Digitisations effect on the inflation rate

-An empirical analysis of possible digitisation channels

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Abstract

This thesis investigates the impact of a more digitised economy on the inflation rate. European countries have historically done well in reaching their inflation target. In recent years however, policymakers have been puzzled over low inflation rates that seem to be difficult to stimulate. Just recently the impact of digitisation on price stability has gained some interest in economic research however the lack of empirical evidence on this relationship is severe.

Based on scarce literature and existing theories hypotheses were constructed to test certain digitisation channels effect on the inflation rate. By gathering relevant data on inflation and the identified digitisation channels for 17 European countries over an 11-year period, econometric models corresponding to the hypotheses were analysed.

The estimated results show that digitisation have a varying net-effect on the inflation rate, demonstrating that digitisation plays a role in determining fluctuations in price stability when controlling for other macroeconomic factors. These findings indicate that policymakers should consider digital technological development when targeting inflation, even though the effects may be temporary.

Key-words: Digitisation, Digitalisation, Digital technology, Inflation, Inflation rate, Automation, E-commerce, Better-informed consumers, ICT-products, CPI, Arellano-Bond
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1 Introduction

“Inflation is going to be left to the Federal Reserve and that’s going to be bad news. An effective program to reduce the rate of inflation has to extend beyond monetary policy and needs to be complemented by programs designed to enhance competition and to correct structural problems”

Federal Reserve Chairman William Miller uttered the above stated citation in 1978 (Romer and Romer, 2012). The view of monetary policies effectiveness regarding controlling the inflation rate was quite low during the time. Central banks later turned to more active forms of monetary policy as a result of high inflation along with high unemployment rates during the 1970s. Stagflation, which was quite a new phenomenon at the time, were the prime reason for why the federal reserve and many economists changed their views on active monetary policy (Barsky and Kilian, 2000). The following years also proved the importance of these policies since inflation rates swiftly declined in the 1980s and onwards. However, the financial crisis in 2008 later taught us that price stability seem to be a necessary condition for economic stability, but not a sufficient one (Papademos, 2006).

One of the most important aspects of economics is undoubtedly the inflation rate. This is perhaps why the inflation rate very well could be the most recurring topic in academic publications. Economists have always been interested in explaining fluctuations in inflation since it has a powerful influence on economic behaviour. The ideal inflation rate is stable and relatively low. This will, according to economists, provide an environment where individuals, households and firms do not have to consider inflation to the same extent as if it were unstable (The Riksbank, 2011). At first, stable inflation reduces the uncertainty about future price changes. If uncertainty is high, economic actors demand an insurance against the future risk of a devaluation of the currency. This insurance drive interest rate up which in turn causes economic activity to slow down. Secondly, a high unstable inflation rate causes firms and individual investors to hesitate on whether or not to invest due to the higher degree of uncertainty (ibid). Important questions that economic actors ask themselves are therefore more difficult to try to answer during a period with a high and fluctuating inflation rate. These hesitations also cause the economic activities to slow down further. Lastly, a stable inflation rate also eases the process to separate changes in relative prices of certain goods from rising inflation in the overall economy and make price signalling more effective and reliable.
Historically, European countries have done quite well regarding their targeted inflation rate. The inflation target for the Euro area is just below two per cent with slight deviation for other countries in Europe. The Eurozone had on average an inflation rate of 2.1 per cent between 1999 and 2010 where Germany showed the lowest rate of 1.6 per cent and Greece the highest with 3.4 per cent (ECB, 2016). These results strongly support that monetary policy is in fact a most important tool for keeping the inflation rate at a level that facilitates economic stability and growth. In recent years however, central banks all over Europe have been puzzled over too low and even negative inflation rates that have sustained for a long period of time. The European Central Bank for example has missed their goal of a two percent rate for three consecutive years (ibid). Monetary policy has been debated thoroughly in academia and media as how to conquer these worrying signs, and arguments has been made that the monetary tools considered to turn this trend may in fact result in worse consequences than the outcome of low inflation rates especially since severe expansionary monetary policy, including negative interest rates, has failed to do so.

But why bother with low and negative inflation? While low inflation for a successive period of time is what monetary policy should strive for, the answer to this question is more complicated than what first is believed. An important aspect of deflation and too low inflation rates is the time period in which it concurs. Deflation is not necessarily a complicated condition if it only occurs for a very brief period of time. However, if deflation is long-spun it could have devastating implications on the economy in question (The Riksbank, 2012). Another important distinction that needs to be put forward is if deflation is a result of changes in aggregated demand or aggregated supply. Demand-oriented deflation is a result of a rapid decrease in consumer demand in relation to the supply. This phenomenon is usually the result of a decline in consumer’s purchasing power and results in falling prices due to a decrease in economic activity. Supply-oriented deflation however, is the other side of the same coin. If supply suddenly increases due to technological development, supply will exceed demand and prices will fall accordingly. There is an important distinction between these two scenarios. When deflation is a result of changes in demand production decreases and is therefore considered to be bad for the economy and has worried policymakers for decades. However, if deflation is the result of supply-oriented changes as technological improvements or other structural changes it is generally considered to be good for the economy, since production increases (The Riksbank, 2003). Supply-oriented deflation is considered to be rare and most time deflation occurs it is as an effect of changes in demand.
The low and negative inflation rates Europe is experiencing today is in large explained with factors that are known to economists. One factor that is emphasised is that markets have recovered more slowly than expected from the financial crisis. This fact is compatible with demand-orientated factors for low and negative interest rates and is therefore considered to be a negative state for the economy. Another factor that is believed to have a heavy influence on recent years development is a drastic decrease in oil prices given that oil is a major input in most economic activities (Federal Reserve, 2015). But are these factors enough in explaining the current destabilising of the economy and the severely low inflation rates which in turn has resulted in relatively controversial measures in monetary policy? Or is it something more abstract and far-fetched that also plays the part? As we learned from the quote of William Miller in the beginning of this chapter, structural changes also seem to affect the inflation rate and central banks also consider these changes to their best ability when predicting the inflation rate. Structural changes however, provide a much more difficult challenge for economists and policymakers due to its complicated nature, since they tend to vary over time and can be difficult to measure (Memedovic, 2010).

In light of what is unfolding in Europe today, one structural change that is of rising interest among economists is the digital technological development and its spread into daily life activities. Digital technology has left no one unaffected and has revolutionised a great deal of our everyday life; from how we consume products, to how we interact with technology and the implications this have on individual’s behaviour (European Commission, 2014). The effects of digital technological development have been debated thoroughly but have mainly focused on the implications for economic growth and productivity. However, very few papers mention a relationship between digital technological development and the inflation rate and no sufficient empiric study to date has focused on this relationship. The articles that mention the effect of digitisation on inflation do so in a hypothetical manner suggesting that the lack of empirical research is severe. This fact took us a bit by surprise since inflation and digital technological development by themselves constitute a significant share of economic research.

1.2 Study objective

Since there is a lack of knowledge regarding the relationship between digital technological development and the inflation rate within academics we have chosen to focus on this relationship in this paper, thereby trying to shine light on whether or not digitisation can be viewed as a form of structural change that partly can explain the current descending inflation rates that seem to be difficult to combat with expansionary
monetary policy. We therefore argue that it is clear that the following research is based on a current and unexplored relationship that may contribute to our knowledge about fluctuations in the inflation rate. By constructing this paper, we aim to provide some empirical evidence on whether or not digitisation is a force that central banks need to consider in their calculations regarding their inflation targeting and to provide empirical evidence in a field that is of utmost importance in economies that is characterised of rapid changes due to technological enhancements. It is also important to mention that if central banks were completely efficient in using their instruments in targeting inflation it would be pointless to try and estimate a relationship between digitisation and inflation, since this relationship then would have been countered by central banks. This would in turn imply that if the results were to indicate a significant relationship, central banks can be argued to be using their instruments inefficiently to counter these consequences.

