—they are a pre-condition for production. Examples of exogenous variation include changes in the exchange rate,[11] regulations, and international conflicts. All these will most likely have an effect on the demand for products/services. For example, if demand goes down, it is naturally in the interest of the DMU to take action to produce less, causing the frontier to move downwards. In the literature, this is sometimes doubtfully labeled as "technical regress." To make it clear, there are only a few examples when referring to technical (or technology) regress is appropriate, for example, if a new regulation is imposed forcing firms to use a less efficient way to produce. Secondly, if firms do not reinvest at the necessary pace, more capital is used than replaced.[12] In both these examples, it would be appropriate to use the wording "technical regress." However, in most cases, what is called "technology regress" is adapted to a situation caused by factors that are outside the control of management.[13]

3.2. Summary

To summarize, TFP is defined by outputs over inputs, and TFP changes are driven by two components: efficiency change (EC) and technological change (TC). If TFP changes positively (TFP>1), it means that we produce more per input unit in year *t*+1, and if TFP is influenced negatively (TFP<1), we produce less in period *t*+1 than in period *t*. Considering TFP>1, this could be due to the fact that efficiency has been improved, which means that a DMU produces

[10] In Sections 5 and 6, we shed some light on what exogenous factors relate to TFP and its components.

[11] Since 1992, Sweden has had a flexible exchange rate.

[12] For example, the infrastructure of railways in Sweden. The railway infrastructure deteriorates over time due to use and aging. If the authorities do not reinvest in maintaining and upgrading the infrastructure, the railways will become less efficient due to outdated technology.

[13] Several studies provide a robust theoretical and empirical foundation for how, for instance, government regulations and R&D expenditures influence TFP (Andrews et al., 2015; Ascari & Cosmo, 2004; Baltabaev, 2013; Cameron et al., 2005; Goldin et al., 2020; Griffith et al., 2003; Hamamoto, 2003; Jones, 1995; Romer, 1990; Sobieraj & Metelski, 2021).

more at a given input level. In the model, this is indicated by EC>1 and corresponds to the movement of a specific DMU closer to the frontier. This can be caused by several factors, including adopting new technology, skill upgrades, exogenous factors, and better management decisions.

If a DMU is producing more in period t+1 than was possible in period t at a given input level, TFP>1. To do so, the frontier, consisting of efficient DMUs in the sample, must have moved outward. What is driving this outward movement is that frontier units have adopted or invented new technology. If a country is on the frontier in both t and t+1, EC=1, and any TFP improvement is entirely due to TC. Conversely, if the frontier is unchanged (TC=1), TFP improvements arise solely from efficiency gains. Factors influencing frontier movement include technology and innovation, exogenous management-controlled factors, and external factors outside the control of management (e.g., weather or regulations). Positive TFP change reflects improved efficiency or the adoption of technology, while negative TFP change indicates declining productivity due to inefficiency.

When we talk about the fact that Sweden's technological change component is positive (TC>1), it should be interpreted as meaning that Sweden has adopted or innovated new technology that makes it possible to produce more in period t+1 than what was possible in period t. It does not necessarily mean that it is Sweden that is driving the frontier's movement in the sample.

4. Cross-Country Comparisons

Many studies (see, e.g., Persson et al., 2024) that compare productivity development by country have no or little motivation for why the sample is chosen. There are a lot of studies using, for example, the OECD or a sample of OECD countries or the EU or a sample of EU countries. The choice of countries in a comparative study is, in some respects, important for policy conclusions, but the motivations are widely neglected. To illustrate, if, in a comparative study, we find that Sweden is ahead in terms of productivity development, a policy conclusion might be that to preserve this advantage, policy initiatives may be directed toward innovation in order to maintain that lead. However, if, in a comparative study, we find that Sweden is doing worse than the leading countries, a relevant policy recommendation would be, for example, to catch up by using investment support. Thus, justifying the choice of the sample used could be very important for the conclusions drawn. In this respect, our report is not free of subjective selection of countries. However, we try to form our sample in a way that allows us, at least to some extent, to justify the degree of similarity among the selected countries. Demonstrating how to make an optimal selection of countries for the sample is beyond the scope of this study but would be a very important contribution.

To ensure a meaningful comparison, we compare Sweden's productivity development with a group of similar economies based on specific characteristics. We categorize countries into small, advanced, and open economies. A small economy is defined by the size of the population, with a cut-off of 20 million.[14] An advanced economy is defined by its GDP per capita, specifically, US$30,000 or more.[15] The openness of an economy is defined by the export-to-GDP ratio. Based on these criteria, Austria, Belgium, the Netherlands, Switzerland, Denmark, Sweden, Finland, Norway, Iceland, and Ireland are defined as SAOEs. However, this comparison leaves out some of the most important countries for Sweden, namely, Germany, the USA, and Canada. We have therefore also included these countries in separate computations of productivity. The extended group of countries is referred to as advanced open economies (AOEs). Finally, as a third extension, we use SAOEs and AOEs and include what is categorized by the IMF as major advanced economies (MAOEs), namely, the UK, Japan, France, and Italy.[16]

Thus:

SAOEs: Austria, Belgium, the Netherlands, Switzerland, Denmark, Sweden, Finland, Norway, and Ireland.

AOEs: Austria, Belgium, the Netherlands, Switzerland, Denmark, Sweden, Finland, Norway, Ireland, Germany, the USA, and Canada.

MAOEs: Austria, Belgium, the Netherlands, Switzerland, Denmark, Sweden, Finland, Norway, Ireland, Germany, the USA, Canada, the UK, Japan, France, and Italy.

[14] The Irish Government Economic and Evaluation Service (IGEES), Govt. of Ireland, has defined SAOEs based on population size, GDP per capita, and trade openness: file:///C:/Users/aun/Downloads/180714_bb20702c-af59-4292-9255-99d76f3759d5.pdf.

[15] The IMF's definition of advanced economies: https://www.imf.org/-/media/Files/Publications/WEO/2024/April/English/statsappendix.ashx.

[16] To construct the country groups, we have taken the average of the output and input vectors of the countries. An alternative would have been to take the average of the computed indexes.

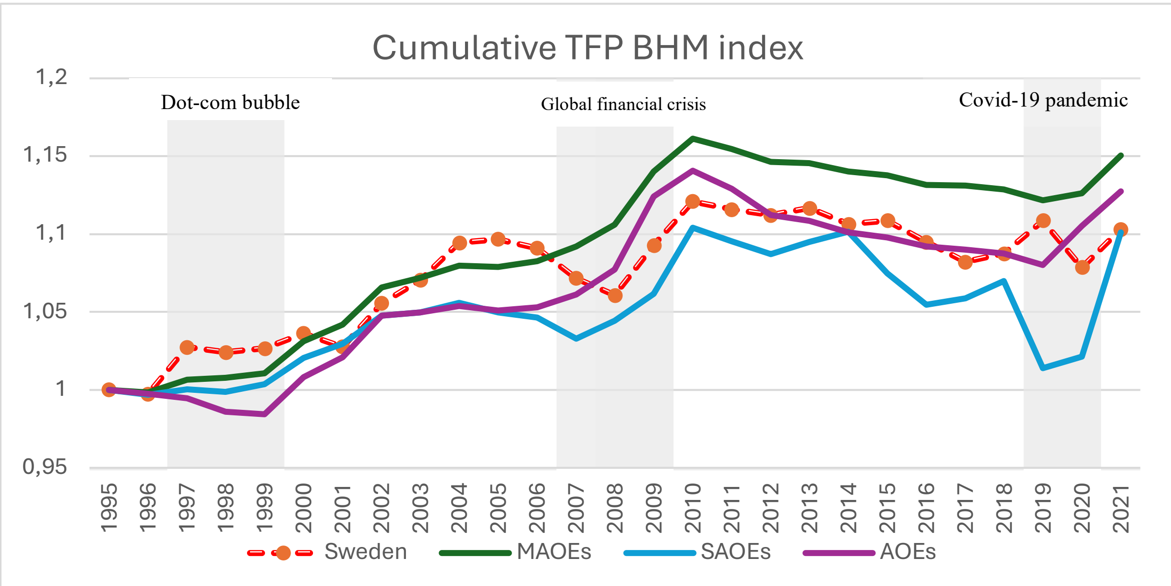
4.1. Comparing TFP Development in Sweden with Groups of Countries

In this section, we compare TFP development in Sweden with the three groups of countries defined above, namely, SAOEs, MAOEs, and AOEs, and highlight that the performance of Sweden depends on which group of countries it is being compared with.[17] As in Unnikrishnan and Månsson (2023) and as discussed in Sections 2 and 3, we use the BHM index to compute TFP.

