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A Supply Side Perspective on the Historical Short Term Co-movement of Output and Prices in Norway

Empirical Evidence and Implications for Monetary Policy

Fredrick Gran

Supervisor: Ola Honningdal Grytten

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Abstract

This thesis explains how inflation targeting as an objective for monetary policy, to some extent, relies upon the inflation rate reflecting output cycles in the short-term. It also explains how this assumption does not hold in response to supply shocks, and can lead to pro-cyclical monetary policies and financial instability. In order to determine if this assumption holds in Norway, the historical co-movement between output and prices 1830-2017 is investigated.

Looking at the contemporanous correlations between these two variables, they are always strongly negative or close to zero. In fact, post-WWII they are all strongly negative. In opposition to the underlying assumption of current monetary policy, the evidence suggests that the inflation rate has historically not reflected output cycles. Even worse, post-WWII output and prices have clearly tended to move in opposite directions. Although these results do not reveal causality, they might indicate that short-term movements and shocks from the supply side have been, and are more influential to output and price cycles than often assumed.

This hypothesis is explored by looking at the co-movement between inflation and variables representing key supply side factors: capital (incl. natural resources), labour and productivity. In all sub-periods since 1900, productivity has a clearly negative relationship with inflation, helping to explain the lack of historical co-movement between output and inflation. Negative correlations between labour supply and inflation is also found pre-WWI and especially post-WWII. Lastly, the correlation between import prices and inflation is strongly positive across all sub-periods. Reflecting that import prices strongly influences inflation. However, the correlation between import prices and output shifts from positive to negative post-WWII. This may suggest that strong imported supply shocks have moved inflation oppositely of output.

Therefore, the results might indicate that short-term movements on the supply side can provide important information to understand the lack of any significant co-movement, and even negative relationship, between output and inflation. These findings implies that inflation targeting can be fundamentally pro-cyclical and lead to financial instability. Thus, it is important that central banks considers output gaps and financial stability in monetary policy.

Preface

By filing and publishing this thesis I will earn the degree Master of Science (M.Sc.) in Economics and Business Administration from the Norwegian School of Economics (NHH). I will be the first person in my family to ever get a master's degree. I also wrote this thesis while working full-time as an Investment Banking Analyst in Skandinaviska Enskilda Banken (SEB). I would not do it again. However, working as a debt capital markets and loan originator has underlined the importance of prudent monetary policy to ensure financial stability in the economy. In a very competitive banking industry it is difficult for us to shoulder this responsibility alone.

It does concern me that interest rates are historically low and even negative in some OECD countries, while unemployment is currently at its lowest in decades with inflation rates still below targets. Through this research I have discovered that many economists share my concerns, and many central banks are reviewing their current inflation targeting practices. Monetary policies will likely change in the coming years. I hope this thesis can inspire central bankers and other economists to look at the supply-side, in order to better understand the short-term cycles in output and prices.

I would like to thank Professor Ola Honningdal Grytten for simply being the best supervisor I could have asked for. It has been a privilege to have one of the most prominent contributors of data, foundational research and literature as a supervisor while working on this thesis. Secondly, I would also like to thank my colleagues in Debt Financing at SEB Norway for entrusting me to finish this thesis while working there. I will admit, I sometimes doubted if I would be able to finish this thesis in time, but I did.

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1. Introduction

In 2012, Ola Honningdal Grytten and Arngrim Hunnes published an article in the International Journal of Economics and Finance titled "A Long Term View on the Short Term Co-movement of Output and Prices in a Small Open Economy". In opposition to one of the key assumptions behind inflation targeting as an objective for monetary policy, they found that short-run price movements did not reflect short-term swings in the Norwegian economy for large parts of the 20th century. As a result they suggested that supply side shocks could offer important information in order to explain the difference in short-term output and price cycles

1.1 Research problem

This thesis revisits the historical short-term co-movement between output and prices in Norway, first analysed by Grytten and Hunnes in 2012, using new filtering techniques and data. In an attempt to extend the existing research and investigate their hypothesis of short-term movements on the supply side being more common and influential than often assumed in conventional economic theory. This thesis will also analyse the short-term co-movement between prices and each of the key supply side factors – capital, labour and productivity.

Thus, the research question this thesis will attempt to answer can be formulated as follows:
"Can short-term movements on the supply side contribute to explain the lack of any significant historical co-movement between output and inflation?"

1.2 Approach

In order to measure the short-term movements or cycles in the relevant macroeconomic time-series, the stationary cyclical components are extracted by the well-known de-trending tools: Hodrick-Prescott filter and Christiano-Fitzgerald filter. Annual changes, often referred to as first order differences, are also used as an estimate of cycles. However, most emphasis is placed on the filtered cycle components as they provide an actual approximation of the cycle.

Cross correlations between the cycles in the two relevant variables are computed in order to determine strength and direction of their relationship. The correlation coefficients do not reveal causality, but combined with a sound understanding of economic history and macroeconomics they can provide valuable indications of how the two variables interact.

1.3 Outline

To provide the reader with an overview of the reasoning and research process leading to the results and conclusion, The thesis is structured as follows: Section 2 provides a brief overview of the current debate around inflation targeting and previous work to test the relationship between output and prices. Section 3 provides a useful introduction to the foundations of inflation targeting, explains how supply side shocks can lead inflation and output in opposite directions and why this can lead to unhealthy financial imbalances under an inflation targeting regime. Section 4 describes the data and their sources in great detail to ensure full transparency. Section 5 describes, discusses and explains the methodological framework of the quantitative analyses. Section 6 presents the results of the quantitative analyses and the corresponding discussion of these. Finally, the conclusion is presented in section 7.

2. Literature review

2.1 Current debate

Prior to the global financial crisis in 2008 it was generally accepted among central bankers and economists that flexible inflation targeting was the most appropriate framework for monetary policy. However, the crisis revealed important weaknesses that has disrupted this consensus. Bini Smaghi (2013, p. 31) argued that it is evident that inflation targeting neither prevented the financial crisis, nor provided sufficient stimulus to get the economy out of the crisis. Several well-renowned scholars, practitioners and market participants have since debated whether inflation targeting should remain or not (Reichlin and Baldwin, 2013).

Partly motivated to learn from the financial crisis, the central bank of Norway (Norges Bank) launched an extensive 4-year research project titled "Review of Flexible Inflation Targeting (ReFIT)" that concluded in 2017. The goal was to explore inflation targeting and alternative monetary policies in light of concerns raised by the financial crisis. However, very little is done in this review to investigate the impact of supply side shocks on the development of inflation and output. In contrast, Frankel (2012) went as far as to announce the death of inflation targeting. He even argued that the lack of an equivalent announcement from the central banks attested to the esteem in which inflation targeting was held among them, its convenience to their credibility and that they fear there are no better alternatives.

Frankel (2012) specifically points out two fundamental problems with inflation targeting. The first being the obvious lack of response to asset bubbles leading up to the financial crisis. The second is its pro-cyclical responses to supply and terms-of-trade shocks. He argues that an economy is healthier if monetary policy responds to an increase in world prices of its exported commodities by tightening enough to cause the currency to appreciate. However, as the exported commodities typically only accounts for a small portion of the consumption basket, increased prices of the exported commodities will not be significantly reflected in the inflation. Instead, inflation targeting regimes will first tighten monetary policy in response to increases in the world price of imported commodities – exactly the opposite of accommodating the adverse shift in the terms of trade. To exemplify, he refers to the European Central Bank's decision to raise interest rates mid-2008, as the world was sliding into a global recession, because oil prices were just reaching an all-time high (Frankel, 2012).

Ben Broadbent, member of the Monetary Policy Committee in Bank of England, responded to Frankel's criticism and characterised it as somewhat of a strawman (2013, p. 51-57). Broadbent acknowledges that a rigid inflation target would compel a central bank to tighten monetary policy in the face of shocks that can raise inflation, while having a negative effect on economic activity. Such shocks included higher oil prices or other deteriorations in the terms of trade, but also significant changes in productivity. However, he argues that no inflation targeting regime is rigid in this way and that ECB's interest hike mid-2008 was the exception and not the rule. Broadbent emphasises that the goal of a flexible inflation targeting central bank is not to peg inflation at its target, but to get there within reasonable time and without creating undue instability in the economy. In other words, the "flexible" part of the policy is designed to accommodate cost and supply shocks.

The difference between the arguments made by Frankel and Broadbent comes down to one key assumption. Broadbent assumes that short-term swings in the economy are primarily demand-led. This would allow a central bank to accommodate relatively rare supply shocks, but also bring the inflation rate back to its target in reasonable time and without creating undue instability in the economy. However, if supply side shocks are more common in the short-term. It can be quite difficult to bring the inflation rate back to its target in reasonable time and without creating instability in the economy. This is Frankel's (2012) fundamental point.

2.2 Previous work

The key question is then how important are supply side shocks to short-term movements in the economy. This has typically been investigated by looking at the relationship between output and prices . A negative correlation would indicate that output and prices have moved in opposite directions, which is the signature of supply side shocks. Husebø and Wilhelmsen found that output and consumer prices in levels were negatively correlated in Norway between 1982 and 2003, with prices leading output (Husebø and Wilhelmsen, 2005, p. 11).

Grytten and Hunnes tested the relationship between output and prices in Norway from 1830-2006 (Grytten and Hunnes, 2012). For years prior to WWI they found negative contemporaneous correlations among the cyclical components estimated by the Baxter-King (BK) filter and first order differences (FOD), but also found a positive correlation among the cyclical components estimated by the Hodrick-Prescott (HP) filter. During the interwar period they find a negative contemporaneous correlation using HP, but weak positive correlations using BK and FOD. Therefore, they could not conclude on any significant negative or positive correlation in these periods. However, after WWII they find strong negative contemporaneous correlations for all three methods used and a majority of negative price-lagged correlations, but positive price-led correlations. They conclude, since price-movements have not mirrored short-term swings in the economy for large parts of the 20^{th} century, that supply side shocks have been more important for historical output and price cycles in Norway than often assumed.

Internationally, Cooley and Ohanian investigated the relationship between prices and output in the US for different sub-periods from 1822-1987 (Cooley and Ohanian, 1991). They find that price-movements did not mirror short-term swings in the economy in any periods except for the inter-war period. Smith studied the relationship between output and price cycles in ten different countries (Australia, Canada, Denmark, Germany, Italy, Japan, Norway, Sweden, the UK and US) and found a positive relationship until WWII and a negative relationship for the post-depression period (Smith, 1992).

Den Haan introduced a new methodology using correlation coefficients of VARs at different forecast horizons to study the co-movement between output and prices in the US from 1948-1997 (Den Haan, 2000). He found a positive relationship in the short-run, but a negative relationship in the long-run. In later research he reached the same conclusion for the rest of the G7 countries (Canada, France, Germany, Italy, Japan, the UK and US) in the post-war period (Den Haan and Summer, 2001). Parker (2005) extended the research by Den Han and used his methodology to investigate earlier historical periods such as 1875-1914 and 1920-1941. In the US he finds a strong positive relationship between output and prices for both these periods. He also studied other countries (Belgium, Canada, Germany and Sweden), but only for the interwar period and he also finds a strong positive relationship between output and prices for all these countries. Leading him to conclude that a negative relationship between output and prices is a post-WWII phenomenon.

3. Theoretical framework

3.1 Introduction

This section provides a useful introduction to the foundations of inflation targeting, which are at the centre of attention in the empirical work of this thesis. It explains how one of the key assumptions behind inflation targeting is that prices reflect the output cycle in the short-run. In addition to when this is not the case, and how it can lead to pro-cyclical monetary policies and financial instability. As this paper investigates and compares the cycles of several macro-economic variables, relevant business cycle theory is also discussed and linked to the analyses.

3.2 Inflation targeting

3.2.1 Background

In Norway, an inflation target was first defined as the operational target of monetary policy in the form of a mandate to Norges Bank in 2001. Importantly, this mandate also instructs Norges Bank to consider developments in the real economy. Operating with this flexible inflation target has worked well, but the global financial crisis in 2008 arguably revealed some drawbacks analogous to the pro-cyclical properties of previous monetary policies.

Since 1830, Norges Bank has tied monetary policy to different fixed exchange-rate regimes in order to convey their intentions to the public, ensure accountability and anchor expectations. Over different periods the currency value has been fixed to a value in silver, gold, USD or ECU. Each regime brought significant benefits at the time, but also entailed very pro-cyclical properties. These regimes all eventually floundered whether on an abundance of silver, a shortage of gold or an uneven development in the relative productivity between trade partners.