1.3 Problem Formulation

In this thesis we aim to answer the following research question:

_How does digitisation affect the inflation rate?_

We will in addition to this question try to answer four hypotheses that are tied to digitisation through various channels that are expected to affect the inflation rate. We will also extend our discussion to what extent digitisation affects the inflation and what implications, if any, this has on monetary policy. We will also discuss how and to what extent our econometric methods affect our interpretation of the econometric estimates.

1.4 Demarcation

There are a few reasons why we find it reasonable to restrict our research question and the process of conducting the research. At first we need to adapt to the given time frame, which implies that the analysis and results are to be interpreted as guidelines and recommendations. Also, the complex nature of digitisation, which we will discuss in the next section, forces us to restrict the concept of digitisation to a more concrete approach that is measureable. This restriction can however be viewed as a positive since a wide definition is exposed to risks of being too general. Since digitisation is a relative new phenomenon that also differs between countries (especially between industrialised and developing) it is also motivated to restrict our analysis to countries where digitisation
has advanced. Perhaps the most important demarcation in this paper regards available data. The concept of inflation do not pose a problem, however, the way digitisation is measured does. These are the reasons why we have chosen to limit this research to 17 European countries for an 11-year period.

1.5 The concept of Digitisation

What is meant by digitisation? Digital technology is a concept that includes many different important aspects and is a driving force in the economy today. Inventions as the Internet and digital electronics are now a natural part of individual’s everyday activities. Digital inventions have drastically changed the landscape for how economies function and how individuals interact with each other and with digital technology. Vogelsang (2010) has contributed on how to think about the processes included in digitisation. He argues that every integrated digital technology have at least one thing in common, namely that information in digital technologies are expressed in strings of 0 and 1 that are known as binary digital strings. A more simplified way to think of this process is to imagine analogue information being converted to digital information. He follows this argument by stating that networks play a vital part in digitisation, since the network is what connects producers and consumers with digital goods and IT-services. Digitisation, which is the concept we adapt in this thesis, has many labels including digitalisation, digitising and digitised technology. They all have a great deal in common and can be very difficult to distinguish. For simplicity we apply digitisation in this thesis as the overall concept of the above stated processes in which analogue information is transformed to digital and then applied into overall economy activities.

1.6 Outline of the thesis

The following chapter will present the reader with a sufficient theoretical background on the general determinants of inflation, previous structural changes and digitisation channels that may affect the inflation rate. We then proceed by constructing hypotheses regarding our research question. Chapter three will present the models and data being used to test these hypotheses along with a discussion on the limitations of the data. In chapter four we present which types of regression models that were used along with an interpretation of the results. We finally in chapter five draw conclusions from our findings and discuss policy recommendations.
Digital consumption is argued to substitute physical goods in some parts of the economy. This would imply that demand for inputs in traditional production might be dampened as a result of substitution. Digitisation may therefore play an important part in creating environmental sustainability. The impact of digitisation on environmental sustainability is however diffusing since it requires a significant share of energy sources to function. A more relevant aspect of sustainability in the context of the research question is how it may impact economic and social sustainability. If policymakers fail to recognise, or even ignoring, a phenomenon that impacts the predictability in an economy it can have devastating effects for macroeconomic outcomes. Efficient monetary actions from central banks can therefore aid the economy and give rise to a less volatile unemployment rate. In order to maintain a high level of economic activity along with stable unemployment rates central banks must respond to the given phenomenon in question to offset the possible effects. This thesis is therefore an important step in the development of more sustainable macroeconomic policies and could act as reference literature and guideline for future research regarding the effects of a more digitised economy.
2 Theory and previous literature

This section will at first deal with theories on general determinants of inflation. The following part deals with previous research regarding our research question and instances when it is mentioned on economic platforms. Lastly it will present a more detailed description of a hypothetical framework regarding the relationship published by the Swedish Riksbank. This hypothetical framework constitutes the vast foundation for the empirical research in this thesis.

2.1 General determinants of inflation

The rate of inflation is difficult to predict and economists still discuss what and in which way different factors have an effect. There is in other words no perfect model that is able to fully explain inflation in a coherent way as a phenomenon, but substantial studies can give a good indicator on what to account for. One of the most famous citations regarding inflation comes from Milton Friedman who famously stated that ‘inflation is always and everywhere a monetary phenomenon’ (Friedman, 1970, p.11). The widely accepted definition of inflation is the increase of the general price level of services and goods. This essentially implies that money in one year will be worth less than it is today.

Very little empirical regularity in the field of economics is so well as the co-movement of money and inflation. Laughlin (1924) stated in The Quantity-Theory of Money that as money supply increases while supply of goods remains the same, it is held that the increase in money supply must be evenly spread over the supply stock resulting in a higher price level, and vice versa if money supply decline. McCandless and Weber (1995) expanded this relationship by arguing that the correlation between the growth of the monetary base and inflation is more evident for countries with more rapid rates of money supply over time than for countries with more reluctant growth rates.

However, King (2001) stated that the relationship of money supply and inflation is much less apparent in the short run than in the long run. This also holds up to empirical evidence. Although monetary growth is viewed as the sole determinant of inflation in the long-run and over larger time periods, the positive relationship between money growth and inflation is somewhat controversial and much less apparent in the short-run. Another factor that is considered to affect the inflation rate from a macroeconomic perspective is the exchange rate. Theory and evidence suggests that if a currency
appreciates, foreign goods will be more attractive compared to domestic goods since relative prices decreases. The rational choice for firms is then to import foreign goods that are cheaper than domestic and therefore lowering prices thus increasing the competition that in turn will have a negative effect on the inflation. The opposite holds for when a currency depreciates. Foreign investors will invest in the cheaper domestic products, which in turn have a facilitating effect on inflation.

Phillips (1958) found an inverse relationship between unemployment and the change of money wage rates. The correlation was estimated in a study conducted in the United Kingdom over a 96-year period from 1861 to 1957. In the most basic form, the Phillips curve describes the negative relationship between inflation and unemployment. Since the early Phillips curve the theories and models on unemployment and inflation has been modified and improved. Parachowny (1993) stated that a relationship between unemployment rates and output could be derived directly from the original Phillips curve commonly known as Okun’s Law. This law suggest that a one per cent decrease in the unemployment rate corresponds to a two per cent decrease in the GDP-rate in contrast to what it would have been if the increase in unemployment were absent. Therefore a positive output gap suggests that there will be excess demand for output and inflation will therefore be driven up.

2.2 Structural changes and inflation

When studying previous structural changes like the steam engine it is evident that it experienced several improvements over the years. Around 1870, the golden days of steam power, productivity growth was quite rapid but decreased when electricity was implemented in the 1890s. Jovanovich and Rousseau (2005) state that an era is over when the diffusion curve flattens out and reaches a plateau. The electricity era reached its plateau around 1929. When microprocessors were introduced in 1971 indicating the arrival of the IT-age the introduction did not reverse the decline in productivity growth observed from earlier periods. We began to see the computers effect on productivity figures closer to two decades later.

There are discussions today on whether or not digitisation is strong enough to be a driving force to affect future productivity growth. Robert J. Gordon (2011) stated that there was virtually no growth before 1750, and that there is no guarantee that growth will continue indefinitely. He even went so far and stated that the economy has reached a standstill and has reached a technological plateau. On the other hand Brynjolfsson and McAfee (2014) argues that what we are witnessing now is just the beginning and that
the second machine age make humans and software-driven machines substitutes, rather than complements as in the first machine age.

Jovanovich and Rousseau (2005) list some predicted symptoms from previous known theoretical models within the area of general-purpose technologies (GPT). The list brings forward some interesting views. One is that productivity should initially slow down when introducing a GPT. GPTs may not be very user-friendly at first since it takes time for both users and the economy to adjust to a new playing field. David (1991) reinforces the view that a GPT does not deliver productivity improvements immediately upon introduction. Another is that the skill premium should increase; implying that skilful labour in the specific area becomes more desirable on the market than those who are not.