4.1.1. Sweden and MAOEs, AOEs and SAOEs

During the period of analysis, 1995–2021, Sweden's productivity growth was robust since the country showed resilience and was able to adjust to changes over time, exhibiting an adaptive pattern (Figure 4).[18] Despite being significantly affected during crises and the pandemic, Sweden demonstrated better resilience than other SAOEs.[19] SAOEs' TFP increased significantly between 1995 and 2010, peaking around the global financial crisis. But since 2010, there has been a decline in TFP, although the level in 2019 was still above that in 1995, meaning that productivity had not regressed entirely to its starting level. However, that productivity has seen a decline in growth over the past decade relative to its peak. The cumulative TFP development for Sweden and the three groups is illustrated in Figure 4.

Figure 4. *Cumulative TFP development, Sweden vs. SAOEs, AOEs, and MAOEs, reference year 1995*



The relative productivity development of Sweden varies significantly depending on the group of economies with which it is compared. When compared with MAOEs, Sweden is lagging, and the productivity trend is more volatile. This might be attributed to Sweden's smaller size[20] and higher sensitivity to economic shocks relative to major economies.[21] A similar trend is evident when comparing AOEs. As a result, Sweden is bound to lag when its performance is compared with economies that are double its size and, therefore, more resilient. On the other hand, when compared to SAOEs, which have similar characteristics, Sweden performs

[17] The decomposition of TFP for AOEs and MAOEs is included in Appendix 2.
[18] The cumulative development is computed as the product of yearly changes, with 1995 set to 1.
[19] Sweden is excluded from the group when making comparisons with SAOEs, MAOEs and AOEs.
[20&18] Eichengreen et al. (2024) argue that major advanced economies are more resilient to crises and pandemics due to their structural policies.

significantly better. The ability of Sweden to have higher productivity growth than the groups of SAOEs indicates a competitive edge.

We also observed a consistent varying pattern of adoption among firms for all the groups and Sweden. This is indicative of the fact that there are firms in a country that can be categorized into “laggards” and “early adopters,” where the early adopters leverage the advancements in technology while the laggards wait to adapt to the technical progress, leading to varied impacts on productivity. One of the main takeaways from these comparisons is that the policy conclusions reached depend on what group of countries make up the comparison sample.

4.2. Differences and Similarities Between Sweden and SAOEs

In the following sections, we focus on the results for Sweden versus SAOEs. This comparison is the main result of the study. For the Sweden versus SAOE countries comparison, we also report results disaggregated into the manufacturing and service sectors. The performance of Sweden vis-à-vis SAOEs will be discussed, followed by a discussion on decomposing TFP and analyzing the variation in TFP.

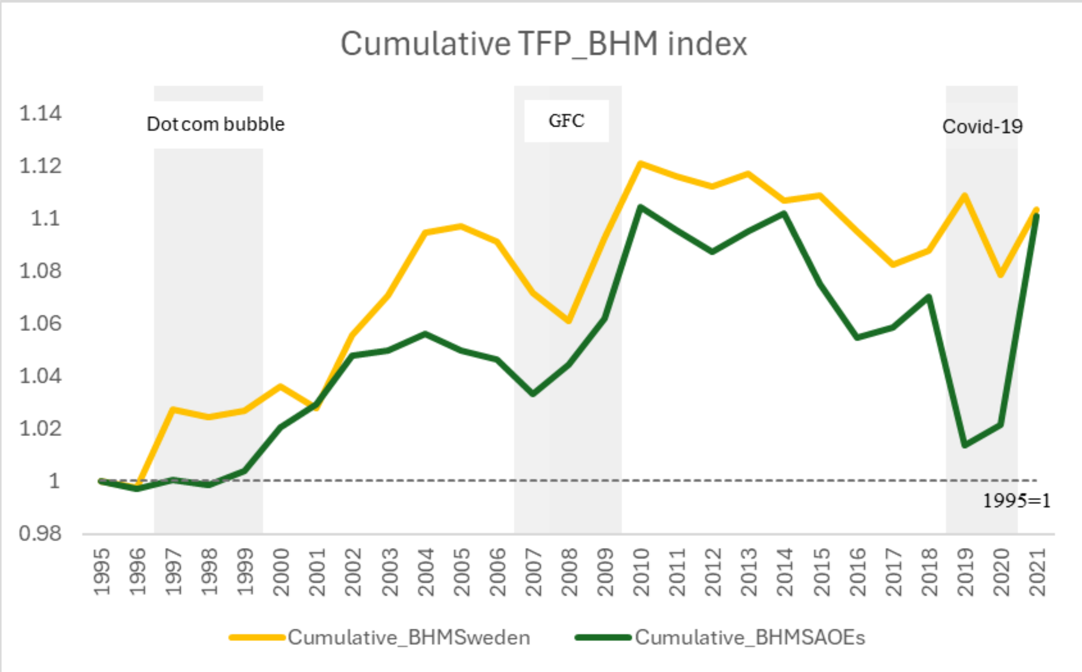
In this section, we begin by discussing the cumulative TFP development in Sweden and SAOEs. As presented in Section 4, the SAOEs include Austria, Belgium, the Netherlands, Switzerland, Denmark, Finland, Norway, and Ireland. Next, we delve into understanding the decomposition of TFP into technological changes and efficiency changes. We also consider several exogenous factors and managerial decisions that may influence productivity. We perform a panel data regression to evaluate the drivers of variations in TFP. The results of the regression analysis are presented and discussed in detail, offering insights into the key factors contributing to productivity growth in Sweden and the SAOEs over the period 1995–2021.

4.2.1. Cumulative TFP Using the BHM Index

In Figure 5, the cumulative TFP development, using 1995 as the base year, is presented. To compute the cumulative index, we multiply the observed changes over the years.

The trend in productivity growth for Sweden compared to SAOEs exhibits an interesting pattern, specifically the robustness and adaptive capabilities of Sweden in maintaining consistent growth rates during crises and the pandemic.

Figure 5. *Cumulative TFP, comparing Sweden and SAOEs, reference year 1995*



Sweden has higher TFP growth than its counterpart, the SAOEs, during the period 1995–2021, except in the year 2001. From 2001 to 2007, Sweden showed an upward trend in productivity. Since Figure 5 shows the cumulative TFP development, it is productivity boosts in some years, mainly in the mid-1990s and early 2000s, that make Sweden's cumulative TFP higher than the average of the SAOE countries. Looking at the results more closely, it is the productivity growth in the manufacturing sector[22] and in information, communication, and technology that are the main drivers of this.[23] Post 2010 and until 2014, the productivity index converged between Sweden and the SAOEs. Even though Sweden had a higher cumulative productivity growth compared with the SAOEs until 2018, during the COVID-19 pandemic, Sweden was adversely affected. Sweden's productivity declined by approximately 2% from 2019 to 2020, whereas for SAOEs there was a slight increase of 0.75%. Post 2020, although Sweden's productivity increased, the SAOEs demonstrated greater resilience in enhancing their productivity. For SAOEs, the decline in 2019 is shown in Figure 8, which depicts a sharp drop in the technological change component. The increase in TFP after 2020 may be attributed to increased investment in business enterprise expenditures in R&D[24] and intangibles[25] along with the post-COVID-19 economic rebound.

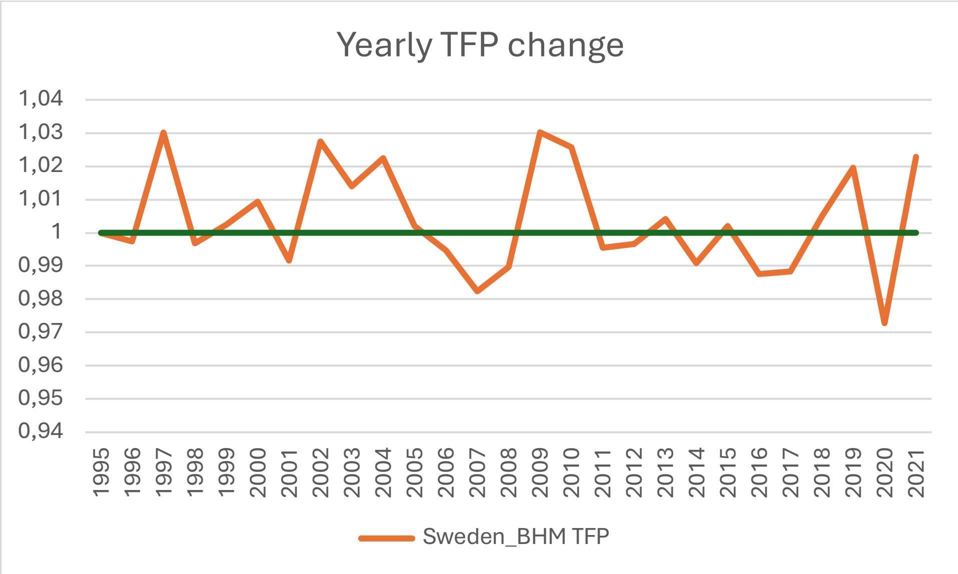
4.2.2. Decomposition of TFP

As seen in Figure 5, the cumulative productivity development is driven by development in some years. However, these productivity changes do not follow smooth growth, and it is rather boosts in separate years that make up the cumulative productivity growth, as illustrated in Figure 6.