The issue with a fixed exchange-rate is the rigid system and how it requires everything else to be constant. Most critically it assumes that the relative productivity between trade partners remains constant as the economy grows. This is often not the case, and the currency of the more productive country should appreciate relative to the other. However, this is not allowed under a fixed exchange-rate regime and forces the central banks to make pro-cyclical policy decisions. The more productive country, which is already better off, must lower the interest rate, while the less productive country must increase the interest rate (pro-cyclical).

3.2.2 The foundations of inflation targeting

By adopting inflation as an objective for monetary policy central bankers hoped to avoid the pro-cyclical properties of previous targets. The policy is built upon two key intellectual foundations. The first being that there is no long-run trade-off between inflation and output (Friedman, 1968). The second is the seminal work by Kydland and Prescott (1977) on time inconsistency of optimal policy rules, which was further investigated related to monetary policy by Barro and Gordon (1983) and Rogoff (1985).

3.2.3 Long-run output is beyond our control, but not inflation

The key insight from Friedman (1968), is that although a short-term trade-off exists, allowing higher output at the cost of higher inflation and vice versa. The level of output will be independent of inflation in the long-run. Therefore, as an unpredictable inflation rate is detrimental to economic growth and output is beyond the control of central banks in the long-run. The logical conclusion is that central banks should focus on what they can control, which is achieving an optimal inflation rate.

3.2.4 Time inconsistency

The key insight from the before mentioned economists on time inconsistency is that because a short-term trade-off exists. The market may fear that the central bank will occasionally take advantage of short-term nominal rigidities to raise output. If the market believes this will happen, they will respond by increasing inflation expectations, leading inflation astray from the optimal rate. In other words, the information asymmetry between the central bank and the market significantly increases the variability of inflation, which negatively effects economic growth.

Therefore Rogoff (1985) argued to implement institutional structures that would encourage central banks to commit to an optimal inflation outcome that would be accepted by the market. If this outcome is obtained, the central bank would not only achieve the long-run optimal inflation rate, but also face a friendlier short-term trade-off against output. Since inflation expectations will tend to stay anchored in response to shocks. The institutional structures will hold the central bank accountable to achieve the inflation target, overcoming the information asymmetries between the central bank and the market. Because the market can trust the central bank and views the inflation target as credible, the central bank has more short-term flexibility.

3.2.5 What is the optimal inflation rate?

Negative effects are not only associated with high inflation, but also exist when inflation is low. However, the negative effects increase with rising inflation as the variability generally increases (Okun, 1971, p. 493). Unexpected variations in inflation can incur significant losses to creditors and debtors as they sign contracts in nominal terms. If inflation is higher than expected the real value of the contract falls, and opposite if inflation is lower than expected.

Therefore, to not discourage investments or savings, and ensure efficient use of resources, a low and stable inflation rate is a good rule of thumb. However, if the inflation is too low it can create economic challenges. Importantly, we want to avoid deflation and lower inflation rates leave less headroom before prices are falling instead of slightly increasing. In addition, the consumer price index, the standard measurement used for inflation targeting, overstates the actual inflation as it is difficult to separate quality improvements from pure price increases.

Deflation discourages investments as nominal asset values are continuously declining and increasing the real value of cash. Furthermore, the real debt servicing burden increases for debt financed assets as their nominal value is declining, while the nominal value of debt is fixed. This can lead to a negative spiral where asset prices further fall as debtors default loans or must sell assets to service debt, while the market is afraid to buy assets declining in value.

The so-called zero lower bound has also received a lot of attention in this discussion. It refers to a situation where the short-term nominal interest rate is at or near zero. Which means that the capacity of the central bank to stimulate the economy is at its limit. However, a higher inflation target lowers the risk of monetary policy reaching the zero lower bound, as it allows the real interest rate to be pushed further down. A high enough inflation target to avoid this will also cover the risk of deflation, as this will only arise if monetary policy is at its limit.

Then what is the optimal inflation rate? In theory there is an optimal inflation rate which minimizes the social costs of inflation, but current research does not provide a definitive answer. In practice, price stability itself is considered as optimal and is the objective for most central banks. This might suggest an inflation target of 0%, but due to the drawbacks of very low inflation, a standard rate of 2% has emerged among most inflation targeting countries. Notably, Norway was among the few countries operating with a slightly higher inflation target of 2.5%, but was adjusted to the standard rate of 2% in 2018.

3.2.6 The divine coincidence

Once the optimal inflation rate is achieved, it enables a central bank under an inflation targeting regime to ensure output and price stability simultaneously. As inflation expectations are anchored by a credible inflation target, the central bank can interpret changes in the inflation rate as a pure reflection of the output cycle due to the short-term trade-off between inflation and output. For example, a negative output gap will be reflected in a lower inflation rate, which allows the central bank to simply lower the interest rate in order to close both the output and inflation gap. This theoretical result is often referred to as the "divine coincidence" due to its convenience.

3.2.7 The Phillips curve

It should by now be apparent how one of the key assumptions behind inflation targeting as a successful monetary policy is that the inflation rate in the short-run to some extent reflects the output cycle. This result depends on the existence of a short-term trade-off between inflation and output, which is fundamentally based on insights gained from the Phillips curve:

$$\pi = \pi^e + \gamma y + u \tag{3.1}$$

where, π represents inflation, π^e represents inflation expectations, γ measures the strength of the demand channel (how much of a change in y will be reflected in π), y represents the output gap and u represents an inflation shock.

The key assumption behind the Phillips curve is that there is a rigidity in prices and wages in the short-term. In other words, demand pressures (y) bring gradual increases in prices (π). However, as pointed out by Friedman (1968), the long-term Phillips curve will be vertical as rigidities are overcome and increased inflation expectations will be fully impounded in inflation. In other words, it is not possible to achieve higher output at the cost of higher inflation in the long-run since there is no long-term trade-off between inflation and output. Therefore, the long-term Phillips curve can be denoted as:

$$\pi = \pi^e \tag{3.2}$$

where, y = 0 and u = 0.

3.2.8 When the inflation does reflect the output cycle

Based on the Phillips Curve, short-term pressures in the economy or a positive output gap (y) will lead to increased inflation (π). Two explanations are: First, high demand for goods and services will allow many companies to increase their profit margins by raising prices. Secondly, increased activity in the economy will typically raise the cost level. For example, lower unemployment will put pressure on wages as unions will demand higher wages and employers will thus have to outbid each other to find available labour.

Therefore, a change in output will result in an equivalent change in the inflation rate. However, for the output cycle to be purely reflected in the inflation rate in accordance with the short-term Phillips curve (3.1), inflation expectations (π^e) must be constant and there cannot be any inflationary shocks (u=0). If these assumptions hold, then indeed, the output cycle would be accurately reflected in the inflation rate.

3.2.9 When inflation does not reflect the output cycle

The danger of blindly viewing the inflation as a reflection of the output cycle is that the inflation rate can be distorted by inflation shocks (u). It is possible, while the output gap (y) is significantly positive and creating pressures in the economy (π), that other shocks (u) significantly reduces the inflation (π) below target. In other words, inflation shocks can mask large output gaps which would otherwise be reflected in the inflation rate. Even if the central bank is aware of the inflation shock, contrary to the "divine coincidence", they will instead face a conflict between price stability and stability in the real economy.

The Phillips curve basically treats short-term price movements as a demand-led process and designates the supply side to the residual (u). However, the supply side can be a significant source of inflationary shocks. Cheaper imports, an increase in total-factor productivity or an unexpected moderate wage settlement can all reduce inflation and even up output and/or employment. If the central bank responds with a more expansionary monetary policy it will be able to raise the inflation, but in the process also provide a further boost to output and employment which may not be healthy or sustainable. Supply-side shocks are therefore difficult to neutralise as there is no "divine coincidence" in this situation.

3.2.10 Mathematical and graphical analysis

The reason why the output cycle is reflected by inflation during demand shocks, but not necessarily during supply shocks under an inflation targeting regime can be explained in more detail mathematically and illustrated better graphically. Optimal policy in an open economy with an inflation target can be described in a mathematical model (Røisland and Sveen, 2018):

The monetary policy goal in an inflation targeting country can be described by a loss function:

$$L = \frac{1}{2}[(\pi - \pi^*)^2 + \lambda y^2] \tag{3.3}$$

where, π represents inflation, π^* represents an inflation target, y represents the output gap and λ measures how much weight the central bank assigns to stability in output relative to inflation.

The central bank's task is to minimize this loss function, which depends on the output gap and the difference between actual and targeted inflation. If λ = 0, the central bank is only concerned about reaching the inflation target regardless of how large imbalances in output it may cause. This is called a strict inflation targeting regime and the literature often refers to those who operates such regimes as "inflation nutters". In practice, no central banks pursue such a policy. In fact, Norges Bank is explicitly instructed to consider the developments in the real economy. In other words, to apply a positive λ, often referred to as flexible inflation targeting.

The optimal monetary policy minimizing the loss function (3.3) in a neutral state and in response to various shocks can be described in a model. It consists of a demand curve expressing the output gap as a function of the real interest rate, a supply curve expressing inflation as a function of the output gap and a curve expressing monetary policy.

3.2.11 Demand curve

Aggregate demand is represented by the investment savings (IS) curve for an open economy:

$$y = -(a_1 + a_2)(r - \bar{r}) \tag{3.4}$$

where, r is the domestic real interest rate and $\bar{r}$ is the domestic neutral real interest rate which is the domestic real interest rate that closes the output gap. Also, a_1 measures the strength of the interest rate channel - how much does a change in r affect y. a_2 measures the strength of the exchange rate channel - how much does a change in the real exchange rate (e) affect y. Simply explained, equation (3.4) states that a higher domestic real interest rate (r) leads to a lower output gap (y), while a lower domestic real interest rate (r) leads to a higher output gap.

Real exchange rate changes are reflected by $\bar{r}$, which can be expressed as follows:

$$\bar{r} = p + \frac{1}{a_1 + a_2} v + \frac{a_2}{a_1 + a_2}\left((r^* - p) + e^e + z\right) \quad (3.5)$$

It is useful to know that the domestic neutral real interest rate ($\bar{r}$) is a function of the strength of both the interest and exchange rate channel ($a_1$and a_2), in addition to exogenous variables effecting the real exchange rate: r^* is the foreign real interest rate, p is the long-term domestic equilibrium real interest rate, e^e is the expected logarithm of the real exchange rate and z represents a currency shock. Increased value of exchange rates implies depreciation.

For example, it can be seen from formula (3.5) that a higher foreign real interest rate (r^*) increases the domestic neutral real interest rate ($\bar{r}$). This is because a relatively higher foreign interest rate will depreciate the domestic currency, improving competitiveness which boosts exports, leading to a positive output gap and consequently a higher ($\bar{r}$) to close this gap. Similar mechanisms exist between the other exogenous variables and the real neutral interest rate.

3.2.12 Supply curve

The supply side of the economy is represented by the Phillips curve for an open economy:

$$\pi = \pi^e + (\gamma_1 + \frac{\gamma_2}{a_1 + a_2})\, y + u^{open} \quad (3.6)$$

where, $\gamma_1 = (1 - \varphi)\gamma_1^H$, $\gamma_2 = \varphi\gamma_2^F$. Notably, φ = share of imports in the consumption basket. γ_1^H measures the strength of the domestic demand channel - how much of a change in y will be reflected in domestic π. γ_2^F measures the strength of the direct exchange rate channel to inflation - how much of change in the real exchange rate is reflected in foreign π. Lastly, u^{open} represents an inflation shock to an open economy.

Earlier in this section, the Phillips curve was expressed differently (3.1). This is the simpler and standard version of the Phillips curve which only describes a closed economy. This Phillips curve (3.6) describes an open economy, where the output gap (y) affects the inflation (π) through the demand channel (γ_1) and indirectly through the exchange rate channel (γ_2).

To explain, an increase in the output gap (y) increases demand for domestically produced goods and γ_1 measures how much this will increase inflation. Also, for the output gap to increase (without any changes in shocks), the central bank must lower the real interest rate (r) by $\frac{1}{a_1+a_2}$ (see 3.4). However, a lower real interest rate (r) also increases the real exchange rate (e) which in turn increases inflation (π) and γ_2 measures how much this will increase inflation.

$$u^{open} = u + \frac{\gamma_2}{a_1 + a_2}[a_1\big((r^* - p) + e^e + z\big) - v] \tag{3.7}$$

It is useful to know that inflationary shocks (u) in an open economy can be caused by both domestic (u^H) and foreign inflation shocks (u^F), $u = \varphi u^F + (1-\varphi)u^H$. Total effect is simply weighted by their respective share of the total consumption basket. The last part of expression 3.7 highlights that demand shocks (v) will be able to significantly affect the real exchange rate and again the inflation (π) measured by (γ_2).