There should be a desire for firms to reallocate assets, both human and physical, to adapt to the new playground. This would imply that mergers should increase and that new and young firms will dominate the new ground. Consequently the market share and market value of young firms should rise relative to old firms. The question then becomes if digitisation can be classified as a general-purpose technology in itself. Most economists treat modern ICTs, for analytical purposes, as GPTs and are generally widely accepted as one as well. This is primarily built on the definition that GPTs has disruptive effects and that they, in order to make the transition, are initially time-consuming and expensive (Towse and Handka, 2013).

When one stresses the definition with a GPTs technological characteristic, implying that potential for much scope for improvement that eventually comes to be widely used then digitisation clearly fill this definition. Judging by our definition of digitisation in the introduction, the assembly of components that uses electronic binary logic as would include computers, networks, cell phones, and “smart” devices as cloud solutions, streamed media and components that facilitates activities associated with the concept of “sharing economy” can all be viewed as consequences of digitisation as a GPT (Towse and Handka, 2013). The earliest implementations of this type were military and research computers for breaking codes and solving non-linear equations and have ever since been evolving exponentially. Today, almost every sector has been affected by the digitisation and it has revolutionised the way we are consuming media, communication, financial services, government services etc. (ibid).
2.3 Previous research on digitisation

Earlier research on the relationship between digitisation and the inflation rate is surprisingly absent in academic journals. Economists have so far mainly focused on the impact of digitisation on growth and productivity but the effects on the inflation rate and through which means it affects it is yet unknown in empirical research. It is important to mention that studies on digitisations effect on different economic outcomes are difficult to implement due to the wide interpretations on what digitisation includes and the limited availability of data. Structural changes, as for example digitisation, are also hard to measure and are sensitive to bias. At the same time it is also difficult to single out the effects of a structural change on a certain outcome. From a time perspective digitisation will according to popular opinion, most likely have a temporary effect on inflation since the generally accepted view is that only money supply determines inflation in the long run. Along with the inflation rate digitisation can be argued to be an abstract phenomenon that at best will explain a fraction of its fluctuations. But it is still our strong view that examining this relationship is of great significance for an advanced economy that is characterised by rapid changes.

An early study conducted by Choi and Yin (2004) investigated the increasing usage of the Internet on the inflation rate. By using cross-country panel data over a nine year-period controlling for macro-effects they estimated that a 1 per cent increase in Internet users in relation to total population corresponds to a 0.04 to 0.13 per cent decrease in the inflation rate. The main reasons for these findings were argued to be that Internet usage reflects increases in productivity that in turn dampens the inflation rate. A disadvantage of the study is that it does not specify in which way the Internet were being used by the share of population falling into that category. This fact is understandable since Internet users made up a small fraction of the population during the time and that certain means of the Internet that may have a larger impact on productivity and inflation were not yet developed.

The effect of a more digitised world on price stability has in later years captured some interest in articles regarding future challenges. Breman and Felländer (2014) are two economists who have discussed this relationship in a hypothetical sense. They argue that the low inflation rates we are now witnessing in Europe can be partly assigned to growing an increasing degree of digitisation through various channels. These channels, according to the authors consist of a growing share of e-commerce that in turn effects competition, which finally results in pressure on prices. The increased pressure on prices is also reinforced by a growing number of companies that are defined as “born globals”, that is, companies that reach an international market from the start-up. They
continue their argument by stating that digital development results in a process where the marginal costs of producing and distributing digital goods approaches zero. This act as an incentive to increase production of digital goods that in turn puts pressure on prices. They close their discussion by mentioning that there may be a reason to suspect a lower pressure on wages due to technological unemployment.

Martin Flodén, Deputy Governor of the Swedish Riksbank highlighted in a speech at Fores (2015) that a great share of the critic being aimed at central banks inflation targeting is that digitisation and globalisation has such a high dampening on the inflation rate that the inflation target of two per cent and that central banks should allowed themselves to deviate from the two per cent target. However, Flodén argues that it is far from evident that digitisation would have a permanently lowering effect on inflation and that the low inflation Europe now is experiencing is mainly a result of other factors. Deputy Governor Cecilia Skingsley reinforces this view and argues that it seems reasonable to assume a dampening effect on inflation and since some countries with low inflation does not experiencing poor economic performance it is logic to search for explanations through structural changes like digitisation (BIS, 2015). The debate in Sweden is therefore more of what extent the digitisation affects the inflation rate and less of the direction of the relationship.

It is evident when reviewing academic literature that there is a severe lack of empirical research regarding the subject. Digitisation and inflation are mostly discussed in a hypothetical manner at different economic platforms. Digitisation is viewed as a structural change that most likely has an effect, but that this effect is temporarily until the economy reaches a long-term equilibrium. It is important to note however that putative effect of digitisation does not become irrelevant even if the arguments of temporary effects were 100 per cent accurate since central banks also responds to changes in the shorter run. The temporary effect could also very well last for a long period of time.

2.4 Hypothetical framework from the Swedish Riksbank

The central bank in Sweden, the Riksbank, publishes a monetary policy report every second month. In that report they describe challenges that the central bank is facing along with the considerations they make in order to establish an effective monetary policy. In February 2015 the Riksbanken published a monetary report that included a more detailed account on the effects of digitisation on inflation. The Riksbanks report acts as a hypothetical framework on how to think about how digitisation affects the
inflation rate through various channels. They are clear, however, that the hypothetical framework is not to be regarded as an in-depth analysis, but that the channels through which digitisation may affect the inflation rate described is the most intuitive and important. The following section will describe this framework along with neoclassical theory that will act as our main background for our econometric analysis.

The Riksbank identifies four channels that it considers to be the main reasons through which digital technological improvements may affect the inflation rate negatively. These four channels include e-commerce, better-informed consumers, automation processes and cheaper information and communications technology products. The figure below explains through which economic occurrences these channels may affect the inflation rate. It is important to repeat that all channels are a result of digital technological development i.e. digitisation. The sections below will generate five hypotheses that will be tested in the next chapter.

2.4.1 Effects through Automation
The first channel that the Riksbank presents regards the consequences of an increase in firm productivity through different tools. An increase in digital technological development is for example argued to change the structure of the labour force by acting as both substitutes and complements to labour. Historically this has proven to be true. The act of substituting labour, automation has meant that fewer low-skilled workers are demanded and that this demand has fallen more rapid than the supply of low-skilled workers (Gottfries, 2014). This puts pressure on wages and reduces the input costs of companies. Also, when companies complement their labour forces with technological improvements they automatically become more productive thus reducing the costs further. If policymakers do not take the productivity enhancements from increases in technological development into account, or misjudges them, demand will fail to be stimulated as it has potential to and therefore put pressure on inflation.

Further, when discussing digitisations effects on labour it is also important to mention that it has created a more mobile labour market. Production factors as labour and capital can now be moved to different locations at reduced costs implying an increase of competition in the labour market, thereby putting further pressure on the wage rate. Enhancements in digital technology have also blurred the traditional lines between technology and capital as two separate inputs in production. Digital capital has low marginal costs and can be easily transferred from one entity to another (Papanyan 2015 BBV). The reduction of capital costs implies that firms reduce their input costs for production that in turn have a dampening effect on inflation.
Finally, there is an on-going debate in academics if these effects will create a long-term technological unemployment. Historically this has not been the case. Low-skilled workers have managed to find work elsewhere. However, there is some concern that the technological improvements have escalated to a state where ICT-products have become so cheap that many see them as a viable complement to labour. Arguments have been raised that as much as 46 per cent of all existing jobs may be exposed to automation within the next 20 years (Frey and Osborne 2013). If technological unemployment is a force to be reckoned with, it will affect broader groups in the economy than has historically been the case, and will result in further pressure on inflation since these groups will face a downward pressure on wages. The figure below gives an overview for how automation may affect the inflation rate.