[22] See Figure 9.
[23] See Appendix A.1.2.
[24] See Figure A.3.1.2.
[25] See Figure A.4.1.

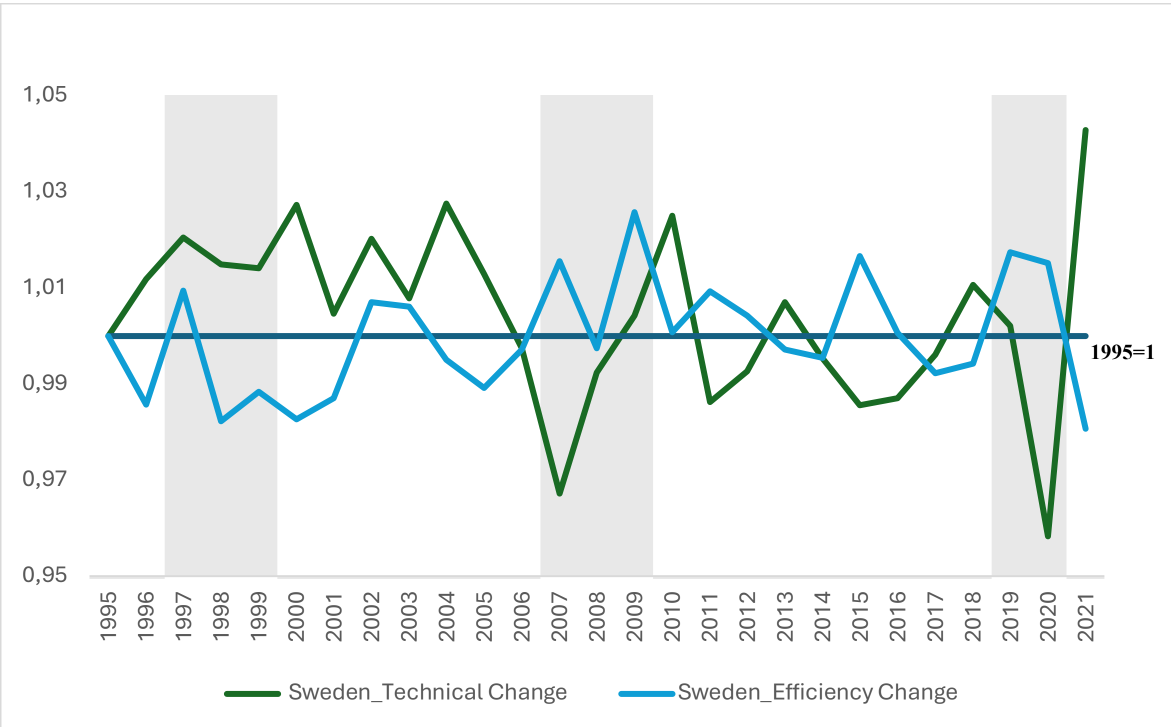
Figure 6. *Yearly change in TFP for Sweden*

1 = no productivity change between the two years, a value lower than 1 indicates a declining productivity change, and a value above 1 indicates productivity growth.



For example, in 1997 and in the period 2002–2004, productivity increased by almost 3% per year, but there were no improvements in the period 1998–2001. In the years of the study, the last year for a productivity boost happened in 2018–2019 when the productivity growth in Sweden almost reached 2%. In Figure 7, the components of TFP for Sweden are illustrated.

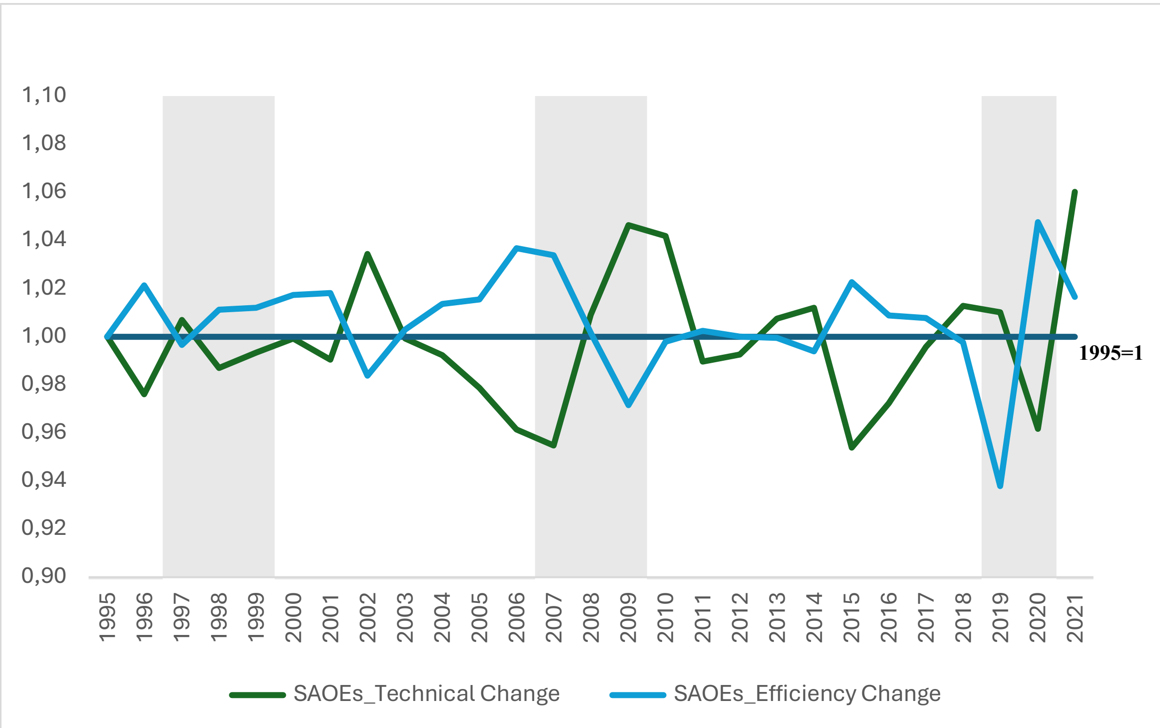
Figure 7. *Yearly development of the TFP components technical change and efficiency change for Sweden*[26]



[26] The cumulative changes are included in Appendix 1.a.

Recall that in Section 3, we referred to technological change as movements of the frontier itself while efficiency change refers to movement towards or away from the frontier. If the frontier moves outward, it can be viewed as increasing the potential for future productivity increases. That is, new technology has been introduced among countries that make up the frontier, which makes it possible to produce more in period *t*+1 compared to what was possible in period *t* if this technology is diffused and adopted. However, as also observed in Section 3, to interpret the decomposed results, we need to have the whole picture. For example, in the period 1995–2010, there was, as shown in Figure 5, an improvement in productivity. For this period, TC is on average above 1, and EC is on average around 1. This indicates that the frontier has moved. However, Sweden has not moved closer to or further away from the frontier, but, at the same time, Sweden is producing more given its resources (TFP>1). The only way this could happen is that Sweden adopted new and improved technology, for instance. In the period after the financial crisis (2010–2018), the movements in TC and EC are in opposite directions and approximately the same in magnitude. Thus, movements towards the frontier (EC>1) or away from the frontier (EC<1) are offset by the fact that the frontier moved inward (TC<1) or outwards (TC>1), and, as a result, TFP is unchanged (TFP=1). In 2019, TC is equal to one, indicating that no movement in the frontier has occurred; however, Sweden has moved closer to the frontier, as indicated by an EC>1 Finally, in 2020, TC is, compared to other years, very low (around 0.95). This indicates that the frontier has moved inward. In the research literature, this would have been labelled as technological regress. In the absence of efficiency improvement, this meant that productivity decreased by 5%; however, there are also efficiency improvements. This efficiency to some extent balances out the observed TFP decline. That we have this pattern around exogenous shocks is not surprising since we can expect that inefficient firms within the country will close down, making the aggregate of firms more efficient.

Figure 8. *Yearly technological change and efficiency change, SAOEs, reference year 1995*[27]



The cumulative TFP development for SAOE countries and Sweden is highly correlated, but the cause of the development is rather the opposite. While it is the technological change component

[27] See Appendix 1a for graphs of the cumulative changes.

that has the biggest positive impact on TFP for Sweden, it is the efficiency change component that has the biggest positive impact on TFP for the SAOE countries. From 2015 onward, the TFP slowdown in the SAOE countries has mixed explanations. Around 2015, TFP growth went down, and, as seen in Figure 7, this was due to an inward movement of the frontier. In Sweden, this inward movement was almost totally offset by the fact that Sweden moved closer to the frontier in the same magnitude as the change in the TC component. Thus, for Sweden, TC*EC was around 1, indicating neither productivity growth nor a slowdown. However, for the SAOE countries, the movement towards the frontier (EC>1) is much less than the inward movement of the frontier (TC<1), which in total meant that TFP growth was declining. During the year of the COVID-19 pandemic, there was again an inward movement of the frontier, indicated by a TC<1, but the movement towards the frontier (EC>1) for 2020 was larger for the SAOE countries than for Sweden.