3.2.13 Monetary policy curve

The central bank sets the interest rate (r) to minimize the loss function (3.3). For simplicity it is assumed that the central bank determines the real interest rate. The minimum point of the loss function (3.3) can be found from the first order condition:

$$\frac{dL}{dr} = (\pi - \pi^e)\frac{d\pi}{dr} + \lambda y\frac{dy}{dr} = \pi - \pi^* + \frac{\lambda}{\gamma_1}y = 0 \tag{3.8}$$

where, π represents inflation, π* represents an inflation target, y represents the output gap, γ_1 measures how much y increases π and λ measures how much weight the central bank assigns to stability in y relative to π. To be precise, when differentiating inflation (3.6) and output (3.4) the exchange rate related variables are disregarded as they are indirectly considered in the loss function by output and inflation stability. Therefore, $\frac{d\pi}{dr} = -a_1$, $\frac{dy}{dr} = -a_1\gamma_1$.

As expected, monetary policy is optimal if both the output (y) and inflation gap ($\pi - \pi^*$) equals zero. Alternatively, a pareto optimality is achieved if: $\pi - \pi^* = -\frac{\lambda}{\gamma}y$. Which simply means that if the central bank cannot close both gaps, it is optimal to end up in a situation where one of the gaps is positive and the other is negative. It might be that the central bank cannot close the output gap by adjusting the real interest rate without increasing the inflation gap more. In addition, since the loss function is squared, a large gap involves a larger loss compared to equally small gaps. If both gaps are positive, the central bank can achieve a pareto improvement by raising the real interest rate until both gaps equal zero or $\pi - \pi^* = -\frac{\lambda}{\gamma}y$.

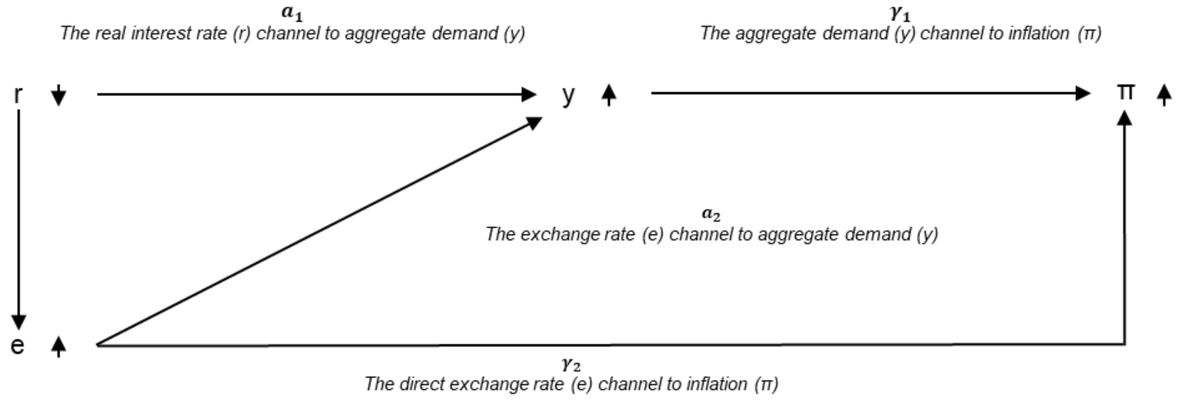

Figure 3.1: Overview of the monetary policy transmission mechanisms in an open economy (Røisland and Sveen, 2018, p. 32)

3.2.14 Graphical analysis

Using the defined demand, supply and monetary policy curves, monetary policy can be presented in a diagram of the output and inflation gap. The open economy is described by the Phillips (PC) curve (eq. 3.6). How the central bank weighs the developments in the real economy (output gap) against the inflation gap is illustrated by the monetary policy (MP) curve (eq. 3.7). The investment savings (IS) curve (eq. 3.4) shows how the central bank can manoeuvre the interest rate to effect output. In equilibrium there is no output or inflation gap, and the real interest rate equals the long-term domestic equilibrium real interest rate (p).

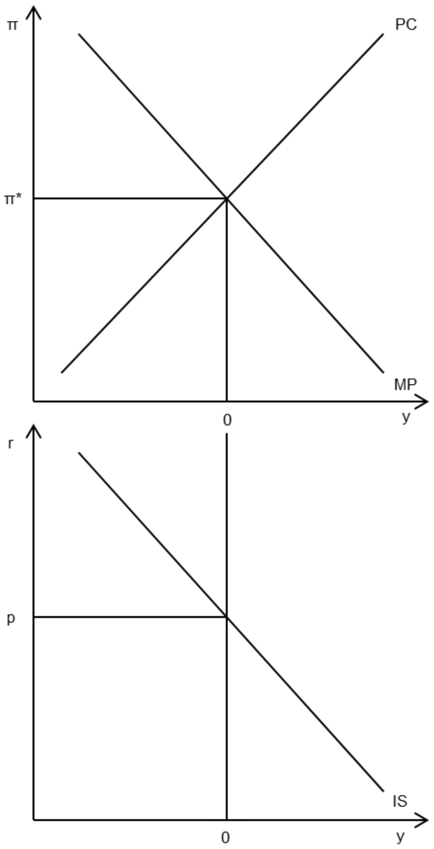

Figure 3.2: The PC-MP-IS chart (Røisland and Sveen, 2018, p.16)

The PC-curve has a positive slope because of the short-term trade-off between output and inflation. Higher economic activity, an increase in the output gap, creates pressures in the economy and leads to increased inflation.

The MP-curve has a negative slope because the central bank trades off a larger positive output gap against a more negative inflation gap and vice versa.

The IS-curve has a negative slope because the central bank trades off a lower interest rate against higher output in the short-term and vice versa.

The model is static and will show the result after monetary policy has worked through the economy for 1-3 years (Røisland and Sveen, 2018, p. 4).

3.2.15 Negative demand shock (v < 0)

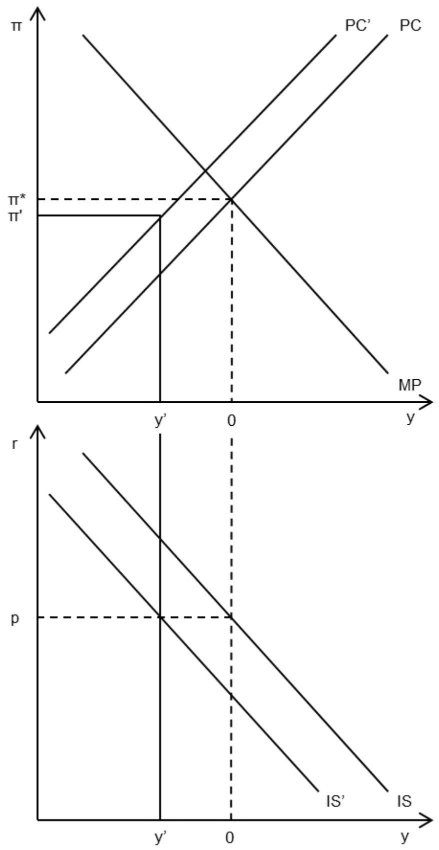

Figure 3.3: PC-MP-IS chart illustrating optimal policy response to v < 0

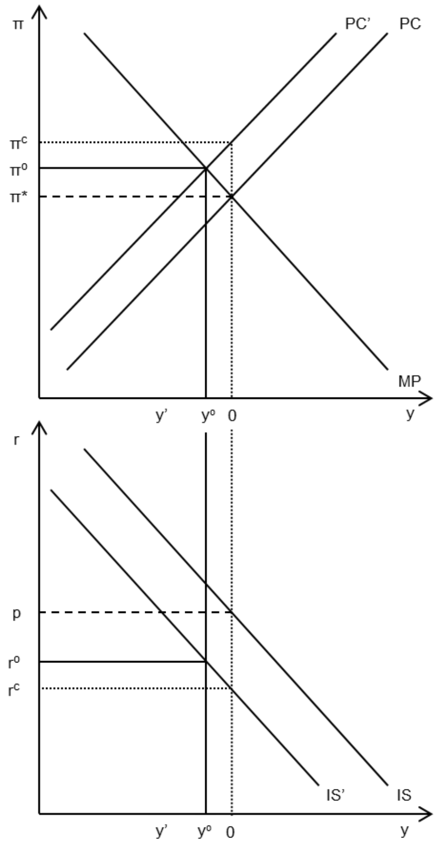

Figure 3.4: PC-MP-IS chart if the central bank does not respond to v < 0

Examples of negative demand shocks (v < 0) is a temporary increase in the household savings rate or a tightened fiscal policy. These shocks will lead to a negative output gap. Since the real interest rate (r) is unchanged, it indicates that the neutral real interest rate ($\bar{r}$) is now lower. This causes a negative shift in the IS-curve (eq. 3.5). The open economy PC-curve will also shift upwards (eq. 3.7). For a given y, a negative demand shock must lead to a weaker exchange rate for demand to be unchanged, which again leads to higher imported inflation.

If the central bank does not respond to a negative demand shock with any monetary policy changes, the reduced demand is fully realised (y') and reflected in a lower inflation rate (π'). Importantly, both inflation and output move in the same direction. However, by lowering the interest rate, the central bank can bring both inflation and output upwards and closer to their respective targets. Importantly, once again, this will move both inflation and output in the same direction. The optimal response is to lower the interest rate to r^o, bringing the inflation slightly above its target (π^o) and output slightly below its target (y^o). Lowering the interest rate further to r^c would neutralize the output gap, but at a greater cost since the inflation gap grows.

3.2.16 Negative inflation shock (u < 0)

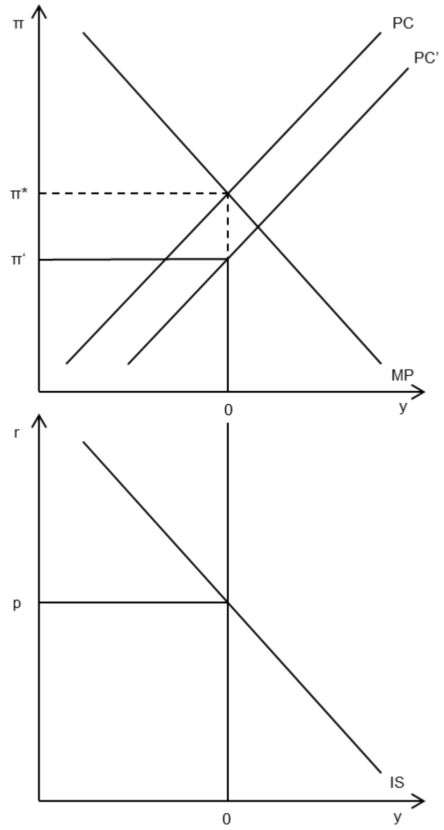

Figure 3.5: PC-MP-IS chart if the central bank does not respond to u < 0

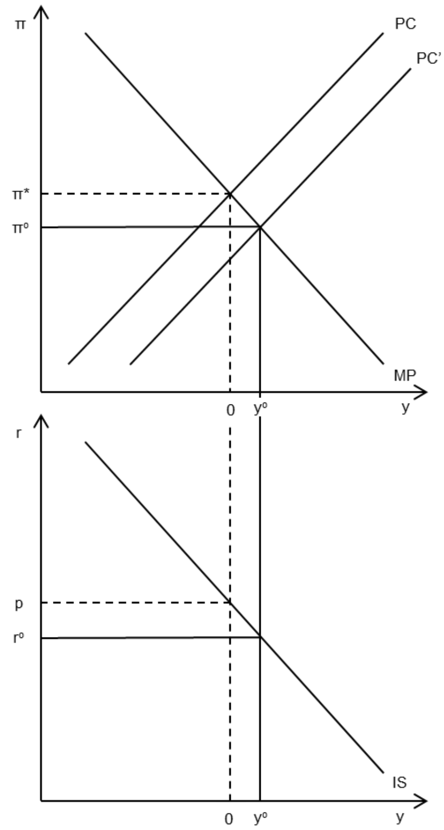

Figure 3.6: PC-MP-IS chart illustrating the optimal policy response to u < 0

Examples of negative inflation shocks (u < 0) are typically supply shocks such as an increase in productivity, cheaper imports or an unexpected moderate wage settlement. These shocks will lead to a negative inflation gap and shift the PC-curve downwards (eq. 3.7). If the central bank does not respond with any monetary policy changes, the output gap is unchanged, but at the cost of a large negative inflation gap. Importantly, inflation and output do not move in the same direction.