### 2.4.2 Effects through E-Commerce and Better-Informed consumers

Perhaps the most obvious consequence of digital technological development and technological innovations is the widespread usage of the Internet that has made large shares of information available to individual consumers and businesses (Paunov and Rollo, 2016). Riksbanken argues in their monetary report that Internet usage affects the matching and interaction between consumers and producers. An evident example of a channel through which an increase in the usage of digital technology results in is e-commerce. E-commerce drastically reduces the distance between the seller and the buyer. An individual who previously were reduced to a supply in their nearest proximity has through e-commerce access to a global market. An expanded market implies that suppliers are facing more competition in the market place.

The Internet further allows consumers to perform market research for goods and services. By doing so they are able to review products and compare prices and quality in a way that previously were very time-consuming and unattractive. Riksbanken argues that if consumers through digital technology become more conscious about the market firms lose some of their market power and find it more difficult to increase their margins by raising prices. Instead they are forced to raise productivity in order to reduce their costs. The economic implication that the growing share of e-commerce and better-informed consumers has on the market is that firms are being subjected to a larger degree of competition. If firms experience increasing competition they are, all else equal, forced to cut costs that according to economic theory will result in lower prices (Perloff, 2010). E-commerce and better-informed consumers are therefore to be regarded as having a restraining effect on the inflation rate.
The European Central Bank (2015) also mentions that even though there is limited empirical evidence on the effects of e-commerce and more informed consumers on inflation it should intuitively have a negative impact. Their argumentation is similar to Riksbanken; E-commerce implies cost saving in wholesale and retail markets in comparison to brick-and-mortar based institutions thereby passing on decreases in prices to consumers. They also state that European consumers that search for information on goods and services online have drastically increased in the past decade.

### 2.4.3 Effects through components in CPI

Inflation is measured through the construction of a consumer price index (CPI). CPI is constructed by including goods and services that are subject to everyday consumption such as food, petrol and the price for a cinema ticket. This bundle is then compared over time to analyse how the inflation rate has evolved. However, a certain amount of goods and services that is included in this bundle when measuring inflation are themselves subject to price developments as a result of digitisation. One dynamic to consider is that the cost of production decreases as a direct result from cheaper advanced electronics such as mobile phones and computers, a factor that were previously discussed in the section of automation. Another dynamic is that we can observe how physical distribution of goods is now being distributed digitally. The transformation from physical to digital distribution puts pressure on distribution costs and marginal costs are in cases of for example streamed music and movies moving towards zero, just as in the case of digital technology. The price trends of goods that are related to digitisation, ICT-products, are shown to have fallen more rapidly compared to non ICT-related products. Since CPI measures inflation and ICT-products constitutes a share of CPI, the decline in prices for ICT-products are affecting the inflation rate directly. The price development for ICT-products can therefore be argued to be the most obvious channel through which digitisation may affect the inflation rate negatively even though a relatively small proportion of these products are affected by direct improvements in digital technology (Breman & Felländ, 2014).
2.5 Hypotheses

With reference to the theoretical background five hypotheses have been constructed. Four of these are minor hypotheses aiming at testing the individual digitisation-channels that are derived from the theoretical framework of above. The last hypothesis is more extensive and aims to test the broader cohesive effect of digitisation on the inflation rate. Each hypothesis corresponds to an econometric model that will be presented in the next chapter.

\[ H_{1a} : \textit{Automation is negatively correlated with the inflation rate} \]

\[ H_{1b} : \textit{E-commerce is negatively correlated with the inflation rate} \]

\[ H_{1c} : \textit{Better-informed consumers are negatively correlated with the inflation rate} \]

\[ H_{1d} : \textit{The price of ICT-products is positively correlated with the inflation rate} \]

\[ H2 : \textit{Digitisation is negatively correlated with the inflation rate} \]
3 Methodology and Data

3.1 Model specification

An econometric approach enables our hypotheses to be tested with regression analysis. The model is constructed to examine and analyse how and to what extent digitisation affect the inflation rate. By letting the inflation rate make up the left hand side of the equations below we can introduce the explanatory variables in the right hand side to perform statistical tests. Each of the models corresponds to the hypotheses that were derived from the previous chapter. The econometric approach used for testing the models are is discussed at the beginning of the result and analysis chapter.

Models testing digitisation channels separately:

\[ H_{1a}: \quad \text{Inflation}_{it} = \alpha + \beta_1 \text{OutputGap}_{it} - \beta_2 \text{Automation}_{it} + \epsilon_{it} \]  

\[ H_{1b}: \quad \text{Inflation}_{it} = \alpha + \beta_1 \text{OutputGap}_{it} - \beta_3 \text{E}_\text{Commerce}_{it} + \epsilon_{it} \]  

\[ H_{1c}: \quad \text{Inflation}_{it} = \alpha + \beta_1 \text{OutputGap}_{it} - \beta_4 \text{BIC}_{it} + \epsilon_{it} \]  

\[ H_{1d}: \quad \text{Inflation}_{it} = \alpha + \beta_1 \text{OutputGap}_{it} + \beta_5 \text{ICT}_{it} + \epsilon_{it} \]  

Model testing digitisation channels combined:

\[ H_{2}: \quad \text{Inflation}_{it} = \alpha + \beta_1 \text{OutputGap}_{it} - \beta_2 \text{Automation}_{it} \\
- \beta_3 \text{E}_\text{Commerce}_{it} - \beta_4 \text{BIC}_{it} + \beta_5 \text{ICT}_{it} + \epsilon_{it} \]  

3.2 Data

A data set was constructed to enable an econometric analysis. The data is limited to European countries for several reasons. At first, it would be pointless to estimate effects of digitisation for countries that are not digitally develop since there would be no effect to begin with. Europe has come a long way in digitisation with some variations between countries (see appendix A). Another obvious reason is that European countries have had significant changes in their respective rates of inflation. The fact that these two entities are observed together constitutes the research question this thesis.
It is always preferable to include data over a long time period in order to create a robust data set, but since digitisation is a relatively new phenomenon we are unable to observe changes for a single country over a long time period. Panel data allows examining observations of multiple occurrences over multiple time periods for the same countries (Cameron and Trivedi 2009). By including many countries that has experienced rapid digital progress over a short time period enables us to build time-series panel data. Originally, data were collected from 27 European countries from 2003 and 2015. Due to missing values, mainly regarding the digitisation variables, we had to omit certain countries (see appendix B). When correcting for these values we obtained a strongly balanced panel set implying that included countries are not missing values. The data set contains observed values from 17 European countries during 2004 through 2014 corresponding to 187 observations (see appendix B). However, the usage of panel data complicate the use of econometric methods since the standard errors of estimators need to be corrected since observed time periods is not independent of previous periods (Ibid).

Measuring effects of digitisation on inflation requires serious considerations regarding the choice of data. At first we have to decide how digitisation is going to be quantified and what variables that is of interest. Some existing indices of digitisation are available that measures differences between countries digital properties. However, since the theoretical background regarding the relationship is very scarce we base our data on the theoretical background that does exist. Available indices on digital progress would fit poorly to the existing theory and the presented models. These indices would not measure what we intent to measure since they contain unnecessary properties that in many ways are unrelated to the research question. The next challenge then present itself in finding proper data that fits these channels, which we will discuss below.

3.2.1 Response variable

Inflation (CPI)

In order to measure the impact of changes in the different digitisation channels on the inflation rate we need a reliable estimate for changes in price levels for each country. The consumer price index represents an exhaustive basket of goods indicating prices that consumers face. As prices of different goods and services do not change at the same rate, the CPI only reflects the average price level in a country corresponding to the price level. Data on CPI has been gathered from World Economic Outlook published by the International Monetary Fund (IMF) and will act as the response variable in our models.
The CPI variable is expressed in percentage change on a year-to-year basis in order to capture how the rate of inflation is affected.