The technical change component of the BHM index captures shifts in the production frontier, tailored to the input levels and composition unique to each country. However, it does not identify the specific countries driving these shifts. To determine which nations acted as "frontier movers," we identified, by computing yearly technical efficiency, which countries make up the frontier in the SAOE–Sweden sample on a yearly basis. The result is presented in Table 1.

Table 1. *Frontier countries by year based on a computation of yearly technical efficiency, DEA*[28]

Year	Countries that make up the frontier	Year	Countries that make up the frontier
1995–1996	Switzerland, Norway & Ireland	2008–2009	Switzerland, Norway & Ireland, Denmark
1996–1997	Switzerland, Norway & Ireland	2009–2010	Switzerland, Norway & Ireland, Denmark
1997–1998	Switzerland, Norway & Ireland	2010–2011	Switzerland, Norway & Ireland, Denmark
1998–1999	Switzerland, Norway & Ireland, Denmark	2011–2012	Switzerland, Norway & Ireland, Denmark
1999–2000	Switzerland, Norway & Ireland	2012–2013	Switzerland, Norway & Ireland, Denmark
2000–2001	Switzerland, Norway & Ireland	2013–2014	Switzerland, Norway & Ireland, Denmark & Finland
2001–2002	Switzerland, Norway & Ireland	2014–2015	Switzerland, Norway & Ireland, Denmark & Finland
2002–2003	Switzerland, Norway & Ireland	2015–2016	Switzerland, Norway & Ireland, Denmark & Finland
2003–2004	Switzerland, Norway & Ireland, Denmark &Finland	2016–2017	Switzerland, Norway & Ireland, Denmark & Finland
2004–2005	Switzerland, Norway & Ireland, Denmark & Finland	2017–2018	Switzerland, Norway & Ireland, Denmark & Finland
2005–2006	Switzerland, Norway & Ireland, Finland	2018–2019	Switzerland, Norway & Ireland, Denmark & Finland
2006–2007	Switzerland, Norway & Ireland, Denmark & Finland	2019–2020	Switzerland, Norway & Ireland, Denmark & Finland
2007–2008	Switzerland, Norway & Ireland, Denmark	2020–2021	Switzerland, Norway & Ireland, Denmark & Finland

The technical efficiency scores derived from the DEA analysis highlight a consistent pattern among countries making up the frontier. Switzerland, Norway, and Ireland emerge as the core countries consistently making up the efficiency frontier across the entire period from 1995 to 2021. Denmark joins this group intermittently, starting in 1998–1999, and becomes a consistent part of the frontier from 2007 to 2021. Finland also contributes to the frontier but does so sporadically, with noticeable gaps during certain periods. This pattern underscores Switzerland, Norway, and Ireland as the foundational reference countries for the frontier, while Denmark and Finland play increasingly prominent but varying roles over time.

4.3. Determinants of TFP Development for the Total Economy: the Role of Exogenous Variables

In the following analyses, we have not made any distinction between exogenous variables that relate to management control and those outside of management control. However, it is worth bearing this distinction in mind when interpreting the results. The literature points to several factors that, on a country level, relate to productivity. We categorize the variables into macroeconomic, innovation, human capital, and institutional variables. Table 2 summarizes the literature surveyed and the indicators used in our analysis.

[28] The Netherlands is also one of the countries making up the frontier. However, it is a country that is never used as a reference or a peer country, meaning that it is never used as a peer for evaluating the inefficiency of other countries, indicating that it is not comparable as a benchmark for other countries in the dataset.

Table 2. *Exogenous factors influencing TFP according to the literature*

Variables	Indicators
Macroeconomic	Imports (Bas & Strauss-Kahn, 2014; Bigsten et al., 2016; Blalock & Veloso, 2005; Busse & Groizard, 2008; Goldberg et al., 2010; Hwang & Wang, 2012; Kim et al., 2007; Ramzan et al., 2019; Ray, 2012; Wang et al., 2021). Trade openness (Chen, 1999; Coe & Helpman, 1995; Edwards, 1998; Frankel & Romer, 1999; Goldin et al., 2020; Howitt & Aghion, 1998; Krueger, 1997; Lucas, 1988; Miller & Upadhyay, 2000; Romer, 1986, 1990; Sachs et al., 1995; Tavares & Wacziarg, 2001). Population (Jones, 1995; Khan, 2005; Kremer, 1993; Ramzan et al., 2019; Strulik, 2005). Exchange rate (Mcleod & Mileva, 2011; Diallo, 2010; Berka et al., 2014). Intangibles (Adarov & Stehrer, 2019; Brynjolfsson et al., 2021; Corrado et al., 2017b; Goldin et al., 2020; Goodridge et al., 2018; Haskel & Westlake, 2018). Tangibles (Adarov & Stehrer, 2019). Demand, Consumer Price Index (Kataryniuk & Martínez-Martín, 2019; Malik et al., 2019).
Innovation and R&D	Government expenditure in R&D (Ascari & Di Cosmo, 2004; Baltabaev, 2013; Brynjolfsson et al., 2021; Cameron et al., 2005; Hamamoto, 2003; Sobieraj & Metelski, 2021).
Human capital	Population with tertiary education (Goldin et al., 2020; Sobieraj & Metelski, 2021). Secondary school enrolment rate (Akinlo & Adejumo, 2016; Englander & Gurney, 1994; Narayan & Smyth, 2005). Persons employed in science and technology (Ascari & Di Cosmo, 2004; Sobieraj & Metelski, 2021).
Institutions	Government effectiveness (Acemoglu et al., 2000; Baltabaev, 2013; Sachs & Warner, 1997; Sala-i-Martin et al., 2003). Regulatory variables (Olomola & Osinubi, 2018).
Shocks	Business cycles (Goldin et al., 2020; Vergeer & Kleinknecht, 2014). Crises and pandemics (Bussière et al., 2015; Caballero et al., 2017; Ollivaud et al., 2016; Reifschneider et al., 2015). Country and time effects.

Macroeconomic variables

- *Population*

Population is generally associated with positive effects on economic growth in endogenous growth models, as a larger population generates more ideas and fosters greater innovation (Jones, 1995). Kremer (1993) supports this view by pointing out long-term historical data that shows a positive relationship between population growth and technological progress. However, other theories suggest that the impact of population growth can be either positive or negative depending on whether households have altruistic or selfish motives (Strulik, 2005).

- *Trade openness*

Theories suggest that trade openness enhances long-run economic growth by increasing technology and facilitating spillovers (Coe & Helpman, 1995; Goldin et al., 2020; Howitt & Aghion, 1998). New growth theories (Lucas, 1988; Romer, 1986, 1990) argue that trade openness boosts growth through technology and specialization via learning-by-doing activities. Empirical studies generally support this, showing that outward-oriented countries often experience higher growth (Edwards, 1998; Frankel & Romer, 1999; Sachs, 1995; Warner, 1995). Chen (1999) found positive effects of trade openness on growth in Asian and Latin American countries. However, the findings are mixed. Some studies report positive links (Krueger, 1997; Miller & Upadhyay, 2000; Tavares & Wacziarg, 2001), while others find no correlation or negative effects, particularly if countries focus on sectors with comparative disadvantages (Lucas, 1988; Sarkar, 2008). Rodriguez and Rodrik (2000) argue that discrepancies in results are due to different estimation methods. Ulaşan (2015) concludes that trade openness alone does not correlate with growth, suggesting that the impact depends on various intervening variables. These findings underline the importance of trade openness in promoting innovation and steady economic growth. For developing countries, the positive relationship between trade openness and economic growth suggests the need to enhance domestic TFP levels to fully benefit from open trade policies (Ramzan et al., 2019).

- *Imports*

There are two streams of literature on the effects of imports: one emphasizing positive impacts, and the other highlighting negative impacts. Ramzan et al. (2019) argued that the introduction of new varieties through imports boosts domestic TFP levels. Firm-level evidence supports this relationship: Bigsten et al. (2016) found that input tariff liberalization correlated with higher firm-level TFP in Ethiopia. Similarly, Bas and Strauss-Kahn (2014) showed that French firms increased their TFP by 2.5% by importing more varieties of intermediate inputs. Goldberg et al. (2010) demonstrated that lower input tariffs were responsible for 31% of new products introduced by domestic firms in India. Further evidence indicates that imports of new technology enhance GDP growth through TFP development, especially in developing countries. Blalock and Veloso (2005) and Busse and Groizard (2008) found that long-term imports of new technology increased GDP growth by raising TFP levels. On the other hand, Ray (2012) recognized that imports have a negative impact on TFP growth in India. Hwang and Wang (2012) found a non-significant relationship between imports and TFP in Taiwanese and Korean manufacturing industries. Moreover, while the complexity of imported products can drive domestic industries to imitate and learn, it also risks production failures and inefficient resource allocation, potentially harming the domestic market (Wang et al., 2021). Kim et al. (2007) also noted that increased productivity in an import-substituting industry reduces imports and negatively impacts the domestic market.