The optimal policy response is to lower the interest rate (r^o) and bring inflation closer to the target. However, this comes at the cost of an increasingly larger output gap (y^o). In contrast to a regular demand shock scenario, the central bank is now forced into a pro-cyclical monetary policy. The inflation shock will drag inflation downwards without affecting output, but the central bank is forced to lower the interest rate to ensure a credible inflation target. As a result, inflation and output will primarily move in opposite directions during this period. If a positive demand shock strikes simultaneously, this can be masked by the negative inflation shock depending on their relative strength.

3.2.17 Financial stability

The fundamental danger of the positive output gap generated by the optimal policy response to negative inflation shocks (3.2.16). Is its potential disruption to the financial stability of the economy. Loss of financial stability implies that the financial system is no longer robust to economic shocks, and that it is no longer capable of providing further financing, arranging payments and redistributing risk in a satisfactory way (Norges Bank, 2004, p. 24).

Holding the real interest rate (r^o) below the long-term equilibrium rate (p) over longer periods of time, especially amid an already positive output gap, can cause the money supply to grow faster than the economy. The excess supply of money will be placed in pure inflation, and typically increasing asset and real estate prices (Grytten and Hunnes, 2016, p. 37-43). As these prices will inflate, market players will become increasingly more dependent on credit to participate. This can result in significant financial instability as large debt bombs, which the financial system is incapable of servicing if price developments turn around, can build up.

Empirical evidence shows that financial instability is often the first step towards a financial crisis (Grytten and Hunnes, 2016, p. 38). Shularick and Taylor (2012) shows that credit growth is reliable predictor of financial crises. In addition, Jordá et al. (2013) finds that high credit growth in expansions often results in deeper and more long-lasting recessions. Minsky (1982, p. 17-29) argued that it is completely necessary to consider the financial markets when evaluating the economy at an aggregate level. In contrast, prior to the global financial crisis in 2008, many economists considered market failures to be impossible (e.g. asset bubbles and banking crises). This was fundamentally rationalized by the "efficient market hypothesis" by Fama (1970). In light of the global financial crisis it now obviously seems very irrational.

Røisland and Sveen (2018) described financial imbalances mathematically as a function of the real interest rate:

$$q = -ø(r - p) + w \tag{3.8}$$

where, w is a "financial shock" which is a change in q unrelated to the real interest rate (r). Parameter ø measures how much the financial imbalance or gap increases when r changes.

It is possible to include q in the central bank's loss function. However, both the IMF (2015) and Yellen (2014) concluded against formulating monetary policy to include financial stability. IMF (2015) argues that most often there will not be a conflict between the objectives of stable output and inflation, and the objective of financial stability.

3.2.18 Summary

This section has explained theoretically, expressed mathematically and illustrated graphically that the inflation rate does not necessarily reflect the output cycle. In fact, supply shocks can decrease or increase inflation without resulting in an equivalent change in output. These type of shocks can force an inflation targeting central bank into pro-cyclical policies, as they are bound by their institutional structures to eventually close the inflation gap – even at the cost of an output gap. A pivotal problem of this pro-cyclicality is that it builds up financial imbalances that can disrupt financial stability. In other words, inflation targeting regimes frequently affected by supply shocks will have an inherent risk of financial crises.

Contrary to the initial hope of central bankers, it seems inflation targeting inherently entails pro-cyclical properties analogous to previous monetary policies. Previously, if one country became relatively more productive under the fixed exchange rate regime, enabling it to produce more at a lower cost increasing exports. This would appreciate the currency. However, this was not allowed. Instead the central bank was forced into the pro-cyclical decision of lowering the interest rate, increasing the output gap further, in order to counter-depreciate or close the “exchange rate gap”. This mechanism for example built up large financial imbalances that culminated in the Great Depression at the end of the interwar period. It is also almost identical to pro-cyclical mechanisms of inflation targeting in response to supply shocks. Which in part led to the global financial crises in 2008 (Grytten and Hunnes, 2016, p. 244).

However, inflation targeting can be a reliable counter-cyclical monetary policy if one crucial assumption holds. Short-term movements in output and prices must primarily be demand-led and changes on the supply-side must be more long-term movements. This thesis will challenge this assumption and empirically explore whether it holds for the Norwegian economy.

3.3 Business cycles

3.3.1 Definition

In some periods the economy is thriving, unemployment is low, and most companies are expanding their production capacity. In other periods economic activity is falling or stagnant, unemployment is high, and most companies are operating below their production capacity. In the previously defined model, the former is represented as a positive output gap and the latter as a negative output gap. The observed cyclicality between these two states of economic activity in modern economies is business cycles. One of the key objectives of monetary policy is to minimize the variability of these cycles.

The modern business cycle theory is largely defined by the seminal work of Burns and Mitchell (1946). They defined business cycles as the fluctuations found in the aggregate economic activity of nations that organize their work primarily in business enterprises. They identify cycles, periods of expansions or contractions, as a rise or fall in a broad range of economic indicators over more than one year up to twelve years. However, there is no regularity in the timing and duration of these cycles.

3.3.2 Measurement and length

Business cycles are most commonly measured by fluctuations of the GDP in fixed prices compared to the underlying trend. However, as Burns and Mitchell (1946) argued, business cycles can be found in a broad range of macroeconomic variables. In fact, since the actual underlying trend of GDP is unknown, it can be an imprecise measurement of business cycles.

As explained in the chapter (3.2), inflation is supposed to be another key macroeconomic variable where business cycles can be identified. Importantly, if inflation expectations are anchored, the underlying trend is known and enables better cycle measurements. However, supply shocks can distort its ability to reflect the business cycle.

Therefore, the cycles of other economic indicators from the supply side might offer important information to understand the potential difference in the cycle development of these two key macroeconomic variables.

In order to measure cycles, it is necessary to apply a de-trending technique to a time series of the relevant macroeconomic variable. Selected methodologies for this will be detailed in section 5. However, fundamentally this measurement is made possible by viewing a macroeconomic time series as a function of four components (Pindyck and Rubinfeld, 1991):

$$y_t = g_t + c_t + s_t + \varepsilon_t \tag{3.9}$$

where, g_t is a trend component, c_t is a cyclical component, s_t is a seasonal component and ε_t is a residual or measurement error.

By removing s_t from the time series, minimizing ε_t and estimating g_t it is possible to estimate the value of the cyclical component representing the business cycle as: $y_t - g_t = c_t$. In other words, the difference between the actual value and the estimated potential/trend value.

Business cycle measurements are commonly based on a direct (band-pass filters) or indirect (the HP filter) assumption of the length of the business cycles. As mentioned, Burns and Mitchell (1946) argued that business cycles lasts between one to ten or twelve years. However, business cycle pioneers such as Juglar and Kitchin have both argued for different intervals. Kitchin (1923) argued that the economy moves in inventory cycles of three to five years, while Juglar (1916) argued that investment cycles from seven to eleven years. In short, there is no pat answer to how long business cycles last. The analyses will assume a cycle length one to seven years in the band-pass filter approximation. This is further explained in section 5.

4. Data

4.1 Introduction

In this section the data will be described in detail by referring to the sources of the datasets, explaining how the data has been collected and how the time series have been constructed. A point of emphasis has been to be very detailed with the oldest parts of the data. In order to be as transparent as possible and convince the reader of their validity and reliability.

4.2 Consumer price index/Cost of living index (CPI-CLI)

4.2.1 Price cycles in annual terms

To measure price cycles in annual data, I use the combined cost of living index (CLI) and consumer price index (CPI) for Norway from 1516-2017 published in 2004 and subsequently updated by the central bank of Norway (Norges Bank). It is worth mentioning that Norges Bank and central banks worldwide use CPI to measure price movements for inflation targeting.

The index is a mixture of a cost of living index and a consumer price index before 1959, which means that it does not solely reflect market prices, but also the cost of providing necessities for the average family. The entire index is spliced together of ten different indices across different sub-periods, and from 1830-2017 there are six. The first five indices are constructed using one representative base year for each index and the last one has continuous shifts.

4.2.2 1830-1877

The first sub-period (1830-1877) is covered by an index constructed by Grytten (2004, p. 66) from 1819-1871. It includes 29 commodities within eight consumption groups from 1819-1830 and 47 commodities within nine consumption groups from 1830-1871. The index is based on observations from 40 different locations in Norway, includes most kinds of consumption less services and is almost completely based on monthly or quarterly retail or market places prices reported by governmental decree. These data should therefore be considered reliable despite being very old. The main source of the data is Professor Dr. Ingvar B. Wedervang's Archive on Wages and Prices. For further information on the Wedervang Archive, the reader is advised to read Norges Bank's Occasional paper 38 (2007, p. 203-221).

4.2.3 1871-1910

The second sub-period, 1871-1910, is covered by an index constructed by Ellingsæther (2007). It includes 96 commodities within 12 consumption groups. The index improves upon previous indices of the period by including more data and covering a larger part of the household consumption (Ellingsæther, 2007, p. 47-66). The key data sources for this dataset are also the Wedervang Archive.

4.2.4 1910-1916 & 1916-1919

The third sub-period, 1910-1916, is covered by a cost of living index from the Statistical Office of Kristiania (Oslo) and includes 57 commodities and six consumption groups (Grytten, 2018, p. 32). Although the index is only based on observations from Oslo it is considered fairly reliable by Statistics Norway (Grytten, 2004, p. 71). The fourth sub-period 1916-1919 is covered by another cost of living index by the Ministry of Social Affairs and includes 60 commodities, mainly related to food and fuel (Grytten, 2004, p. 71). The index is based on observations from 16 major towns across Norway obtained on a monthly basis.

4.2.5 1920-1959 & 1960-2017

The fifth sub-period, 1920-1959, is covered by aggregated monthly data from Statistics Norway's cost of living index. Statistics Norway became the primary provider of cost of living indices after 1919. The index initially included 120 commodities in 1919, but increased over time up to 700 commodities in 1959 and the observations are based on up to 31 urban areas across the entire country.

The sixth sub-period 1960-2017 is covered by Statistics Norway's monthly data for the consumer price index. The cost of living index was replaced in 1960 by the consumer price index representing all kinds of products that can be bought in retail stores at market prices. The number of commodities included has gradually increased over time and now includes over 1000 commodities with observations from the entire country.

4.2.6 Summary

All the index is spliced using a traditional Laspeyres approach, which is a common and established method for historical price indices (Grytten, 2004, p. 47-98). The entire series was first published by Norges Bank as part of a project on historical monetary statistics (Eitrheim, et.al., 2004) and provides a continuous historical CPI index from 1516-2017. Note, only the period from 1830-2017 is utilized and should be a valid and reliable source for the analyses.

4.2.7 Price cycles in quarterly terms

Since Statistics Norway has collected monthly data for their CLI from 1920-1960 and CPI since 1960 it was also possible to splice together a monthly CLI-CPI index from 1920 until today. Norges Bank has published and updates this series alongside the previously detailed annual series from 1516 in their online historical monetary statistics archive (Norges Bank, 2019). Importantly, this time series has also been seasonally adjusted.

However, since quarterly GDP data is first available from 1978, only quarterly CPI data from 1946 is applied. The datapoints from the last month in each quarter is extracted to construct a quarterly CPI time series from 1946-2017 (Q1=31.03, Q2=30.06, Q3=30.09, Q4=31.12). Transforming the data from monthly to quarterly terms.

4.2.8 Newer available datasets

Late in the project, the author found out that Grytten in November 2018 had published a revised and improved historical CLI-CPI index for Norway from 1492-2017. However, since there were relatively minor changes in the data after 1830, it is almost identical to the old CLI-CPI index between 1830 and 2017 (Grytten, 2018, p. 47). However, it was decided to test the new index in the analyses and to compare the results between the indices. The difference between the results was at most five hundredths of a correlation point (0.05). Therefore, it was concluded that it was not necessary to change the dataset.

4.3 Gross domestic product (GDP)

4.3.1 Output cycles in annual terms

To measure output cycles in annual terms, I use annual gross domestic product per capita in fixed prices 1830-2017 published in 2004 and subsequently updated by Norges Bank. This is the standard variable used in output cycle analysis, and to analyse the relationship between output and price cycles, it is necessary to remove price variations in output. The series are spliced together by three different series covering three sub-periods: 1830-1865, 1865-1970 and 1970-2017. The first sub-period uses 1850 as base year, the second sub-period uses 1910 and 1938, and the third sub-period has continuous shifts of base years every five years.

4.3.2 1830-1865

The official Norwegian national accounts only stretch back to 1865, however empirical observations made it possible for scholars from the Norwegian School of Economics to calculate GDP figures from 1830-1865 (Grytten, 2004, p 241-271). The calculations are based on data from the production and expenditure side. To make estimates of GDP in fixed prices both output and input prices are deflated in order to arrive at values in fixed terms (Grytten and Hunnes, 2012, p. 7). The key sources of the data are very reliable, and includes records from contemporary scholars, Statistics Norway and the Wedervang archive. For the period it should therefore be considered as a relatively reliable series.