It is important to mention that there are some worrying signs within how CPI is measured when trying to estimate how it changes due to changes in digitisation. The exclusion of goods and services that are bought online are not yet included to the extent that they are actually faced by consumers. If price changes in goods and services traded online is smaller than for those being traded through physical means, the measurement of CPI may not fully cover the price changes that consumer face. However, there are few studies that can provide us with such evidence (ECB, 2015).

3.2.2 Control variable

Output gap
In order to filter our estimates and control for other factors in the economy we have chosen to include output gap as a control variable in our model. The reasoning behind this decision was discussed in general determinants of inflation. By including this variable we can account for where in the business cycle a certain country is located. Since a positive output gap indicates that countries operate at a high capacity, economic activities should increase, and as such we expect that it will have a positive effect on the inflation rate. The output gap is calculated as the percentage difference between actual GPD and potential GDP in a given year following the equation:

$$ \frac{GDP_{actual} - GDP_{potential}}{GDP_{potential}} $$

The data were collected through Economic Outlook No. 98 that is provided by OECD. Output gap is generally considered to be a good estimator of how an economy is performing, but some concerns can be raised regarding the validity since the estimated potential GDP are subjected to theoretical and practical limits. We choose to omit money supply as a control variable since we limit our research to a short period of time. The relationship between money supply and inflation is, as stated previously, evident through longer time periods, which would make it an inefficient factor in the model.
3.2.3 Explanatory variables

E-Commerce
Measuring the extent of e-commerce would ideally include data on the extent of e-commerce in relation to GDP. Since such data is unavailable, data on percentage of the population that engage in e-commerce is used. E-commerce is therefore measured as the percentage of the total population (aged 16-74) that have purchased goods or services online in the past 12-months. Changes in this variable are believed to mimic the progression of e-commerce in general; where a higher degree of individuals purchasing goods and services online will represent an increase in the effect of e-commerce on the inflation rate. Data on e-commerce were gathered from the Digital Agenda Scoreboard conducted by the European Commission. The Digital Agenda Scoreboard regularly fetches information on digitisation-related usage by European residents through a community survey.

Better-informed consumers (BIC)
Under the assumption of digitisation, rational consumers that searches for information regarding their purchases can with confidence be defined, all else equal, as better informed than their counterpart. Data on the share of individuals conducting online market research can therefore be regarded as capturing the effect of more market-knowledgeable consumers. The Digital Agenda Scoreboard by the European Commission also presents data regarding consumers online-behaviour and their take-up of online activities. The data used on estimating the effect of this behaviour is measured as the percentage of the total population (aged 16-74), that have used Internet in the last three months to search for information about goods and services. In comparison to the collected data by Choi and Yin (2004) the variables measuring e-commerce and better-informed consumers are a clear improvement since they specify certain online-activities that are regarded as having the most intuitive effect on the inflation rate. By only including Internet-usage in general, the risk of capturing irrelevant online-activities on the inflation rate increases.

Automation
Measuring automation poses serious question about the validity of the variable in the model. Automation refers to many complex structures and might be measuring other qualities than what was previously intended. Since uniform data on automation is difficult to construct we used a variable that is intended to mimic the effects. Automation in this study is regarded as a process that affects the inflation rate through pressure on wages and higher productivity. It therefore makes reasonable sense that the
variable should capture the effect of how efficiently labour is used in combination with other means of production and how it is used in the production process.

After careful consideration data on GDP per hour worked is used as a proxy variable that will intend to capture the productivity-enhancing and wage-pressuring effects of automation. The data were collected from OECD and measure GDP per worked hour as an index for a given country during the time-period in question. It is expressed as an index with 2010 as base year (100), were increasing scores corresponds to an increase in GDP per hour worked. We therefore believe that higher scores on this index reflect a more automated labour market that should have a constrained effect on the inflation rate.

A complication with the larger definition of automation as a phenomenon is that not only domestic production is affected but also what a given country is importing. Also, using a measure of productivity per worked hour will most likely capture other effects that are not directly related to automation. A country that for example suddenly overcomes obstacles that are not related to automation will in turn increase their productivity and therefore be accounted higher scores on the index for GDP per hour worked. However, in the absence of more reliable estimates we are confident that it will act as an acceptable measure of the extent of automation.

ICT-Products (ICT)
A significant challenge in trying to estimate how digitisation affects the inflation rate through cheaper ICT-technology is what type of products or services that is to be included in the ICT-bundle. It can be argued that digitisation in a sense has made almost all products cheaper since digital technology is integrated in the production aspect and not in the product itself. The most evident subgroups that have experienced decreasing prices are those directly related to information-and communication technology. Example of these products is recorded media such as Spotify and Netflix, information-processing equipment such as computers and tablets and other electronic devices that are commonly used by consumers.

In order to construct a variable that measures the price changes of ICT-related products we first identified the subgroups of CPI that are of most interest. The subgroups for the ICT-variable consist of price changes for recorded media, information-processing equipment and communications. Each yearly price change for products in these three subgroups has then been included in an index that measures the combined price trend for ICT-products. The variable is measured as the average price change for the current
year. Data on price changes were collected from COICOP Eurostat, which on a regular basis collects price changes for every product that constitutes the measure of CPI. We expect that decreasing observations on the constructed index of these subgroups will correspond to a decrease in the inflation rate.

A general problem in measuring inflation by CPI is that the effects of technological improvements on products are difficult to adjust. A flat-screen TV with newly improved colouring is not the same good as it was before. Quality enhancements should all else equal be regarded as a decrease in price. The translation of improvements for goods into a monetary value is difficult to estimate, especially for highly technical ICT-products. It could also be argued that some form of substitution effect is affecting the measurement of CPI. If we consider the market for DVDs for example streamed film has almost completely replaced this market. The price on DVDs may therefore be accounted a larger weight in the construction of CPI than what consumers are actually facing.

Table 1 - Variable summary (see appendix C for visualisation)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Std.Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI</td>
<td>-4.480</td>
<td>7.935</td>
<td>2.121</td>
<td>1.558</td>
</tr>
<tr>
<td>OutputGap</td>
<td>-15.813</td>
<td>9.206</td>
<td>-.503</td>
<td>3.935</td>
</tr>
<tr>
<td>E_Commerce</td>
<td>1.355</td>
<td>78.749</td>
<td>37.768</td>
<td>20.888</td>
</tr>
<tr>
<td>BIC</td>
<td>13.611</td>
<td>85.896</td>
<td>55.388</td>
<td>17.749</td>
</tr>
<tr>
<td>Automation</td>
<td>82.802</td>
<td>109.439</td>
<td>98.607</td>
<td>4.553</td>
</tr>
<tr>
<td>ICT</td>
<td>-15.433</td>
<td>-.833</td>
<td>-7.265</td>
<td>3.035</td>
</tr>
</tbody>
</table>

3.2.4 Multicollinearity

In order to produce reliable estimates from the models that are being tested we have to diagnose the data and make sure that we account for possible errors. Multicollinearity is a state where the explanatory variables have a presence of a linear relationship (Silvey, 1969). If multicollinearity is present it would imply that two or more explanatory variables to a large extent jointly move in the same directions. It is therefore difficult to determine which of these variables that is responsible for the effect on the response variable. When multicollinearity occur the estimates in terms of coefficients and standard errors tend to be unreliable and significantly decrease the statistical power of the model. By computing a variance inflation factor-test, correlation matrix and using e-commerce or better-informed consumers as the response variable it is clear that e-commerce and better-informed consumers exhibits a strong linear relationship thus giving rise to problems of unreliable estimates (see table 2). The fact that these two
variables correlate strongly makes logical sense. If individuals to a large extent order goods or services online, they are also much more likely to engage in online activities relating to market research and vice versa. In order to overcome this issue the variables measuring e-commerce and better-informed consumers will therefore not be included in the same model, but instead tested separately regardless of the specification of the model.