- *Demand and business cycles*

Decomposing cyclical and long-term factors is crucial to understanding whether slow productivity growth is becoming a permanent feature. Post crisis, investment declines played a key role, but Fernald et al. (2017) argue that these declines followed cyclical patterns. The weak recovery was mainly driven by slower TFP growth and reduced labor force participation. The main explanations for the cyclical, crisis-driven slowdown in investment can be attributed to increased financial risks post 2008 (Caballero et al., 2017) and depressed aggregate demand that slowed investment (Bussière et al., 2015; Ollivaud et al., 2016). The crisis also reduced TFP through cuts in both physical and intangible investments, with public intangibles like information and societal assets being vital for TFP growth (Corrado et al., 2017). Credit restrictions during the crisis also led to lower R&D investments, which further hindered TFP (Redmond & Van Zandweghe, 2016). In terms of labor productivity, Ollivaud et al. (2016) found that TFP slowdown accounted for most of the pre-crisis drop from 1.8% to 1%, while post-crisis declines were due to weaker capital deepening. Finally, increased output gaps exacerbated the reduction in the contribution of capital to long-term productivity growth (Goldin et al., 2020).

Assets

- *Intangibles*

Investment in intangible assets significantly impacts TFP. Corrado et al. (2009) highlight the need to reclassify certain business expenses, currently considered intermediate consumption, as investments. This reclassification could increase the GDP; however, the impact on growth rates and the productivity slowdown remains uncertain (Stehrer et al., 2019). Investments in artificial intelligence (AI) related intangibles could contribute significantly to GDP growth, with estimates suggesting up to a 1% boost (Brynjolfsson et al., 2021). However, following the financial crisis, rising financial risk premiums disproportionately affected intangible investments, limiting their contribution to productivity (Caballero et al., 2017; Duval et al., 2020). Intangible assets, such as R&D, economic competencies, and management practices, are increasingly recognized as essential for sustaining long-term productivity growth (Goldin et al., 2020). The synergies between intangible and IT capital, as explained by Haskel and Westlake (2017), often result in long lags in productivity improvements due to the adjustment costs associated with new technologies. Additionally, Corrado et al. (2017) found that a slowdown in intangible capital services growth contributed significantly to the overall decline in TFP growth in the US (Corrado et al., 2020) after the financial crisis, underscoring the critical role of intangibles in productivity dynamics.

Innovation

- *R&D expenditure*

A substantial body of literature exploring the sources of economic growth (e.g., Aghion & Howitt, 1998; Cameron et al., 2005; Goldin et al., 2020; Griffith et al., 2003; Jones, 1995; Romer, 1990; Sobieraj & Metelski, 2021) emphasizes the connection between R&D expenditures, TFP, and growth. For instance, Hamamoto (2006) studied Japanese manufacturing industries and discovered that increased R&D investment driven by regulatory stringency significantly boosts the growth rate of TFP. Similarly, Ascari and Cosmo (2004) identified a positive relationship between R&D expenditures and TFP in Italian regions. Baltabaev (2013) also found that R&D expenditure positively and significantly impacts TFP. Investment in R&D is a crucial driver of TFP as it fosters innovation and the development of new technologies. Overall, the literature consistently shows a strong relationship between R&D expenditures and TFP improvements. Cameron et al. (2005) pointed out that R&D activities significantly enhance innovation rates and contribute to higher TFP levels. Baily and Gordon

(1989) and Brynjolfsson et al. (2021) show that there is a time lag in realizing the benefits of new technologies. The authors state that while there is optimism about the potential of new technologies and innovations to enhance productivity, the actual productivity gains may be delayed due to implementation and restructuring lags, as well as challenges in measuring the impact of intangible capital.

Human capital

Human capital is crucial for acquiring and utilizing technology, making it a natural prerequisite for high TFP levels (Goldin et al., 2020; Kneller, 2005; Nelson & Phelps, 1966). However, there is a potential issue: human capital might be seen more as an input in the production process rather than a direct source of higher TFP (Mankiw et al., 1992). This raises the question of whether human capital should also be considered a determinant of TFP through knowledge externalities, as suggested by Lucas (1998). Baltabaev (2013) found a negative significant relationship between TFP and human capital, trade openness, and population growth in the sample countries. Human capital, particularly education and health, is a significant determinant of TFP. Alvi and Ahmed (2014) found that health, measured by life expectancy, and education, measured by average years of schooling, have positive and significant impacts on TFP in both developed and developing countries. However, Islam (1995) concluded that while human capital does not have a significant direct impact on output, it influences growth indirectly through TFP. Benhabib and Spiegel (1994) found that when human capital growth is incorporated into output-growth estimations, its effect is either insignificant or even negative. Moreover, Ang et al. (2011) highlight the significance of the composition of educational attainment. In high- and middle-income countries, higher levels of tertiary education can enhance TFP by fostering innovation. Conversely, in developing countries, human capital is less impactful because these countries primarily adopt technologies developed by more advanced nations.

Institutional factors

A robust body of literature investigates the impact of institutions on economic performance. Acemoglu et al. (2000) highlight the critical role of institutions in economic development. Studies by Sachs and Warner (1997) and Sala-i-Martin et al. (2003) also emphasize the importance of institutional quality, including aspects like governance, legal frameworks, and political stability, in promoting economic growth. Baltabaev (2013) includes government effectiveness as the instrument variable and finds that it is highly correlated with attracting foreign direct investment (FDI) and, thus, driving productivity. Good institutions reduce transaction costs, protect property rights, and create an environment conducive to economic activities. Studies have shown that countries with strong institutional frameworks tend to have higher TFP levels (Islam, 2005). For example, government effectiveness, regulatory quality, and control of corruption have been positively correlated with TFP growth.

We employ a fixed effects regression model to analyze the determinants of TFP in SAOEs.[29] Fixed effects regression models are estimated using panel data techniques, with robust standard errors to account for potential heteroscedasticity and serial correlation in the error terms. The results of these regressions provide insights into how macroeconomic, innovation, human capital, and institutional factors influence TFP in SAOEs.[30] In the regression analysis, the

[29] The fixed effect is chosen based on the Hausman test.
[30] The variables chosen for the analysis and their definitions are included in Appendix 5.1.

annual change in TFP is used as a dependent variable, and the variables listed in Table 1 are used as explanatory variables. The regression relationship is:

$\ln TFP_{it} = \alpha_i + \beta_i \mathbf{X}_{it} + \varepsilon_{it}, t = 1,..,T, \ i = 1,...,I$, where α_i is the constant, β_{it} is the parameters to be estimated, and **X** is the vector of covariates.

In the model, all variables are in the natural log except for dummy variables. Only those variables that are significant at the 10% level are reported in Table 3. The full results are presented in Appendix 5.5.

Table 3. *Correlation between exogenous factors and total factor productivity*

VARIABLES	Total Factor Productivity (BHM index)
Macro	
Trade openness	+
Assets	
Intangible assets time *t*	-
Intangible assets time *t*-1	+
Tangible assets time *t*	-
Tangible assets time *t*-1	+
Tangible assets time *t*-2	+
Innovation	
R&D expenditure time *t*	-
R&D expenditure time *t*-1	+
R&D expenditure time *t*-2	-
Human capital	
Population with tertiary education	-
Institutions	
Shocks	
Eurozone crisis	-
Constant	*2.009*
R-squared	0.76
Number of observations	192
Number of countries	9

+/- indicates positive/negative significant coefficients. 0 represents insignificance.

Macro

The positive coefficient for trade openness on TFP suggests that trade openness enhances long-run economic growth by increasing the technological level and facilitating spillovers (Coe & Helpman 1995; Goldin et al., 2020; Howitt & Aghion, 1998).

Assets

There are two variables associated with intangible assets that are significant. The negative sign of intangible assets in period *t* indicates a negative association with TFP. However, the coefficient for intangible assets in the period before (*t*-1) indicates a positive relationship. One interpretation is that if firms invest in intangible assets in one period, it takes around a year before there is some pay-off in terms of increased productivity (see Goldin et al., 2020; Haskel & Westlake, 2018). The same holds to some extent for tangible assets as well despite the negative sign for tangible assets in period *t*. It should also be noted that the variation in TFP is mainly related to efficiency change regarding both tangible and intangible assets. This is because TFP measures how effectively all inputs (both tangible, like machinery, and intangible, like knowledge or technology) are used in production. When efficiency improves, more output is produced from the same amount of inputs, leading to an increase in TFP.