4.3.3 1865-1970

In 1965 Statistics Norway, as part of an international project economic growth, published the national accounts of Norway from 1865-1960. It was built upon international standards for national accounting from the United Nation’s System of National accounts from 1953 (SNA 1953). The series were over subsequent years updated until 1970, when it was replaced by the present national accounts. Although the time series from 1865-1970 are very well documented theoretically, it is not empirically. In 1865 the error margin is about 20 percent, around the change of the century it is about 7-8 percent and from 1930-1970 it is about 3 percent (Grytten, 2004, p. 243). However, at the time, the publication brought Norway to the top of international historical national account and should be considered reliable (Grytten, 2004, p. 243).

4.3.4 1970-2017

The last sub-period is covered by the present national accounts calculated and maintained by the department for national accounting at Statistics Norway. The implementation of SNA 1968 introduced improved computations and changed several definitions and standards (Grytten, 2004, p.264). The framework has later been updated several times and when Norges Bank first published this entire series in 2004 it was based on SNA 1993. Importantly, these GDP figures are considered to be some of the world's most precise.

4.3.5 Summary

The historical GDP calculations 1830-1865, the national accounts 1865-1970 and the revised present national accounts 1970-2017 are then spliced together. The entire series was first published by Norges Bank as a part of their project on historical monetary statistics (Eitrheim, et.al., 2004) and has since been revised and updated several times (Norges Bank, 2019). In the version applied in these analyses, the present national accounts' (1970-2019) framework have been updated to follow SNA 2008 and the European System of National and Regional Accounts 2010 (ESA 2010). In addition, the years prior to 1970 have also been revised and aligned with the SNA 2008 framework.

The entire series have been quality controlled by a research network on the construction of standardized Nordic historical national accounts (Grytten and Hunnes, 2012, p. 7) and should be a valid and reliable source for the analyses.

4.3.6 Output cycles in quarterly terms

To measure output cycles in quarterly terms, seasonally adjusted GDP in fixed prices per quarter from 1978-2017 is used (Statistics Norway, 2019). Note, this is not GDP per capita, as it is not calculated by Statistics Norway and available quarterly data on the Norwegian population is only available until the late 1990s.

Statistics Norway did produce quarterly national accounts from 1953-1970, but unfortunately this was temporarily stopped around 1970 due to the implementation of SNA 1968 (Todsen, 1999, p. 8). Although Statistics Norway has later calculated quarterly national accounts between 1970-1977 and revised the numbers from 1967-1969, these are somewhat inaccurate due to missing data and a sub-optimal calculation method (Todsen, 1999, p. 8).

A new quarterly national accounts system was developed by Statistics Norway during the 1980s and was implemented in 1985, described in detail by Olsen, Reymert and Ulla (1985). Scholars have later calculated and stretched the quarterly national accounts back to 1978. Statistics Norway has published this series in their online archive and continuously updates it. I apply the seasonally adjusted quarterly gross domestic product in fixed prices from 1978-2017 in my analyses. This allows for measuring output cycles in quarterly terms.

4.3.7 GDP revisions

More so than the other data used, the GDP series are not only updated for new observations but is often subject to considerable revisions. Changes in the national accounting framework is relatively a common example. The most recent GDP figures are also often revised when new figures are published. In addition, the national accounts data are also revised from time to time. This happened in both 2006 and 2015. This means that analyses using the same dataset in the past or future might be based on somewhat different GDP-figures. Note, this does not mean that they are completely different, but the differences can have a significant impact on the results and should be kept in mind if the results of this paper are compared to other scholarly work.

4.4 Export and import prices

4.4.1 Annual export and import prices

To measure export and import price cycles in annual terms, I use the annual price deflators from 1830-2017 published in 2004 and subsequently updated by Norges Bank (Norges Bank, 2019). Importantly, these figures are based on empirical observations from public records and the Wedervang Archive. Other deflators in the historical national accounts are often not based on empirical observations but estimated implicitly. Furthermore, the price observations from the foreign sector are among the most valid and reliable data cited in the Norwegian historical national accounts (Grytten and Hunnes, 2012, p. 9) and should be considered trustworthy and valid for these analyses.

4.5 Exchange rate

4.5.1 Annual import weighted exchange rate

To measure exchange rate cycles in annual terms, import weighted exchange rates from two separate sub-periods is used. The first period (1919-1939) is covered by the effective exchange rate (EER) index constructed by Klovland (1998). The second period (1979-2017) is covered by the real effective exchange rate (REER) calculated and published by the World Bank. The purpose of these indices is to give nuances to the import and export price cycles, as they could be a result of a stronger or weaker currency. Notably, these are the only periods included because it is the only periods from 1830-2017 with floating exchange rates.

Both the import weighted exchange rate indices are constructed by highly reputable sources, provides a solid measurement of the development in the overall strength of the currency and should be considered valid and reliable for the analyses.

4.5.2 1919-1939

Based on monthly data of currencies quoted on the Oslo Stock Exchange in the period, Klovland (1998) constructed an effective exchange rate index from 1919-1939. The weights used to derive the index are calculated from the value of bilateral trade in non-oil exports with 16 countries in 1929, excluding unmanufactured foodstuffs and raw textiles (Klovland, 2004, p. 297). The base year is set to 1929 (= 100) and a rising index value indicates an appreciating trade weighted exchange rate.

4.5.3 1979-2017

The World Bank's real effective exchange rate (REER) is the nominal effective exchange rate, a measure of the value of a currency against a weighted geometric average of the currencies to the most important trade partners, adjusted by a price deflator or an index of costs. Specifically, the weights are derived from industrial country trade in manufactured goods. The base year is set to 2010 (= 100) and a rising index value indicates an appreciating trade weighted exchange rate.

4.6 Multifactor productivity (MFP)

4.6.1 Productivity cycles in annual terms

To measure productivity cycles, annual data of gross investments in fixed prices and employment from 1900-2017 is used to calculate changes in multifactor productivity (MFP). These annual changes are then used to construct a continuous MFP index from 1900-2017. The limiting factor in the time series is the employment figures, as these are only available from 1900. Whereas the figures on gross investments stretch back to 1836.

4.6.2 Employment 1900-2017

The historical employment statistics is published by Statistics Norway and covers employment figures from 1900-2017. The figures from 1900-1929 are based on public records of hours worked in companies subject to employee accident insurance laws combined with employment figures from the ten-year censuses between 1890-1930 (Venneslan, 2007). From 1930-1969 the figures are based on the national accounts 1865-1960 (NOS, 1965) and have been reviewed and revised by Hansen and Skoglund (2008) in accordance with the latest revisions of employment figures in the national accounts after 1970, which are used to cover employment from 1970-2017.

4.6.3 Gross investments 1900-2017

The historical gross investment statistics from 1830-2017 was published in 2004 and is subsequently updated by Norges Bank as a part of the expenditure GDP calculation. For more details regarding the sources, this is described under section 4.3 GDP.

4.6.4 Computation

MFP is computed using the assumptions suggested by Grytten and Hunnes (2002, p. 205):

$$
\begin{aligned}
Y &= F(C, L) + \epsilon \\
Y &= (1-a)C + aL + \epsilon \\
dY &= (1-a)dK + adL + \epsilon \\
\epsilon &= dY - (1-a)C - adL
\end{aligned}
\tag{4.1}
$$

C = gross investments, L = employment, Y = gross domestic product, d = change, ϵ = residual or MFP, a = labour contribution to growth in production and is assumed to be 0.7 (70%).

The rationale behind MFP as a measurement of productivity is that economic growth can be fundamentally explained by growth in the production factors labour and capital, but also technological and other efficiency improvements. In other words, GDP grows as a result of more workers, resources used and/or more efficient use of these input factors.

However, it is only possible to directly quantify the contributions of gross investments (C) and employment (L). In order to estimate the productivity contribution, MFP assumes that there is a linear relationship between the growth in production factors and their contribution to GDP. This computation assumes that a 1% increase in employment increases GDP by 0.7% and a 1% increase in gross investments increases GDP by 0.3%. If GDP grew 2% in total, then the residual 1% is attributed to productivity. Annual changes in productivity is used to construct an MFP index from 1900-2018 with the base year 2005=100.

By using reliable sources and a theoretically well-established method to compute total-factor productivity, it should be a valid and reliable measurement of productivity for the analyses.

4.7 Net migration

4.7.1 Labour supply cycles in annual terms

As an indicator of cycles and shifts in labour supply, a time series representing net migration, immigration minus emigration, from 1836-2017 is constructed using migration statistics from Statistics Norway (2019). Notably, from 1836-1940 the time series only includes Norwegian emigration to overseas countries due to lack of data on emigration to European countries and immigration in general. However, as these migrations are relatively negligible, overseas emigration alone provides a reliable picture of the net migration flows from 1836-1940. From 1946-2017 more detailed sources are available including immigration and emigration.

4.7.2 1836-1940

Unfortunately, the available historical data from 1836-1940 only includes Norwegian emigration to overseas countries. From 1836-1863 the emigration transport was not officially controlled. Therefore, relative to the rest of the period these figures are more uncertain (Backer, 1965, p. 156). However, the figures are based on registers from local police chiefs in the coastal cities where emigrants boarded the ships to sail across the Atlantic Ocean. These statistics were then sent to the county governor and has been a part of Norway's official population statistics, "Folkemængdens Bevegelse", since 1856 (Søbye, 2014, p. 40).

From 1863 the transporting agents were legally required to fill out a contract with each emigrant and send the documentation to the police who kept records of emigrants (Backer, 1965, p. 156). This law essentially meant that the police records has a complete overview of the Norwegian overseas emigration and should be a valid and reliable source.

Historical immigration statistics are not available in this period. Not including immigration in the net migration calculation could have been a significant source of error, but emigration has been far greater than immigration in Norway from 1836-1930. Changes in net migration during this period are primarily a reflection of fluctuations in the overseas emigration. Even though the Great Depression during the 1930s more or less caused a complete stop in overseas emigration and significant return migration, this is reflected in a strong decrease in emigration. It is also the only ten-year period, in peace time, from 1866-1940 where net migration is, or is anywhere close to positive (Backer, 1965, p.180). Therefore, the overseas emigration data should provide a valid and reliable measurement of the cycles in net migration in this period.

4.7.3 1946-2017

In 1946 population registers were initiated by law for every municipality in Norway, which has enabled Statistics Norway to produce net migration statistics since. Citizens were required by law to register their migrations both in and out of the country to the population registers. Statistics Norway functioned as the central population register and eventually took over the full responsibilities from the municipalities in 1966 through the National Population Register. Since 1991, the Norwegian Tax Administration has controlled the register.

One thing to note is that these statistics do not include seasonal workers, a number which increased exponentially after the EU was expanded to include ten new member countries and all of them from Eastern Europe in 2004. In addition, it is still a significant problem that citizens do not register their migrations. However, these statistics should still undoubtedly provide a valid and reliable measurement of net migration from 1946-2017.

5. Methodology

5.1 Introduction

The data for CPI, GDP, MFP, export/import prices, exchange rates and immigration makes it possible to analyse the co-movement between the cycles in these economic variables. The study of cycles necessarily begins with the measurement of cycles; however, there are still no widely accepted de-trending method without notable weaknesses. Although it would be best to have a de-trending method capable of endogenously transforming the data into stationary processes and resolving other problems contaminating the cyclical component. Little work has been done in this area (Perron and Wada, 2014, p. 285).

One reason is that macroeconomists are still not sure about basic econometric issues such as whether macroeconomic time series, like GDP, are trend or difference stationary (Cheung and Chinn, 1996, p.134). Shocks to trend stationary processes have transitory effects, whereas shocks to difference stationary processes permanently shifts the trend. These properties of the relevant macroeconomic time series have dramatic implications for their long run dynamics. Understanding these properties are critical to develop and use the appropriate de-trending methods. Unfortunately, for any finite amount of data there will be a deterministic and stochastic trend fitting the data equally well (Hamilton, 1994, p.152).

Therefore, to extract the cyclical component from the time series, three different de-trending methods is applied: First Order Differences (FOD), the Hodrick-Prescott filter (HP filter) and the Christiano-Fitzgerald filter (CF filter). As each method has its own strengths and limitations, by being aware of them, together they can yield results that are more trustworthy.