Table 2 - Correlation matrix

<table>
<thead>
<tr>
<th>Variables</th>
<th>CPI</th>
<th>OutputGap</th>
<th>E_Commerce</th>
<th>BIC</th>
<th>Automation</th>
<th>ICT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OutputGap</td>
<td>0.501</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E_Commerce</td>
<td>-0.315</td>
<td>-0.220</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIC</td>
<td>-0.332</td>
<td>-0.259</td>
<td>0.922</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automation</td>
<td>-0.235</td>
<td>-0.218</td>
<td>0.461</td>
<td>0.556</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>ICT</td>
<td>0.065</td>
<td>-0.168</td>
<td>0.012</td>
<td>0.007</td>
<td>0.223</td>
<td>1.000</td>
</tr>
</tbody>
</table>

3.2.5 Heteroscedasticity

When the variance in the error terms of the regression is non-constant the data suffers from problems of heteroscedasticity. It suggests that one of the basic assumptions of the OLS-model is being violated since the error term needs to be constant in order to be regarded as homoscedastic. If the variance of the error term were non-constant, thus violating the OLS-assumption, it would imply that another estimator with less variance would suit the data better. It further implies that the estimates of the standard errors will be incorrect. (Hill, Griffiths and Lim, 2011). By computing a visual plot of residuals against fitted values, a Breusch-Pagan test along with White’s test that assumes that the error terms are unevenly distributed it is evident that our data contains heteroscedasticity for the four explanatory variables measuring digitisation. By using robust standard errors, which relaxes the assumptions of constant variance, we counter the consequences of biased standard errors when estimating the models.

3.2.6 Autocorrelation

When dealing with panel data or time series it is important to account for that the error term may be linearly related to each other over different time periods. When interpreting results from regressions one assumes that there is no-serial correlation between the idiosyncratic errors.
\textbf{Cov}(u_t, u_s) = 0, \quad t \neq s \quad (7)

When there is presence of serial correlation or autocorrelation the model can then be misused for predictions, the autocorrelation will cause the standard errors of the coefficients to be smaller than they actually are in practice, this in turn will give the model a higher explanatory power (a higher r-squared value). In other words autocorrelation refers to the phenomenon where there is a correlation between variables own past or/and future values. It is therefore important when doing regressions to account for autocorrelation. The Wooldridge’s method use the residuals from the regressions first-differences, central to the method is that if the idiosyncratic errors are not serially correlated then the \textit{corr} (\Delta \epsilon_{it}, \Delta \epsilon_{it-1}) = -0.5. Given this the method then take the residuals from the first-differenced variables of their lags and tests if the lagged residuals are equal to -0.5 as well (Drukker 2003). When applying the Wooldridge test for autocorrelation on our data set we found that there was presence of autocorrelation.

Further, no statistical outliers that may have an influence on the results were found during visual inspection.
In order to test the five stated hypotheses a series of different regression analyses were computed to give an account for the previously stated characteristics of the data set. Multicollinearity does not pose a problem for model H1a to H1d since the variables better-informed consumers and e-commerce are not included in the same model. This will however be a problem when testing hypotheses H2 where all digitisation variables are included in the same model. In order to solve this we separated better-informed consumers and e-commerce and tested them with hypothesis H2 respectively.

An ordinary least squares (OLS) regression does not account for problems of heteroscedasticity and autocorrelation automatically. One has to, as previously mentioned apply a robustness correction to the standard error in order to account for the heteroscedasticity problem. However, autocorrelation still give us smaller error terms and higher r-squared values, implying that the simple pooled OLS regression model is not the most appropriate model to use, since its true variance is underestimated. An OLS-regression can still give a good indicator on what direction the relationship is pointing at but the estimators must be interpreted with more caution.

In order to account for any cross-correlation between the idiosyncratic error terms and the explanatory variables a fixed effects (FE) model were added. A Hausman-test confirmed this decision. A fixed effect model also allows for a limited form of endogeneity (Cameron and Trivedi 2009) which to some extent were expected for the ICT-variable since it is derived from subgroups of how our response variable is composed. Fixed effect-regression does however not account for any lagged effects of the response variable, since the error term is related to the non-lagged explanatory variable, which is of some concern regarding the efficiency of the fixed effect regression.

The Arellano-Bond estimator (AB) with one-step generalised moments of methods (GMM) solves for heteroscedasticity by using robust standard errors. It also handles first order autocorrelation in the responsive variable when including a lagged level of the variable with the explanatory variables. Since ICT may be considered to exhibit some endogenous qualities AB-estimates produce estimates that are not expected to be correlated with the error-term (Mileva, 1997). Arellano Bond-estimator is further suitable for data that contain smaller sets of time countries which is the case for our dataset. A time dummy variable was included in all regressions to account for any time specific effects.
Due to the complex and hypothesised nature of the data we have chosen to include estimates from all of the mentioned regression methods (OLS, FE and AB) in order to give a more nuanced picture of the estimated effects. Each handles the impact on the inflation rate in their own way but has more in common than what sets them apart. Estimates from the ordinary least squares and fixed effect model are more inconsistent than Arellano Bond but can complement AB-estimates to produce a deeper insight in how the relationship changes when leaving out and correcting for different econometric issues.

4.1 Results of hypothesis H1\textsubscript{a} – H1\textsubscript{d}

\begin{equation}
Inflation_{it} = \alpha + \beta_1 OutputGap_{it} - \beta_2 Automation_{it} + \varepsilon_{it}
\end{equation}

<table>
<thead>
<tr>
<th>Variable</th>
<th>OLS</th>
<th>FE</th>
<th>AB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outputgap</td>
<td>0.1971***</td>
<td>0.1814***</td>
<td>0.1507***</td>
</tr>
<tr>
<td></td>
<td>(0.0286)</td>
<td>(0.0275)</td>
<td>(0.0388)</td>
</tr>
<tr>
<td>Automation</td>
<td>-0.1278***</td>
<td>-0.00818***</td>
<td>-0.0804**</td>
</tr>
<tr>
<td></td>
<td>(0.0314)</td>
<td>(0.0157)</td>
<td>(0.0388)</td>
</tr>
<tr>
<td>Constant</td>
<td>14.0414***</td>
<td>9.7961***</td>
<td>9.5169***</td>
</tr>
<tr>
<td></td>
<td>(2.9913)</td>
<td>(1.4319)</td>
<td>(2.8690)</td>
</tr>
<tr>
<td>R\textsuperscript{2}</td>
<td>0.5736</td>
<td>0.6417</td>
<td>n/a</td>
</tr>
<tr>
<td>Observations</td>
<td>187</td>
<td>187</td>
<td>153</td>
</tr>
</tbody>
</table>

(* * *), (**), and (*) indicate significance at \( P < 0.001, P < 0.01 \) and \( P < 0.05 \) levels. Standard errors are presented in parenthesis ( ).