Innovation

As regards innovation variables, R&D expenditure reveals the same pattern. The relationship with TFP is negative in period *t* but positive and significant in period *t*-1. Investment in R&D has lagged effects (Baily & Gordon, 1989; Brynjolfsson et al., 2021). For example, consider a company adopting AI to automate customer service. Initially, there will be a period when the AI system is being integrated, employees are being trained, and processes are being adjusted. During this period, productivity might not improve significantly, and the benefits of the AI system might not be fully measured. However, once the AI system is fully operational and optimized, the company will most likely see a substantial boost in productivity.

Institutions

None of the variables in the institution category are significant. One reason for this might be that the countries that make up the group of SAOEs are very similar with respect to the institutional variables used.

Shocks

The Eurozone crisis was significantly negatively related to productivity change, suggesting that firms faced several disruptions. The structural and economic challenges within the Eurozone compounded the difficulties, leading to a reduction in overall productivity.

5. Sector-Wise Comparison Between Sweden and SAOEs

The results for the manufacturing and services sector are presented in this section. The cumulative TFP growth for Sweden and the SAOEs is compared. The results for Sweden and the MAOE and AOEs are included in Appendix 2.

There are several production environmental factors that can affect TFP changes, such as technical advances, investment in tangibles and intangibles, economic crises or pandemics, changes in exports/imports, changes in fiscal policies, and managerial efficiency. When explaining the decomposition of productivity growth, it is crucial to connect the observed patterns of technological change with the specific behaviors and characteristics of each sector. Consider the introduction of AI and automation technologies. Some firms rapidly adopt these new technologies, thus enhancing their efficiency and productivity. However, not all firms can keep pace with these changes. Firms that are slower to adopt new technologies or face barriers to adoption may see a relative decline in their productivity. This divergence also highlights efficiency changes, as firms that integrate AI and automation early gain advantages, while lagging firms experience temporary inefficiencies. Over time, as lagging firms begin to catch up by adopting these new technologies, there is a convergence toward the new production frontier as the efficiency gaps narrow. The introduction of new technologies also creates incentives for other firms to conduct more R&D to innovate and remain competitive. For example, removing financial constraints that prevent managers from purchasing expensive technologies or eliminating patent protections that limit access to new innovations can accelerate the diffusion of technology. In summary, the decomposition of productivity involves understanding how technological changes, such as the introduction of AI or other major new technologies, and efficiency changes impact different sectors. It highlights the initial inefficiencies caused by varying rates of technology adoption and the subsequent catch-up process.

5.1. TFP Development

Sweden's manufacturing sector exhibits robust cumulative productivity growth compared to SAOEs. The cumulative productivity for manufacturing depicted in Figure 9 shows a significant increase for both Sweden and SAOEs, and Sweden leads SAOEs.

Figure 9. *Cumulative TFP, comparing Sweden and SAOEs, manufacturing sector*

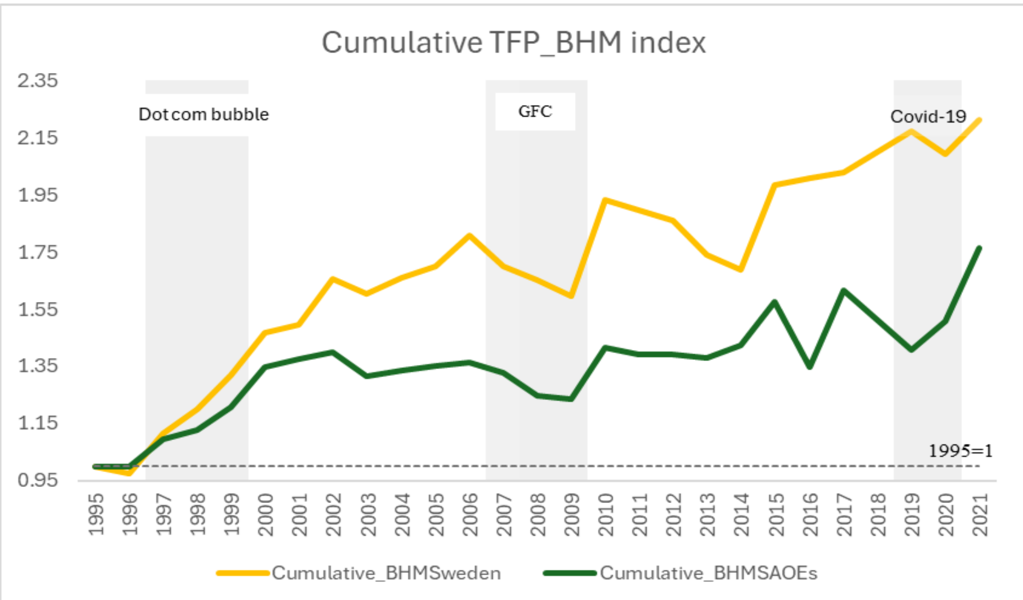
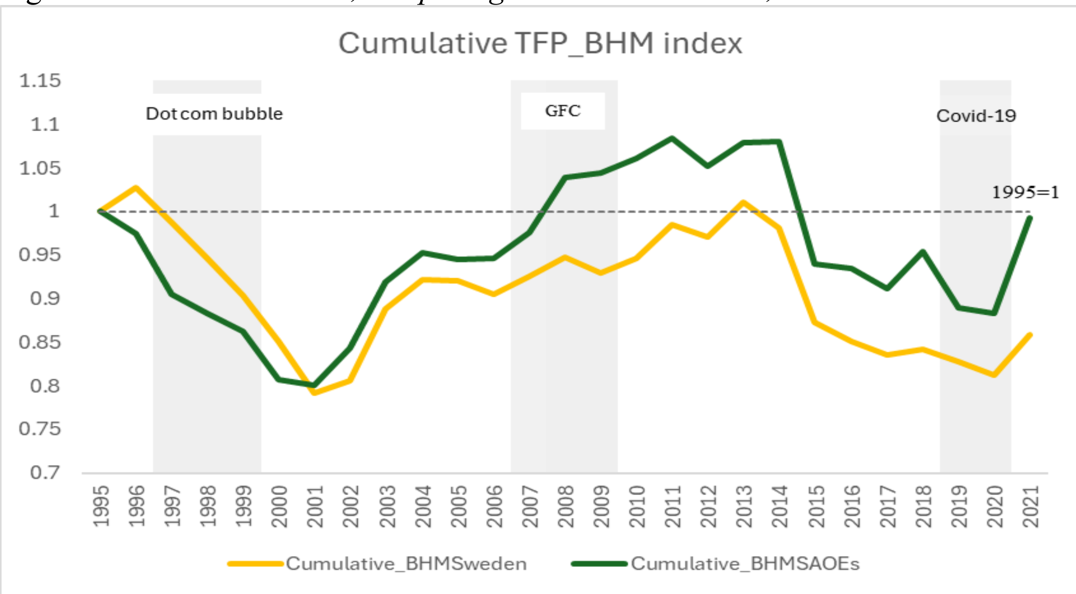


Figure 9 shows that, after 2000, Sweden had significantly higher TFP than the average of the SAOE countries in the manufacturing sector. Both Sweden and the SAOEs experienced a decline in productivity during the global financial crisis and the pandemic period. It is also evident that Sweden recovered more rapidly than the SAOEs, which experienced a modest recovery post crisis.

As shown in Figure 10, the computed cumulative TFP for the service sector indicates a contrasting pattern compared to the manufacturing sector. Until 2001, Sweden led the SAOEs, but since 2002, Sweden has lagged and experienced a fluctuating trend in productivity.

Figure 10. *Cumulative TFP, comparing Sweden and SAOEs, service sector*



The decline in TFP in both SAOEs and Sweden might be attributed to the adverse business cycles, crises and pandemics, shifts in demand, and challenges in adapting to technological progress. Investment in R&D in Sweden and SAOEs was quite low from 2007 to 2014.[31] However, investment in intangible assets in Sweden has shown an increasing trend (Persson et al., 2024) over the years,[32] which should theoretically enhance productivity development. However, the SAOEs have invested relatively more in intangible assets than Sweden, potentially contributing to their higher performance in the service sector compared to Sweden.

Comparing cumulative TFP development in the manufacturing and service sectors reveals heterogeneity between the two sectors. While the TFP development in the manufacturing sector is almost constantly growing, the TFP development in the service sector shows that Sweden is struggling to recover from the productivity decline in the late 1990s.

[31] See A.3.2 in Appendix 3.

[32] See Appendix 4.

5.2. Technological Change and Efficiency Change in Sweden

In Figures 11 and 12, TFP has been decomposed into technological and efficiency change for the two sectors.