However, structural breaks, which are abrupt shifts in the time series indicating a change in the underlying process that produce the series, can bias and distort the results. Applying the HP filter and other standard methods of detrending to a series with structural breaks leads to biased trend estimations and can provide a distorted picture of the cyclical component (Matthias Mohr, 2005, p.38; Perron and Wada, 2014, p.285). World War I and II are two periods where huge external shocks caused structural breaks. Therefore, the war years are excluded from the analyses and split the time series into three sub-periods: 1830-1913, 1919-1939 and 1946-2017. This does involve a significant loss of information, but it is the simplest way to produce a cyclical component uncontaminated by these events.

5.2 First order differences (FOD)

The simplest approach to measuring cycles is to look at first order differences or also known as annual changes:

$$c_t = y_t - y_{t-1} \tag{5.1}$$

Where c_t is the cyclical component and y_t is the observed time series.

However, annual fluctuations do not provide a precise measurement of the cyclical component (c_t). For example, a large fluctuation one year will define the magnitude of the following year's fluctuation. This provides a distorted picture of the output cycle as it actually lasts for some length of time. Nonetheless, it does capture the direction and existence of cycles to a notable degree. Still, most emphasis should be on the detrending filters as they provide an actual approximation of c_t.

5.3 Hodrick-Prescott filter (HP filter)

The HP filter (Hodrick and Prescott, 1997) is the best known and most frequently used de-trending procedure in empirical macroeconomic analyses, particularly to assist in the measurement of business cycles. It is a signal extraction filter, separating the observed time series (y_t), into an I(d) trend component (g_t) , and a stationary cyclical component (c_t):

$$y_t = g_t + c_t \tag{5.2}$$

In the de-trending of y_t , the trend component g_t is determined by:

$$\min \sum_{t=1}^{T} (y_t - g_t)^2 + \lambda \sum_{t=2}^{T-1} [(g_{t+1} - g_t) - (g_t - g_{t-1})]^2 \tag{5.3}$$

The filter minimizes the distance between the trend component (g_t) and the observed time series (y_t), while also minimizing the curvature of the trend component. The trade-off between these two goals is balanced by the λ parameter, also known as the smoothing parameter. If the smoothing parameter (λ) equals zero it implies that all changes in y_t are due to changes in g_t. Whereas if λ approaches infinity, the change in g_t will be constant and g_t will be a straight line. Both these scenarios are unlikely, but it is difficult to know the true value of λ in practice.

However, as the HP filter is the most widely used de-trending method, the literature has established some standard values for λ (Grytten and Hunnes, 2016, p. 61):

Annual data: $\lambda = 100$ Quarterly data: $\lambda = 1600$ Monthly data: $\lambda = 14\,400$

Grytten (2012, p. 22) argues that these standard values for λ multiplied by a factor of 25 provides a better interpretation of the Norwegian business cycles. Therefore, I will be including both the literature's standard values and the ones suggested by Grytten for the Norwegian economy in my analyses.

5.3.1 Limitations

The HP filter is a two-sided asymmetric moving average filter. Firstly, this means that it is essentially just a data-smoothing device and does not have any theoretical foundation. Krugman (2012) has criticized the HP filter for this as it presumes that deviations from the trend component (g_t) are relatively short-term and tend to revert quickly, which means that any protracted cycle slump (c_t) in the data is interpreted as a decline in g_t. Krugman argues that historical reversion to g_t does not necessarily reflect a natural process of recovery, but rather a counter-cyclical monetary policy from the central bank. However, if e.g. a strong shock sends interest rates to the zero lower bound the mechanism goes away, and the HP filter will incorrectly interpret this as a decline in g_t

Secondly, the filter is two-sided in the sense that it averages data before and after each data point. This means that the filter is neither causal nor predictive and that it is necessarily one-sided at the endpoints of the sample, which causes estimation errors towards the end (Baxter and King, 1995, p. 22).

Lastly, one of the fundamental reasons why the HP filter has become the most widely used de-trending method among macroeconomists is that it is supposed to function regardless if the time series are trend or difference stationary process. However, Cogley and Nasan (1995, p. 253) found that HP filtered series often test as having long memory and even a unit root. They also find that this can generate spurious cycles in the de-trended series even though there is none in the original data. This implies that the HP filter might imperfectly filter difference stationary/unit root processes. This contradicts the commonly given solution to the HP filter by King and Robelo (1993, p. 220) showing that it is capable of rendering stationary any integrated process up the fourth order.

5.4 Christiano-Fitzgerald filter (CF filter)

The CF filter is a frequency extraction filter also known as a band pass filter. In theory, the "Ideal" band pass filter could be an exact method of isolating a component of a time series within a certain band of frequencies. For example, the cyclical component (c_t) is a higher frequency component of the data. However, the "ideal" band pass filter requires a time series with infinite length and macroeconomic time series are finite in practice.

Christiano and Fitzgerald (1999) therefore derived an asymmetric approximation, the CF filter, which works well for standard macroeconomic time series. Importantly, the filter is optimal when the underlying data of the observed time series (y_t) have a unit root, as the approximation relies on the (most likely, false) assumption that y_t is generated by a pure random walk (Christiano and Fitzgerald, 1999, p. 2). The filter estimates the cyclical component (c_t) of y_t with period of oscillation between p_l and p_u, where $2 \leq p_l < p_u < \infty$, and is computed as follows:

$$c_t = B_0 y_t + B_1 y_{t+1} + \cdots + B_{T-1-t} y_{T-1} + \tilde{B}_{T-t} y_t + B_1 y_{t-1} + \cdots + B_{t-2} y_2 + \tilde{B}_{t-1} y_1 \quad (5.4)$$

$$\text{where, } \mathrm{B}_j = \frac{\sin(jb) - \sin(ja)}{\pi j}, j \geq 1, \text{and } B_0 = \frac{b-a}{\pi}, a = \frac{2\pi}{p_u}, b = \frac{2\pi}{p_l} \quad (5.5)$$

$$\tilde{B}_k = -\frac{1}{2} B_0 - \sum_{j=1}^{k-1} B_j \quad (5.6)$$

The parameters p_u and p_l are the cut-off cycle length in years for annual data or quarters for quarterly data. Cycles longer than p_l and shorter than p_u are preserved in the cyclical term c_t, everything else is eliminated. Grytten and Hunnes (2012, p. 8) used a period of oscillation between 2 and 7 years for the Baxter King filter (BK filter) to de-trend time series of Norwegian prices and output. As there is no general rule, in my analyses, I have chosen to follow their lead and select periodic components between two and seven years.

A simplified way to consider the computation of the CF filter is to extend the data sample $\{y_t, t = 1, \ldots, T\}$ infinitely in both directions by taking $y_t = y_1$ for $t < 1$ and $y_t = y_T$ for $t > T$ (Estrella, 2007, p. 5). Then the ideal weights (6.6) are applied to the extended sample. The extension is possible due to the predictive properties of the random walk assumption and means that the CF filter converges to the ideal band pass filter as the sample size approaches infinity.

5.4.1 Discussion: Christiano-Fitzgerald vs. Baxter-King

The common and fundamental challenge for band-pass filters is to best approximate the "Ideal" band pass filter. Similar band-pass filters such as the Baxter-King filter (1995) are very effective at approximating the "Ideal" filter, but like the HP-filter, they have to sacrifice observations at the end of the series (Nilsson and Gyomai, 2011, p. 10). Meanwhile the CF filter uses the whole time series for the computation of each filtered data point, enabling it for use in real-time cycle analysis. However, the cost of its practical applicability is that the CF filter does not approximate the "ideal" filter as closely as BK (Smith 2016, p. 1).

However, the CF filter is designed to work well on a larger class of time series than the BK filter, and outperforms the BK filter in real time applications while still converging to the "ideal" filter in the long-run (Nilsson and Gyomai, 2011, p. 10). Thus, the CF filter better suits the analyses for three reasons. Firstly, a relatively broad set of macroeconomic time series is studied. Secondly, unlike the other filters, the CF filter complements the analyses, as it does not have estimation issues at the endpoints. Lastly, as the HP filter imperfectly removes unit roots and the CF filter is optimal for time series with a unit root, the two filters somewhat complement each other.

Note. The Baxter-King filter is a perfectly viable option; this is simply the reason why the CF filter was used in these analyses.

5.4.2 Limitations

Christiano and Fitzgerald (1999, p. 2) found that the filter is nearly optimal for US time series on interest rates, unemployment, inflation and output. However, the filter bases itself on the most likely false assumption that the data are generated by a pure random walk. It allows the CF filer to somewhat overcome the fundamental problem of band pass filters, which is the finiteness of macroeconomic time series, and it is shown to work well. However, the underlying assumption is almost certainly wrong, which is a significant source of error. Furthermore, although it is supposed to be optimal for time series with a unit root, Smith (2016) shows that in the presence of a stochastic trend the CF filter allows cyclical properties of the error term to pass through and distort the estimate of the cyclical component (c_t). The consequence is that the CF filtered c_t might have a higher amplitude and longer duration than the true c_t. However, this is a common defect among band-pass filters.

5.5 Cross-correlation analysis

Correlation analysis is a simple statistical method to determine the direction and strength of a linear relationship between two, numerically measured, continuous variables. Such as two time series. Cross-correlation means that the computation also looks at relationships between lags of each series. The objective of the analysis is to identify the relationship between the cyclical components (c_t) of output and prices, but also look for an explanation through underlying supply side variables such as export/import prices, labour supply and productivity.

The cross-correlation formula takes two observed time series, x_t and y_t, each with T observations, where $\overline{x}$ and $\overline{y}$ represents the sample means and σ_x and σ_y the standard deviations (the subscripts lets the formula compare x_t to lags of y_{t-s} and vice versa):

$$r = \frac{\sum_t^T (x_t - \overline{x}) \sum_s^T (y_s - \overline{y})}{\sigma_x \sigma_y} \tag{5.7}$$

The size of the correlation coefficient (r) measures the strength of the linear relationship and its sign determines the direction of the relationship. The coefficient (r) ranges between +1 and -1, where the former indicates the strongest positive correlation possible and -1 the strongest negative correlation possible. Positive (+) correlation means that variables increases simultaneously, whereas negative (-) means that when one variable increases the other decreases and vice versa. In conclusion, if there is an identifiable correlation between the two series it is indicative of some sort of systemic co-movement between the variables.

5.5.1 Limitations

A common phrase used in statistics to emphasize the key limitation of correlation analysis is that "correlation does not imply causation". In other words, correlation does not determine cause and effect between two variables. Other variables not present in the analysis might distort the results. Then, what is the point of a simple correlation analysis? Firstly, although other analyses such as Multiple Regression analysis can account for more variables, it eventually faces identical problems in terms of irrelevant and omitted variable bias. This makes it equally, if not more difficult to know if the results show the true relationship between the variables. Lastly, the theoretical foundation behind inflation targeting, the Phillips Curve, implies that there is a systemic positive causal relationship between short-term fluctuations in inflation and output. Thus, there should be a clear (positive) correlation between the variables.

6. Results

6.1 Introduction

This section will present and discuss the results of the empirical analyses. The cross correlations between the cyclical components of prices and several macroeconomics variables is computed in order to determine the strength and direction of their relationship. In total, correlations using four different filters is computed. Importantly, the correlation coefficients do not reveal causality, but can provide valuable indications of the correspondence between the two relevant variables.

Durbin Watson tests confirms that all the estimated cyclical components are stationary, except for the first order differences which in some series tested positive for series correlated data. Thus, most emphasis should be placed on the filtered cycle data.

The first part of this section revisits the historical short-term co-movement between output and prices from 1830-2017 by computing the cross correlations between the cyclical components of real GDP per capita and CLI-CPI. These results are also cross checked against the same data in quarterly terms from 1978-2017. As it is generally recognized that quarterly data are more suitable for business cycle analysis. The second part investigates whether short-term movements and shocks from the supply side can help explain the lack of significant historical co-movement between output and prices. Thus, cross correlations between the cyclical components of prices and the supply of capital, labour and change in productivity is computed.

The supply side of the economy can be described in a function of three factors:

$$Y = F(C, L) + P \tag{6.1}$$

Y = total output (GDP), C = capital (incl. natural resources), L = labour, P = productivity.

The effects of short-term changes in capital input is analysed through export and import prices. Labour input is analysed through net migration and productivity is analysed through multifactor productivity. Traditionally the supply side provides the best explanation for long-term economic growth, while the demand side has best explained business cycles. However, in the second part of the results, this view is challenged. Short-term changes in the exchange rate is also analysed to control for potential exchange rate effects in export and import prices.

6.2 Sub-periods

Due to structural breaks in the data it is necessary to split the time series into three sub-periods: 1830-1913, 1919-1939 and 1946-2017. This provides the best foundation in order to conclude on the possible correspondence between the different macroeconomic variables. Some of the time series does not stretch all the way back to 1830, but will be analysed as far back in time as the available data allows.