Table 3 - Regression results for hypothesis H1\textsubscript{a}

When interpreting the results from the regression model corresponding to hypothesis H1\textsubscript{a} it is evident that all coefficient for the automation variable points in the same direction. If the index measuring GDP per hour worked increases with one unit we expect that the inflation rate would decrease with between 0.00818 and 0.1278 percentage points while holding changes in the business cycle constant. The estimates are statistically significant for all regression outputs indicating that it is very unlikely to obtain the estimated coefficients if automation did not affect the inflation rate. The data also seem to fit the model relatively well since the model can explain a large share of the variance in inflation rate. The economic implications of an increase in an economy’s degree of automation on the inflation rate are that inflation most likely will decrease by a small degree. However, between 2009 and 2010 Poland experienced an increase of 6.36 units measured by the index of GDP per hour worked corresponding to a 0.5 percentage points decrease in the inflation rate when analysing the more reliable estimates from the Arellano Bond-model. The effects on inflation can therefore be
argued to be quite extensive if an economy experiences large increase in activities relating to automation. We therefore argue to find strong support for our hypothesis that automation is negatively correlated with the inflation rate and thereby decide to accept it. However, an estimate is only as reliable as the data and methods being used. Given the level of uncertainty, especially regarding the possible measurement error of GDP per hour worked as an indicator of automation, the results should be interpreted with caution.

\[ H1_b: \quad \text{Inflation}_{it} = \alpha + \beta_1 \text{OutputGap}_{it} - \beta_3 \text{E-Commerce}_{it} + \epsilon_{it} \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>OLS</th>
<th>FE</th>
<th>AB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outputgap</td>
<td>0.1871***</td>
<td>0.1488***</td>
<td>0.1330***</td>
</tr>
<tr>
<td></td>
<td>(0.0274)</td>
<td>(0.0325)</td>
<td>(0.0275)</td>
</tr>
<tr>
<td>E-commerce</td>
<td>-0.0216***</td>
<td>-0.0321</td>
<td>-0.0151</td>
</tr>
<tr>
<td></td>
<td>(0.0048)</td>
<td>(0.0264)</td>
<td>(0.0354)</td>
</tr>
<tr>
<td>Constant</td>
<td>2.6719***</td>
<td>1.6171*</td>
<td>0.5122</td>
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<tr>
<td></td>
<td>(0.3712)</td>
<td>(0.5768)</td>
<td>(1.5360)</td>
</tr>
<tr>
<td>Observations</td>
<td>183</td>
<td>183</td>
<td>151</td>
</tr>
</tbody>
</table>

(***), (**), and (*) indicate significance at P < 0.001, P < 0.01 and P< 0.05 levels. Standard errors are presented in parenthesis ().

Table 4 - Regression results for hypothesis H1b

When inspecting the results corresponding to the second hypothesis H1b we can see that the e-commerce coefficients for all the models move in the same direction. Given that one per cent more of the population (aged 16 to 74) would purchase goods and services online we expect the inflation to decrease somewhere between 0,0321 and 0,0151 percentage points, while holding the changes in the output gap constant. However, the coefficients for e-commerce are not statistically significant in each model, meaning that we cannot state with certainty that obtained values are significantly different from zero. The direction of the coefficients can however be considered as an indication of which direction the inflation rates tend to move when the usage of e-commerce increases. The results show that the data have seemingly good explanatory power in the model. This suggests that the effects of e-commerce to some degree affect the inflation rates negatively; this is also strengthened by the previous literature of ECB (2015). Judging by the output we found weaker support for the hypothesis that e-commerce will be negatively correlated with inflation rates and we therefore only accept the hypothesis partially.
When analysing the results from the third hypothesis all coefficients for the better-informed consumers variable moves in the same direction. For a one per cent increase in the population (aged 16–74) that uses Internet to search for goods and services the inflation rate would decrease by 0.0639 to 0.0291 percentages points while holding the business cycle constant. The data fits the model well since it explains a relatively large share of the variance of the inflation rate indicated by the $R^2$-value. The results show a statistical significant relationship for all coefficients presented, indicating that the obtained values are different from zero. The implication of if consumers become better-informed will therefore have an effect on the inflation rate to a certain degree. However, more than half of countries included have increased their share of better-informed consumers from below 40 per cent to around 70 per cent in just 10 years, that is twice as many of the share of the population that have researched information on goods and services which would correspond to an average increase of around seven per cent per year for all countries. The effects on inflation rates can therefore be argued to be quite extensive when such activities increase to that extent. The hypothesis H1c is found to have strong support resulting in an acceptance of the same.
Analysing the regression output for ICT-related products impact we observe a uniformed positive direction of the coefficients. A one per cent increase in the prices for underlying ICT-products would correspond to a 0.0947 to 0.1517 percentage points increase in the inflation rate if output gap is held constant. The estimates are significant except for in the Arellano Bond-model, we cannot with certainty state that every estimated regression are significantly different from zero, but the joint movement of all estimates however indicate that the general correlation between the prices of ICT-products and the inflation rate is negative. It is only in the Arellano Bond-model we have a greater risk of observing the trend even though the true relationship would not differ from zero. The data used can also be argued to fit the model quite well since a relatively large share of the variance of inflation is explained by the model. We therefore argue to find some support of the co-movement of inflation rates and prices of ICT-products. This was, as clarified in the theory section, an excepted result. We can therefore cautiously accept fourth hypothesis H1d that there is a positive correlation between the prices of ICT-products and the inflation rate.

4.2 Results of hypothesis H2a and H2b

\[ \text{Inflation}_t = \alpha + \beta_1 \text{OutputGap}_it - \beta_2 \text{Automation}_it \]
\[ - \beta_3 E_{-Commerce}e_{it} + \beta_5 ICT_{it} + \varepsilon_{it} \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>OLS</th>
<th>FE</th>
<th>AB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outputgap</td>
<td>0.1738***</td>
<td>0.1364***</td>
<td>0.1556***</td>
</tr>
<tr>
<td></td>
<td>(0.0281)</td>
<td>(0.0209)</td>
<td>(0.0350)</td>
</tr>
<tr>
<td>Automation</td>
<td>-0.1099***</td>
<td>-0.0744*</td>
<td>-0.1218***</td>
</tr>
<tr>
<td></td>
<td>(0.0296)</td>
<td>(0.0210)</td>
<td>(0.0364)</td>
</tr>
<tr>
<td>Ecommerce</td>
<td>-0.0134**</td>
<td>-0.0070**</td>
<td>-0.0298</td>
</tr>
<tr>
<td></td>
<td>(0.0042)</td>
<td>(0.0251)</td>
<td>(0.0339)</td>
</tr>
<tr>
<td>ICT</td>
<td>0.1208**</td>
<td>0.1348**</td>
<td>0.1458**</td>
</tr>
<tr>
<td></td>
<td>(0.0370)</td>
<td>(0.0409)</td>
<td>(0.0518)</td>
</tr>
<tr>
<td>Constant</td>
<td>13.5655***</td>
<td>102733***</td>
<td>16.6343***</td>
</tr>
<tr>
<td></td>
<td>(2.8092)</td>
<td>(2.1045)</td>
<td>(4.3475)</td>
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<td>R²</td>
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<td>0.6700</td>
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<td>183</td>
<td>136</td>
</tr>
</tbody>
</table>

(***), (**), and (*) indicate significance at P < 0.001, P < 0.01 and P < 0.05 levels. Standard errors are presented in parenthesis ().
\[ H2_b. \quad \text{Inflation}_t = \alpha + \beta_1 \text{OutputGap}_t + \beta_2 \text{Automation}_t + \beta_4 \text{BIC}_t + \beta_5 \text{ICT}_t + \epsilon_t \]

<table>
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<th>Variable</th>
<th>OLS</th>
<th>FE</th>
<th>AB</th>
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<tr>
<td>Outputgap</td>
<td>0.1691***</td>
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<td>0.1330***</td>
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<tr>
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<td>-0.0103**</td>
<td>-0.0581**</td>
<td>-0.0958**</td>
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<tr>
<td>BIC</td>
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<td>-0.0325**</td>
<td>-0.0541*</td>
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<td>ICT</td>
<td>0.1178**</td>
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<tr>
<td>Constant</td>
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<td>9.7265***</td>
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<tr>
<td>R²</td>
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</tbody>
</table>

(***), (**), and (*) indicate significance at P < 0.001, P < 0.01 and P < 0.05 levels. Standard errors are presented in parenthesis ( ).