Figure 11. *Technological and efficiency change in the manufacturing sector in Sweden, reference year 1995*

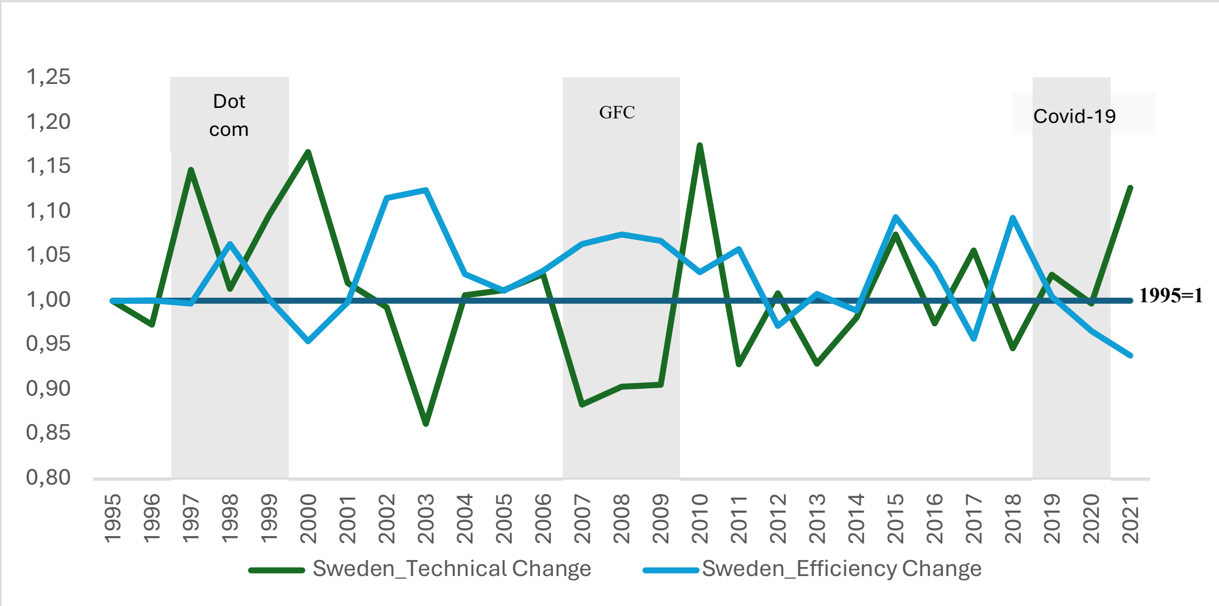
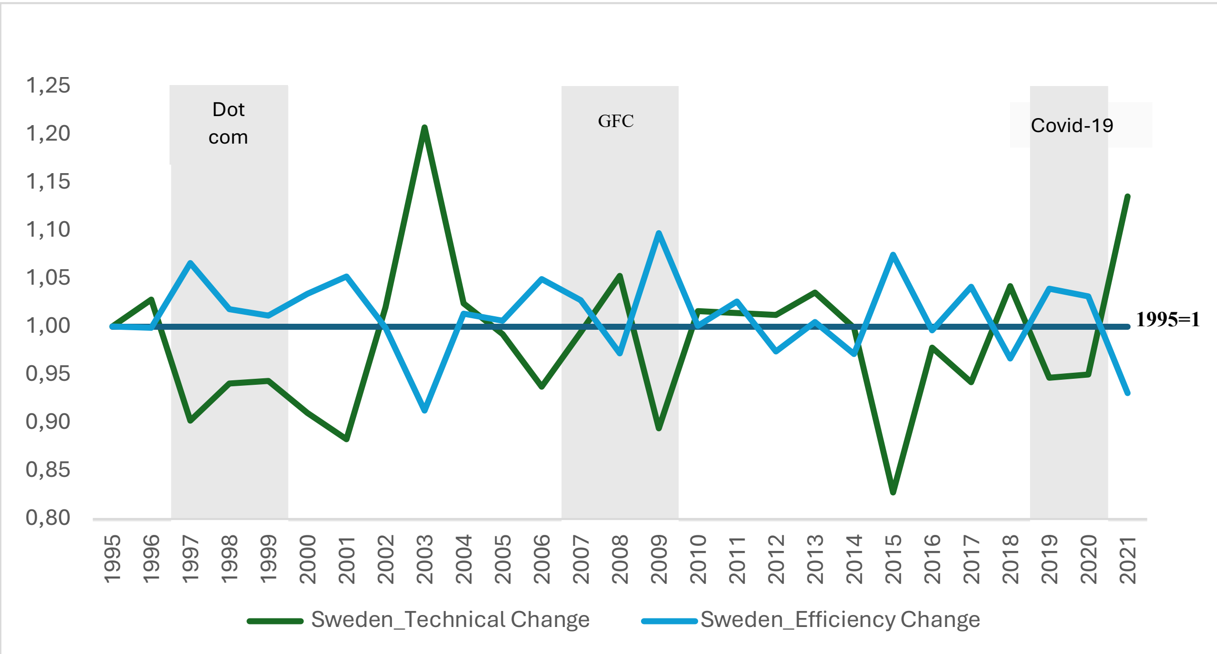


Figure 12. *Technological and efficiency change in the service sector in Sweden, reference year 1995*



A first observation is that what is driving the cumulative TFP development presented in Figures 9 and 10 is mainly the distinct differences in the late 1990s. While the manufacturing sector had a positive technological change (TC>1) and an efficiency change that was on average around neutral (EC=1), this results in increased TFP (TFP>1). During the years of the financial crisis, the best-producing countries among the SAOEs were producing less, causing the production possibility frontier to move inwards. As seen in Section 3, this could be offset by an increased efficiency in that a country moves closer to the frontier. If a country produces the same amount of output using the same amount of inputs in two years, TFP is unchanged (TFP=1). Therefore, the negative change in TC (TC<1) is totally offset by an equal movement closer to the frontier (EC>1), causing TFP to remain unchanged (TFP=1). However, during the financial crisis in the mid-2000s, the inward movement of the frontier (TC<1) is not offset by an equal movement towards the frontier (EC>1), causing TFP to drop (TFP<1). The difference between the two sectors is that the manufacturing sector displays a large improvement in TFP, with both TC and EC well above 1, and the same recovery is not seen in the service sector. It is also evident that the service sector does not have years that boost productivity development in the way the manufacturing sector does. For example, in 2016 and 2019, the manufacturing sector had TFP growth (TFP>1) that was driven by both technological advancements (TC>1) and movements closer to the frontier (EC>1). In the same year, the service sector had a drop in TFP (TFP<1) driven by an inward movement of the frontier (TC<1) that was not offset by an equal amount of movement towards the frontier (EC>1). In summary, there are differences related to the driver of TFP between the sectors. In the next section, we look into what exogenous factors can be important for the development observed above.

5.3. Regressing Exogenous Factors on TFP Development in the Manufacturing and Service Sectors

In the regression results presented in Table 4, the dependent variable is TFP changes.[33] Only exogenous factors that have a significant correlation are presented in Table 4.

[33] The SAOE group at a disaggregated level does not include Switzerland (manufacturing and service sectors) and Ireland (service sector). The data for capital input (GFCF) was unavailable for the manufacturing, construction and service sectors for Switzerland, and data at the service sector level was unavailable for Ireland.

Table 4. *Correlation between exogenous factors and total factor productivity, manufacturing and service sectors*

VARIABLES	**Manufacturing** Total Factor Productivity (BHM index)	**Service** Total Factor Productivity (BHM index)
Macro		
Domestic price (CPI)		+
Exchange rate		-
Imports	-	
Assets		
Intangible assets time *t*	-	
Intangible assets time *t*-1	+	+
Intangible assets time *t*-2	+	
Tangible assets time *t*	-	
Tangible assets time *t-1*	+	-
Inventories	+	
Innovation		
R&D expenditure time *t*	-	-
R&D expenditure time *t*-1	+	+
Human capital		
Institutions		
Shocks		
COVID-19 pandemic	+	+
Constant	+	+
R-squared	0.73	0.44
Number of observations	167	157
Number of countries	8	7

+/- indicates positive/negative significant coefficients. 0 represents insignificance.

As seen from Table 4, overall, few exogenous variables have any significant relation to TFP change in the manufacturing sector. Import is negative and significant, indicating that increased import is negatively related to TFP. This is in line with the stream of literature that argues that importing goods and services will reduce the demand for potential domestic production (Hwang & Wang, 2012; Kim et al., 2007; Ray, 2012; Wang et al., 2021). In the service sector, domestic prices (CPI) have a statistically significant and positive correlation with TFP changes. This suggests that inflation in the studied context has not yet reached a threshold where it adversely affects growth. This is in line with Khan and Sinhadji (2001), who found that inflation begins to negatively impact growth only when it exceeds a threshold of 11%–12% in developing countries. Additionally, these findings are consistent with Ghosh and Phillips (1998), who also highlighted the nuanced relationship between inflation and growth, indicating that moderate inflation can coexist with positive economic outcomes, as observed in our results. Also, the exchange rate has a significant correlation with TFP changes.