During the first sub-period (1830-1913) Norway was one of the most liberalistic countries in international trade and was strongly dependent on this trade. Although agriculture still was the most important industry, many farmers combined it with one of the large export industries: shipping, fishing or forestry. These three accounted for about 90% of all Norwegian exports in the period (Bjerke and Juul, 1966, p. 64). Since the growth of the merchant fleet was also strongly dependent on worldwide transport of raw materials, it meant that international demand for raw materials was decisive for the Norwegian economy.

From 1830-1842 the central bank applied a careful deflationary monetary policy in order to build trust and obtain the par silver value of the currency. Once achieved it was followed by a relatively stable real silver standard from 1842-1873, which was replaced by a real gold standard in 1874 and lasted until 1914 (WW1).

The second sub-period (1919-1939) is fundamentally similar to the first sub-period, although industrialization had to a larger degree started. Norway had also moved from a purely liberal country towards a social liberal state with a significant public sector. The period is very volatile with several years of financial and especially monetary instability. Several crises took place, but there was also relatively strong growth over the period as a whole.

In the last sub-period (1946-2017) the petroleum sector took over as the predominant Norwegian export industry. However, the fishing industry has also experienced somewhat of a renaissance towards the end of the period. The leading political ideology shifted to a social-democratic planning regime after WW2, but has since the stagflation in the 1970s gradually moved towards a more neo-liberalistic regime. Monetary policy has been relatively stable, especially until the fall of the Bretton Woods system in 1971. This caused some turbulence at the time and afterwards. In addition, there was also some monetary policy turbulence in the early 1990s. Notably, a severe global financial crisis also took place in 2008.

6.3 Correlation between output and prices

6.3.1 General

The cross correlations between the cyclical components of GDP per capita and CPI-CLI is computed in order to determine the strength and direction of the relationship between output and inflation. A positive correlation coefficient would indicate that short-term output cycles are demand-led, whereas a negative correlation coefficient would indicate supply-led cycles.

Table 1 reports that only 26 of the 60 estimated correlations are negative. However, 6 of 12 contemporaneous correlations and 17 of 24 price-lagged [-] correlations are negative. This implies that a change in CPI-CLI indicates an opposite change in present and future GDP. In contrast, 21 of 24 price-led [+] correlations are positive. This implies that a change GDP indicates that future CPI/CLI will change in the same direction.

If the price-lagged correlations had been positive it could have indicated that a demand shock had increased prices and eventually a positive increase in output. Implying that short-term cycles in output and prices were demand-led. However the price-lagged correlations are chiefly negative. In addition, if the price-led correlations were negative it could have indicated that supply shocks increased output and eventually caused prices to fall. Implying that short-term cycles in output and prices were supply-led. However the price-lagged correlations are chiefly positive. In short, it is not straightforward to interpret the results. Instead, analysing the contemporaneous correlations in each sub-period might provide more definite results.

Table 6.1: Correlation coefficients between GDP per capita and CLI-CPI for Norway (1830-2017)

Lag	1830-1913				1919-1939				1946-2017			
	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF
-2	0.1076	-0.1193	-0.1352	0.2187	0.1986	0.0865	0.0876	-0.0573	0.1363	-0.3980	-0.2824	0.2084
	(0.3389)	(0.3401)	(0.2510)	(0.0484)	(0.4151)	(0.7249)	(0.7215)	(0.8157)	(0.2641)	(0.0006)	(0.0179)	(0.0834)
-1	-0.0332	-0.0368	-0.0418	-0.1254	-0.3186	-0.3103	-0.1911	-0.4429	-0.0033	-0.5259	-0.3934	-0.3741
	(0.7670)	(0.6477)	(0.6298)	(0.2588)	(0.1838)	(0.1830)	(0.4197)	(0.0505)	(0.9786)	(0.0000)	(0.0007)	(0.0013)
0	-0.0351	0.1112	0.1072	-0.2303	0.1342	0.0128	0.1198	0.0666	-0.0575	-0.4322	-0.3694	-0.6176
	(0.7529)	(0.5035)	(0.4746)	(0.0351)	(0.5726)	(0.9560)	(0.6048)	(0.7741)	(0.6337)	(0.0001)	(0.0014)	(0.0000)
1	0.3019	0.3461	0.2982	0.2055	0.2607	0.2519	0.4384	0.3821	0.1720	-0.0580	-0.1519	-0.0374
	(0.0058)	(0.0033)	(0.0117)	(0.0624)	(0.2811)	(0.2840)	(0.0532)	(0.0964)	(0.1544)	(0.6310)	(0.2061)	(0.7571)
2	0.2461	0.2874	0.2672	0.1508	0.2080	0.0619	0.1925	0.2544	0.2577	0.2881	0.0651	0.2928
	(0.0268)	(0.0049)	(0.0106)	(0.1764)	(0.3928)	(0.8014)	(0.4297)	(0.2933)	(0.0325)	(0.0156)	(0.5921)	(0.0139)

The numbers show the correlation between the cyclical components of GDP per capita in fixed prices and current, leads [+] and lags [-] of CPI. Lag equal to zero indicates contemporaneous correlation. *p*-values in parentheses.

6.3.2 1830-1913

The contemporaneous correlations in the first sub-period (1830-1913) are not unambiguous. The HP cycles yield positive correlations, whereas the FOD cycles yields a negative correlation and the CF filter yields a statistically significantly negative correlation.

As the value of all exports and imports amounts to more than half of GDP for large parts of this period, the Norwegian output cycle must have depended strongly on the business cycles in the most important trading partners (Grytten and Hodne, 2000, p. 97). For example, a negative foreign demand shock such as a recession among key trading partners would lead to lower demand for raw materials. Causing both falling prices and lower economic activity. Which would cause a positive correlation between inflation and GDP.

On the other hand, a negative relationship between output and prices could make sense as the primary sector was the largest contributor to employment and economic growth for the majority of the period (Grytten and Hodne, 2000, p. 190-191). Agriculture, fishing and forestry are the three major industries from this sector in the period. The two latter also accounted for almost half of Norwegian exports in the period (Bjerke and Juul, 1966, p. 64). The supply of raw materials in this period would therefore be decisive for prices and economic activity. Supply side shocks such as poor harvests and low fish catches could lead to lower output, but consequently higher prices. Resulting in a negative correlation between GDP and inflation.

One might also suggest that large productivity increases in especially agriculture, but also other important industries increased output and lowered prices in the short-term This also lowered the demand for labour, and as a more attractive labour market opened overseas, it was a key reason why 750,000 Norwegians emigrated from 1830-1913 (Grytten and Hodne, 2000, p. 130-136). About two thirds of the emigrants from 1905-1914 reported a lack of opportunity for profitable work as their reason to leave (Backer, 1965, p. 178). The overseas emigration, partly as a result of a more efficient agriculture industry, could therefore be viewed as a negative labour supply shock that would lead to lower output and higher wages and prices. Therefore, the total effect of the productivity increase might be more unclear.

The mixed results of the contemporaneous correlations between the HP cycles might indicate that both demand and supply side shocks were important for short-term movements in output and prices from 1830-1913. Importantly, these two types of shocks are not mutually exclusive. For example, Grytten and Hunnes (2012, p. 5 & 12) specifically looked at the relationship between HP cycles ($\lambda = 100$) of agriculture prices and volumes from 1830-1910. They find a clear negative correlation coefficient of -0.40, indicating that supply shocks were decisive for the development in output and prices in this primary sector industry. The result for the economy in general is not as decisive, but it was arguably also more exposed to demand-shocks through the foreign sector than the agriculture industry.

6.3.3 1919-1939

The contemporaneous correlations in the second sub-period (1919-1939) are all positive. However, the correlations are very weak. Therefore, the results are to a certain extent the same as the first sub-period – ambiguous. The key takeaway is that there is once again basically no correlation between the GDP and CPI-CLI cycles, contrary to the common assumption that inflation in the short run to some extent reflect the output cycle.

This period is fundamentally similar to the previous period, but is characterized by numerous shocks to the economy. A world war took place both before and after this period. Furthermore, two severe international depressions struck the economy. In addition, the Norwegian central bank carried out a substantial deflationary monetary policy in order to bring the currency back to its gold standard value. This was achieved in 1928 but was soon followed by an international deflation in the 1930s. However, despite several years of crises, contractionary monetary policy and deflation, significant economic growth took place over the period. Sejersted and Lange (1982, p. 9-19) partly explained the growth by large productivity increases after 1930.

Grytten and Hunnes (2012, p. 9) argued that it would be reasonable, because of the two world wars and the long period of deflationary monetary policy, that the economy in many years was influenced by heavy supply side shocks. Therefore, the inflation could not necessarily have reflected the output cycle for large parts of the period. Towards the end of the period there is also a significant change in the migration pattern. From 1931-1940 the net migration is significantly positive due to the Great Depression. The net immigration over this decade was 25,000 (Backer, 1965, p. 180). Compared to a net emigration close to and above 100,000 in previous decades this is undoubtedly a substantial increase. Therefore, one might suggest that this development represented a positive labor supply shock that would lead to lower wages and prices, but also increased output and a negative correlation between them.

6.3.4 1946-2017

The contemporaneous correlations in the third sub-period (1946-2017) are all strongly negative, except for the FOD correlation which is weaker. All the price-lagged [-] correlations are also strongly negative, except for the two-period lagged FOD correlation. Interestingly, all the one period price-leads [+] are negative, except for the one-period lead FOD correlation. This could indicate that supply shocks increased output, eventually leading to falling prices the following period. On the other hand, all the two-period price-leads are positive. Overall there tends to be a negative relationship between inflation and output in this period, contrary to what was assumed when inflation targeting was adopted as an objective for monetary policy.

Unlike previous periods, the primary sector is the smallest economic sector throughout this period (Grytten and Hodne, 2002, p. 17-20). Therefore, the economy is no longer as exposed to supply shocks in this sector as earlier. In addition, for a large part of this period, the new social-democratic planning regime actively subsidized and directed the economy to ensure stable low inflation and strong economic growth. (Grytten and Hodne, 2002, p. 103-177). However, inflation and output cycles are still clearly negatively correlated during this period.

The results could partly be explained by changes in productivity. For example, the US helped to rebuild war-torn Western European countries after the Second World War by removing trade barriers and providing financial aid to modernize their industries (Grytten and Hodne, 2002, p. 184). As productivity and economic activity in these countries increased enormously, cheaper imports also became increasingly more available from each other causing imported inflation rates to fall, everything else equal. More recently innovations within information technologies fuelled a surge in productivity during the 1990s and early 2000s lowering costs.

Another explanation is the collapse of the Bretton Woods system in 1971. Afterwards, many countries conducted competitive devaluations to win out in trade. The Norwegian government used devaluations relatively often to close trade-deficits during this time (Grytten and Hodne, 2002, p. 246). The depreciation leads to higher inflation and more output, however if trade-partners also frequently devaluates it becomes closer to a zero-sum game in terms of output and only generates higher inflation. Combined with strong negative supply shocks of petroleum due to the embargo in 1971 (OPEC I) and the Iran-Iraq War in 1979 (OPEC II), as oil prices per barrel rose from three to forty dollars during the 1970s, this caused high inflation and a fall in demand for domestically produced goods in the OECD area.

Another explanation is the expansion of the Chinese economy. In 1980 China was home to about one billion people and the world's total population at the time was close to four and a half billion (World Bank, 2019). That is almost one fourth of the world's population, which gives them an enormous production capacity. However, this capacity was not efficiently utilized. Then in three successive waves of investment, the Chinese economy expanded exponentially from being an exporter of agricultural products in 1980 to becoming "the world's factory" as we know it today (Arvanitis et.al, 2003, p. 2-5).

The competitiveness of the Chinese economy increased immensely as they supplemented their access to cheap labour with imported western technologies and opened for foreign direct investments. This led to enormous trade-surpluses, and to prevent currency appreciation most of the profits were invested or spent in foreign countries. Which caused a significant negative inflation shock to OECD countries through cheaper imports. In addition, as OECD countries started to adopt inflation targeting during the 1990s, they responded to the negative inflation shock by lowering interest rates to close the inflation gap. However, this generated a positive output gap that was not sustainable and arguably culminated in the financial crisis in 2008 (for illustration see 3.2.16). Thus, inflation and output once again will move in opposite directions.

Lastly, one might suggest that a significant increase in immigration to Norway during this period might have caused a positive shift in labour supply, leading to a negative inflationary shock caused by cheaper labour. The immigration to Norway was relatively small until 1970, but from there it increased in three phases: Labour immigration in the early 1970s, asylum seekers and family immigrants from 1980 to the late 1990s, and most importantly labour immigration from the new EU countries from Eastern Europe in 2004 (Myhre, 2018).