Table 8 - Regression results for hypothesis H2b

Observing the results from the hypotheses on the digitisation channels jointly effect is what is of most interest for the research question. For the model where better-informed consumers are excluded due to collinearity with e-commerce (H2a) every coefficient contains the expected sign of direction. The models produce useful indicators on how the digitisation channels affect inflation while taking more factors into account. The price of ICT-products and degree of automation has according to the largest impact in comparison to e-commerce. Every estimate in all models shows some degree of significance except the AB-model for e-commerce. Considering the hypothetical background these findings were more distinguished than expected. According to the explanatory variables estimated with Arellano Bond, a unit increase in the automation variable along with a five per cent increase of e-commerce and a two per cent decrease in prices of ICT-products will approximately reduce the inflation rate with 0.56 percentage points all else being equal. In terms of how digital technology is developing and the fine line in what constitutes an acceptable inflation rate the effects are quite strong according to the model. Given the output from model H2a, we find support for hypothesis H2 and accept the statement that digitisation is negatively correlated with the rate of inflation.

When examining the second model (H2b) we also observe that the coefficients move in the expected direction, the price changes of ICT-products and change in automation is indicated to have the highest effects on the rate of inflation. Better-informed consumers have, in comparison to e-commerce, a more satisfactory significance and a stronger impact on our response variable. This occurrence is somewhat surprising since they tend
to measure the same phenomenon. Giving the same theoretical example as for the previous example, an equal increase in the same variables where e-commerce is substituted with better-informed consumers will according to the Arellano Bond-model result in an 0.63 percentage point decrease in the inflation rate. Given the output from model H2b, we find further support for hypothesis H2 and accept the statement that digitisation is negatively correlated with the rate of inflation.

In contempt of Arellano Bond-estimator being the more reliable regression model, OLS and FE act as valuable models to examine our hypotheses. Given the uncertainty regarding the validity of how digitisation is measured, we accept hypotheses H1a, H1c, H1d and H2 with caution while partly accepting H1b. All digitisation channels seem to have the expected effect and this effect remains when we control for them against each other. The degree of automation and the price change of ICT-products seem to have a greater impact on the inflation rate than e-commerce and better-informed consumers.
5 Conclusion and suggestions for future research

In this thesis we set out to investigate what effect digital technological development and the implementation of such technology has on the rate of inflation. Proceeding from scarce existing theory we develop an econometric model with help from a hypothetical framework from the Swedish Riksbank. Relevant data were gathered for 17 European countries over 11 years that enabled an econometric analysis of hypotheses regarding digitisation's effect on the inflation rate. The results showed that the identified digitisation channels have a varying negative effect on the rate of inflation and that the results for most part indicate statistical significance. It is important to mention that the findings should be interpreted as digitisation net-effect on the inflation rate, since the inflation rate is measured after central banks have already implemented monetary tools regarding their respective inflation target. There are concerns however regarding if the identified digitisation channels capture all of the effects of digitisation and if the data used measures the digitisation channels in an efficient way. This was however expected from the beginning since digitisation is a new and complicated phenomenon that is hard to measure for statistical and data-related institutions.

This thesis has focused on the most intuitive channels through which digitisation affects inflation. It is reasonable to assume that some important channels have been left out of the models that may dampen the inflation rate further. The sharing economy, which may constitute one of these channels, is characterised by digital platforms that match buyers and sellers at low transaction costs. By engaging in sharing economy, goods and services are utilised more efficiently by consumers therefore increasing economic utility and competition. These increases, however, are not taken into consideration when estimating GDP. This miscalculation likely implies that growth rates in GDP are underestimated, therefore indicating a lower pressure on inflation and an incentive for more expansionary monetary policy (Blix, 2015). Resource utilisation as a result of sharing economy may have a dampening effect on the inflation rate and GDP given that consumers decide to save a fraction on the monetary savings from such utilisation (e.g. refraining from buying a boat). Lawrence H. Summers (2016) argues that we may experience a “secular stagnation” where consumers and firms display an increasing propensity to save. This would imply that savings attained from resource utilisation in sharing economy may result in lower pressure on economic activities and inflation rates. Summers further argues that digital technological development creates an incentive to
increase savings since new technology make old technology obsolete thereby putting further pressure on the inflation rate.

A generally accepted view is that the effects of digitisation most likely will be temporary until the economy reaches a new equilibrium. However, specifying a time frame for when the economy would reach this state would be severely difficult to answer since the short run in many cases within economics implies a much longer time frame. Central banks discussion on digitisations impact on the price level is also fairly new and many refutes the fact that a dampening effect could have a significant impact on the means of reaching the inflation target. This view is subjected to a certain degree of risk since digitisation is a factor that, as for now, is working against them. The empiric data that does exist has almost exclusively focused on the marginal negative effect of e-commerce. However digitisation acts, as stated, through more channels than e-commerce and the combined effect of all channels will most likely have a greater impact on the inflation rate than what is believed. It bears repeating that if central banks were efficient in using monetary policy to an absolute extent, the results would not indicate a negative relationship as were presented in this thesis since the considerations in monetary policy would already have countered the effects of digitisation. But the fact the Swedish Riksbank, according to our findings, has successfully identified digitisation channels that have proven to exhibit qualities that are inflation dampening shows that they bear digital development in mind.

In the example of Sweden, the Riksbank is along with other central banks currently applying rather drastic means in order to increase the price level and reach their respective inflation target that usually fluctuates around two per cent. Already negative interest rates have repeatedly been lowered further in order to increase short-term interest rates and purchasing large shares of treasuries to control long-term interest rates. These actions are risky since they historically have been proven to create a favourable environment for financial crises. Goodfriend and King (2015) published an extensive review regarding the Riksbanks monetary policy between 2010 and 2015 in which they give recommendations for future operations. One of the most important aspects of this review and recommendations for monetary policy is that the Riksbank should allow itself to deviate from the inflation target of two per cent for a limited period of time and account for these reasons in front of the Finance Committee. With the empirical findings in this research we humbly suggest that digitisation is and should constitute one of these reasons.
Another justification for treating digitisation as a reason for deviating from the inflation target is that we may be far from experiencing the full effects of digital technology. As mentioned in the section of structural changes, digitisation is by many considered to constitute a general-purpose technology. Historical evidence suggests that such innovations need time before reaching their full potential. Along with increasing implementation of digital solutions this would imply that we also might just have seen the beginning of the inflation dampening effects of digitisation.

By authoring this thesis, we have provided empirical evidence in a field that suffers from a severe lack of reference literature and is characterised by untested hypotheses. The requirement of knowledge regarding the relationship is of great importance mainly since policymakers are experiencing difficulties regarding keeping the inflation rate at the inflation target at a time when digitisation becomes increasingly apparent in economic activities. Measurement errors are a significant challenge in trying to single out effects of a more digitised world on the overall economy. A key component for future research is therefore to identify reliable sources of data regarding the way in which digitisation affects the inflation rate. Another aspect that requires attention in this line of research is that it may possess challenges regarding causality since it might be argued that changes in the inflation rate affect digital technological development. We therefore suggest that this thesis could act as a pilot study for more extensive in-depth analyses and surveys regarding the impact of a more digitised economy on macroeconomic components.
6 References


Cameron, A. C., & Trivedi, P. K. (2010). *Microeconometrics using stata (Vol. 2)*. College Station, TX: Stata Press.


Memedovic, O. (2010). *Structural change in the world economy: main features and trends*.


Appendix A. The Digital Economy & Society Index (DESI)
## Appendix B. European countries

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<th>Country (Raw data)</th>
<th>Country (Balanced data)</th>
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<td>2 BELGIUM</td>
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Appendix C.

C.1 – Average inflation rate for all countries by year

C.2 – Average output gap for all countries by year
C.3 – Average share of E-commerce for all countries by year

C.4 – Average share of better-informed consumers for all countries by year
C.5 – Average degree of automation for all countries by year

C.6 – Average price development of ICT-products for all countries by year