Tangibles, intangibles, and R&D expenditure have a positive lagged effect for the manufacturing sector. In the manufacturing sector, R&D often has a lagged effect, most likely because the development and implementation of new technologies, processes, and products typically require significant time. After R&D investments, there is a period for experimentation, testing, and refinement before the innovations can be fully integrated into production. Additionally, employees need time to learn and adapt to new systems, and the market may also take time to respond to new products. This delay between investment in R&D and observable improvements in productivity or efficiency explains why the benefits of R&D are not immediately evident but manifest over subsequent periods. Goodridge et al. (2018) suggest that missing lagged spillovers from reduced R&D investment in the 1990s and 2000s contributed to the slowdown in TFP growth. Several studies support the finding that new technologies have lagged effects (Baily & Gordon, 1989; Brynjolfsson et al., 2021). The lagged effect of investment in tangibles, intangibles, and R&D is also evident in the service sector (Baily & Gordon, 1989; Brynjolfsson et al., 2021).

The positive impact of inventories on TFP suggests that maintaining appropriate inventory levels is crucial for firms to ensure smooth operations, respond to market demands, and enhance overall productivity. For example, maintaining higher inventory levels can help firms buffer against supply chain disruptions, which, for reasonable levels of inventories, ensures continuous production and sales processes, resulting in potentially better utilization of resources and, thereby, higher productivity.

The positive coefficient during the COVID-19 pandemic reflects a significant technological shift and can be partially explained as crises to some extent driving innovation and technological adoption (Lopez-Garcia & Szörfi, 2021). Firms were compelled to adapt to new challenges and opportunities—for example, rapid digital transformation to continue operations remotely. Examples in the service sector include restaurants adopting an online delivery system, educational institutions shifting to online learning, and healthcare shifting towards telehealth services.

In conclusion, the regression results show that the exogenous drivers of productivity differ at the sector level. For example, among the macroeconomic variables in the regression, it is factors related to prices and the exchange rate that correlate with TFP changes in the service sector, while it is import volumes that correlate with TFP changes in the manufacturing sector. But there are also some similarities. For example, R&D investments show a significant, though lagged, correlation with TFP changes for both sectors. These findings emphasize the importance of exogenous factors and management decisions in influencing productivity growth.

6. Conclusion and Concluding Remarks

In the first report (Unnikrishnan & Månsson, 2023), the starting point was a replication of Färe et al. (1994). The motivation was that we would like to have a benchmark concerning the model used, inputs and outputs, and, finally, the data source to be used. The aim was then to extend the analysis to cover a longer time period. In that report, we concluded that the data source used in the original article was too volatile to be used in a study of productivity covering several years. To further investigate what is causing this variation in the results, a correlation analysis between PWT5 and PWT10 was performed. The correlation between the input in PWT5 and PWT10 versions was low and negative. This discrepancy highlighted the limitation of the PWT: it varies substantially across different versions of PWT, for instance, Johnson et al. (2013). This was also noted in the first report (Unnikrishnan & Månsson, 2023), where the results presented based on different versions of PWT varied substantially despite being derived from very similar underlying data and using identical methodologies. Thus, this raised concerns about the consistency of the PWT database, which could potentially impact longitudinal studies and cross-country comparisons. Hence, in Unnikrishnan and Månsson (2023), we recommended an alternative comprehensive database and used the iSTAN database provided by the OECD. In Unnikrishnan and Månsson (2023), we also tried out several more recent productivity indexes.

Our findings and conclusions regarding some of the key questions were as follows: a) we are using the same model specification as in Färe et al. (1994); b) instead of using PWT, as was done in Färe et al., we choose to use iSTAN data from the OECD, basing this decision on the fact that iSTAN is stable over time and also comprises data collected by the OECD; finally, c) we use a productivity index that shares all positive attributes with the Malmquist index used in Färe et al. (1994) but that relies on fewer assumptions (i.e., non-testable preconditions).

In this second study, we take the empirical work further and present productivity development based on our findings from Report One. In this analysis, we utilized the index approach to measure and compare the TFP of Sweden with mainly a group of SAOEs.[34] This index approach provided a decomposition by incorporating both technological advancements and efficiency improvements, thereby offering more informative information about the drivers of productivity changes than is possible with partial measures. The comparative analysis revealed distinct patterns of impact of technological and efficiency changes in Sweden and SAOEs, which is potentially useful when forming policy.

- *Sweden and its peers*

Sweden's relative productivity changes show significant variation depending on the group of economies with which it is compared. When measured against MAOEs, Sweden tends to lag and exhibits more volatile productivity trends. This can be attributed to Sweden's smaller size and its greater sensitivity to economic shocks compared to larger economies. A similar pattern emerges when comparing Sweden to AOEs, highlighting the challenges of such comparisons due to inherent differences in scale and resilience. However, when Sweden is compared to SAOEs, which have more similar characteristics, it performs markedly better. The sector-specific analysis shows that Sweden excels in the manufacturing sector compared to other SAOEs but is lagging behind when the same analysis is performed on the service sector. This highlights the fact that recognizing the unique characteristics of an economy when making comparisons is important for the development of effective strategies that drive economic growth.

- *Decomposition of total factor productivity*

In the report, a decomposition approach is used to analyze TFP by breaking it down into two components: technological change (TC) and efficiency change (EC). This decomposition into TC and EC allows us to identify specific contributions from technological changes, such as the introduction of new technologies and innovation (captured by TC), and distinguish them from better use of resources, which can result from both adaptive innovation and environmental factors or managerial characteristics (captured by EC). This approach, therefore, also aids policymakers in formulating interventions that address specific drivers of productivity growth. Nevertheless, to achieve this level of precision, microdata is imperative for capturing in-depth insights into individual firms and households. However, using microdata is beyond the scope of this study.

- *Variations in total factor productivity*

Even if the decomposition gives a description of how development took place, there are exogenous factors outside production itself that affect it. In this context, we are talking about three different groups of factors. The first group of factors consists of management's ability to make the right decisions. This group of factors requires us to know which people (or person) make up company management. The second group of factors is those that are exogenous to production and that management cannot influence. An example of these is the weather, which

[34] The detailed results when comparing with AOEs and MAOEs are presented in Appendix 2.

affects, for example, the agricultural, construction, and tourism sectors. A third set of factors comprises those that are exogenous to production but where management can choose to act or not to act, can act quickly or slowly, and so on. At the level of aggregation at which this study is conducted, it is mainly factors of the second and third kind that have been included in the regression analysis.

The variables in the regression analysis have been divided into macroeconomic factors, innovations and R&D, labor force composition, institutional conditions, and shocks. In the regressions, we have also included the country's total tangible and intangible asset value.

Of the macroeconomic factors, only the variable that indicates how open a country is to exchange with other countries is positive and significant, which indicates that more open countries generally have higher productivity.

For both the tangible and intangible asset variables, the results show a delay before investments lead to productivity gains. Similarly, R&D expenditure exhibits a lagged positive impact on TFP, indicating that it takes time to transform innovations into productivity improvements and, thus, increased competitiveness. None of the institutional variables were insignificant, most likely because the countries studied here are similar in many of the institutional dimensions measured, which means very little variation between countries. As for the shocks that occurred during the period, it was mainly the Eurozone crisis that had an impact. According to the results, productivity fell by approximately 1.2% because of the Eurozone crisis.

A first observation in the sectoral analysis is that there is a relatively large difference between the manufacturing and service sectors. For example, the results show that the import volume is of primary importance for the manufacturing sector, while the exchange rate is important for the service sector. Furthermore, the results show that assets and R&D are more important for the manufacturing industry than for the service sector. Of the shocks we controlled for, the results show that the COVID-19 pandemic had a weak positive impact on productivity for both sectors.

As mentioned at the outset, the starting point for the entire productivity project has been investigating the possibilities of studying productivity using slightly more modern and complete methods compared to what is usually used. Our conclusion is that productivity can be measured with modern methods, which is why studies that aim to measure TFP recommend using these methods and indices. Using partial measures or other simplifications may have implications for the policy recommendations being made. Finally, by using more modern methods, it is possible to obtain more information about what drives productivity development, which forms a better basis for, for example, growth and industrial policy.

- *Future development work*

Although this work has answered some questions, new questions and areas have also been identified. One of the conclusions of this work is, unsurprisingly, that when comparing countries, the choice of comparison countries is of great importance. In this study, our choice of SAOE countries was based on the fact that they show similarities to Sweden in a number of observable dimensions, which we believe solves some of the problem with choosing comparison countries. However, more research is needed on how a comparable country group can be constructed. Another area where development work is underway is building productivity indices based on aggregated sector analyses rather than calculating productivity based on already aggregated data. However, this requires access to microdata. Finally, there are more groups of explanatory variables that have not been, or will be, available at the aggregate level—for example, variables that can be assumed to correlate with the quality of management decisions (e.g., education and experience with company management). Even these analyses require access to microdata.

7. References

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