6.3.5 Summary

Based on the results from table 1 it can be concluded that the contemporaneous correlation between output and inflation has not been strongly positive in either of the three sub-periods from 1830-2017. Instead, they are consistently closer to zero or strongly negative. This might indicate that supply side shocks are more influential to inflation and output cycles than assumed in current monetary policy. Furthermore, during the third sub-period there is a significant increase in negative correlations in all lags. The evidence therefore suggests that after WWII, inflation has been more likely to move in the opposite direction of output.

6.3.6 Quarterly GDP & CPI

Given the significantly negative results after WWII and as it is commonly recognized that quarterly data are more suitable to analyse business cycles, it makes sense to control the results against equivalent results from quarterly data.

The cross correlations between the cyclical components of quarterly GDP and CPI is presented in table 2. It convincingly reports that 47 of the 68 estimated correlations are negative. All the contemporaneous correlations except FOD are strongly negative. In addition, 29 of 32 price-lagged [-] and 15 of 32 price-led [+] are negative. These results clearly align with the results from the annual data and suggests that inflation has been more likely to move in the opposite direction of output since 1978. They also support previous indications that supply shocks are more important for the cycles in inflation and output than assumed in current monetary policy

Table 6.2: Correlation coefficients between QGDP and QCPI (1978-2017)

Lag	1978-2017			
	FOD	HP (ʎ=1600)	HP (ʎ=40000)	CF
-8	-0.0677	-0.2076	-0.4638	0.0967
	(0.4086)	(0.0031)	(0.0000)	(0.2361)
-7	-0.1262	-0.2988	-0.5012	-0.0097
	(0.1213)	(0.0002)	(0.0000)	(0.9058)
-6	0.0192	-0.3094	-0.4986	-0.1284
	(0.8137)	(0.0001)	(0.0000)	(0.1124)
-5	-0.0860	-0.3712	-0.5076	-0.2636
	(0.2890)	(0.0000)	(0.0000)	(0.0009)
-4	-0.0110	-0.3990	-0.4959	-0.4084
	(0.8921)	(0.0000)	(0.0000)	(0.0000)
-3	0.0405	-0.4481	-0.4873	-0.5451
	(0.6161)	(0.4354)	(0.0000)	(0.0000)
-2	-0.2318	-0.5590	-0.4950	-0.6483
	(0.0035)	(0.0000)	(0.0000)	(0.0000)
-1	-0.1299	-0.5155	-0.4412	-0.6904
	(0.1038)	(0.0000)	(0.0000)	(0.0000)
0	0.0613	-0.3972	-0.3554	-0.6507
	(0.4428)	(0.0000)	(0.0000)	(0.0000)
1	-0.0905	-0.3545	-0.2997	-0.5238
	(0.2579)	(0.0003)	(0.0000)	(0.0000)
2	-0.1501	-0.2619	-0.2227	-0.3278
	(0.0607)	(0.0088)	(0.0049)	(0.0000)
3	0.0393	-0.0665	-0.1036	-0.1019
	(0.6259)	(0.4079)	(0.1967)	(0.2042)
4	-0.0301	0.0768	-0.0001	0.1072
	(0.7104)	(0.3407)	(0.9993)	(0.1827)
5	0.1457	0.2301	0.1088	0.2667
	(0.0713)	(0.0040)	(0.1779)	(0.0008)
6	-0.0075	0.2528	0.1757	0.3661
	(0.9270)	(0.0016)	(0.0293)	(0.0000)
7	-0.0623	0.2775	0.2378	0.4119
	(0.4456)	(0.0005)	(0.0031)	(0.0000)
8	0.0540	0.3567	0.3154	0.4227
	(0.5105)	(0.0000)	(0.0001)	(0.0000)

The numbers show the correlation between the cyclical components of QGDP in fixed prices and current, leads [+] and lags [-] of QCPI. Lag equal to zero indicates contemporaneous correlation. *p*-values in parentheses.

6.4 Can supply side shocks explain the lack of significant historical co-movement between output and inflation?

6.4.1 Export prices

It was suggested earlier that the price of exports, through changes in demand or supply, could impact inflation and output cycles in various directions. To determine if export prices has had an impact on inflation, the correlation coefficients for export prices and CLI-CPI is estimated in table 3. In addition, to investigate if changes in export prices has been demand-or supply-led, the correlation coefficients for GDP per capita and export prices are estimated in table 4.

Based on the estimates in table 3 there tended to be a strong positive relationship between export prices and inflation in the two first sub-periods. Thus, it seems that changes in export prices had a significant influence on the development in the general price level. Which is fairly understandable in a small open raw material based economy. Table 4 reports that export prices largely reflected the output cycle in these periods. This indicates that export price cycles were demand-led and would contribute to a positive relationship between output and inflation.

However, there is a significant change in the results pattern during the third sub-period. There seems to be a shift from a positive relationship in the first two sub-periods towards a negative relationship in the last sub-period of both table 3 and 4. According to the estimates in table 3 there tended to be a weak negative relationship between export prices and inflation from 1946-2017. This indicates that for example increased export prices has coincided with falls in inflation. Theoretically it does not make sense that for example higher export prices could directly decrease inflation if everything else is held constant. Therefore, other variables outside of the analysis is likely effecting the results.

One explanation is that the export basket has changed. In previous sub-periods fishing, forestry and shipping dominated the export basket (Grytten and Hodne, 2000, p. 265; 2002, p. 62). As shown previously, these prices largely reflected changes in the price level of the consumption basket. However, in the last sub-period the petroleum industry and other industry dominates the export basket. However, the domestic consumption basket consists mostly of goods and services other than these. It likely indicates that prices in the rest of the consumption basket have tended to move in the opposite direction of export prices. This could be explained by the export sector shifting towards industries which have had consistently rising prices in this period, which have not necessarily been the case for the rest of the consumption basket.

This result is likely due to cheaper imports. Thus, inflation targeting can be very pro-cyclical since when the world price of the exported goods increase, leading to a positive output gap, the inflation rate have tended to fall. Prompting the central bank to lower the interest rate, which further increases the output gap. Similar to Frankel's (2012) argument in section 2.

There is also a shift towards very weak positive contemporaneous correlations and negative price-led correlations between GDP per capita and export prices in table 4. Although not all the relevant correlations are decisively negative, the downward shift in the correlations might indicate that shifts on the supply side in the export industry have influenced the economy. Grytten and Hunnes (2012, p. 10) found similar results and suggested that supply side shifts from the export sector might have decreased production costs and increased input volumes.

Table 6.3 Correlation coefficients between the price deflator for Norwegian exports and CLI-CPI (1830-2017)

Lag	1830-1913				1919-1939				1946-2017			
	FOD	HP (Λ=100)	HP (Λ=2500)	CF	FOD	HP (Λ=100)	HP (Λ=2500)	CF	FOD	HP (Λ=100)	HP (Λ=2500)	CF
-2	-0.1766	-0.2731	-0.0841	-0.1602	-0.6219	-0.4338	-0.0811	-0.6396	0.1276	0.0528	-0.1946	0.1573
	(0.1149)	(0.0130)	(0.4524)	(0.1506)	(0.0059)	(0.0635)	(0.7413)	(0.0032)	(0.2960)	(0.6644)	(0.1064)	(0.1933)
-1	0.0592	0.1509	0.2529	-0.0058	-0.4941	-0.4905	0.1903	-0.5822	-0.0708	-0.1359	-0.1601	-0.2263
	(0.5976)	(0.1733)	(0.0211)	(0.9586)	(0.0315)	(0.0281)	(0.4216)	(0.0071)	(0.5602)	(0.2584)	(0.1822)	(0.0578)
0	0.4733	0.5970	0.5608	0.3250	0.5596	0.4227	0.6898	0.6098	0.0817	-0.0902	-0.0732	-0.0902
	(0.0000)	(0.0000)	(0.0000)	(0.0026)	(0.0103)	(0.0562)	(0.0005)	(0.0033)	(0.4984)	(0.4514)	(0.5412)	(0.4512)
1	0.3234	0.6182	0.5844	0.0438	0.7224	0.6777	0.8395	0.7483	-0.0132	-0.0554	0.0286	-0.1648
	(0.0030)	(0.0000)	(0.0000)	(0.6939)	(0.0005)	(0.0010)	(0.0000)	(0.0001)	(0.9132)	(0.6463)	(0.8128)	(0.1697)
2	0.1822	0.3744	0.4352	-0.1169	-0.0504	-0.1620	0.4335	-0.1991	0.1569	0.1784	0.1799	0.1559
	(0.1036)	(0.0005)	(0.0000)	(0.2955)	(0.8425)	(0.5076)	(0.0637)	(0.4139)	(0.1980)	(0.1394)	(0.1362)	(0.1975)

The numbers show the correlation between the cyclical components of the price deflator for Norwegian exports and current, leads [+] and lags [-] of CPI. Lag equal to zero indicates contemporaneous correlation. *p*-values in parentheses.

Table 6.4: Correlation coefficients between GDP per capita and price deflator for Norwegian exports (1830-2017)

Lag	1830-1913				1919-1939				1946-2017			
	FOD	HP (Λ=100)	HP (Λ=2500)	CF	FOD	HP (Λ=100)	HP (Λ=2500)	CF	FOD	HP (Λ=100)	HP (Λ=2500)	CF
-2	0.1518	0.1506	0.0667	0.2157	0.1328	-0.0742	0.1275	-0.2462	-0.0749	-0.1521	-0.3885	-0.1317
	(0.1761)	(0.1769)	(0.7860)	(0.0516)	(0.7698)	(0.7627)	(0.6029)	(0.3096)	(0.5406)	(0.2087)	(0.0009)	(0.2772)
-1	0.2344	0.3066	0.2397	0.1618	-0.1980	-0.0399	0.3443	-0.3053	0.0403	-0.0403	-0.1581	0.2338
	(0.0340)	(0.0048)	(0.3087)	(0.1439)	(0.4165)	(0.8673)	(0.1371)	(0.1905)	(0.7406)	(0.7387)	(0.1879)	(0.0497)
0	0.0473	0.2923	0.3173	-0.1467	0.5218	0.4590	0.6743	0.5055	0.1855	0.0422	0.0304	0.4141
	(0.6712)	(0.0070)	(0.1610)	(0.1831)	(0.0183)	(0.0363)	(0.0008)	(0.0194)	(0.1215)	(0.7249)	(0.7997)	(0.0003)
1	0.2310	0.2935	0.3567	-0.0159	0.0732	0.1701	0.4460	0.2055	0.0068	-0.0568	0.1127	0.0032
	(0.0368)	(0.0071)	(0.1227)	(0.8863)	(0.7657)	(0.4734)	(0.0487)	(0.3847)	(0.9557)	(0.6380)	(0.3496)	(0.9787)
2	0.0291	0.1231	0.2723	-0.1022	0.0937	-0.2306	0.0310	-0.0872	-0.1453	-0.1194	0.1983	-0.3582
	(0.7962)	(0.2704)	(0.2593)	(0.3608)	(0.3573)	(0.3423)	(0.8996)	(0.7227)	(0.2336)	(0.3247)	(0.0998)	(0.0023)

The numbers show the correlation between the cyclical components of GDP per capita and current, leads [+] and lags [-] of the price deflator for Norwegian exports. Lag equal to zero indicates contemporaneous correlation. *p*-values in parentheses.

6.4.2 Import prices

Earlier analyses suggested that imports could be a significant source of inflationary shocks due to shifts on the supply side. To determine if import prices has had a significant influence on inflation, the correlation coefficients for import prices versus CLI-CPI is estimated in table 5. In addition, to investigate if supply side shifts in imports have been the driving factor, the correlation coefficients for GDP per capita and import prices are estimated in table 6.

Based on the estimates in table 5 there tended to be a strong positive relationship between import prices and inflation in all sub-periods. It is clear that import prices has had a significant impact on inflation. Which is expected in a small open economy utilizing its comparative advantages to maximize trade. As a result, large parts of the consumption basket are imports, and import prices strongly influences inflation. Table 6 reports that import prices also reflected the output cycle in the two first sub-periods. Positive correlations means that short-term cycles in output and import prices were demand-led, moving output and prices in the same direction. This is likely explained by international prices, when these changed so did domestic output.

However, in the last sub-period of table 6 there is a significant change in the pattern of the results. There is a shift to negative correlations, and the few positive correlations remaining are all significantly weaker. Thus, the evidence suggests that imported inflation has tended to move in opposite directions of output in this period, and that short-term cycles were supply-led, contributing to a negative relationship between output and inflation. This is likely related to export prices moving oppositely of CPI in the period. Higher world prices of exported goods would increase output, while cheaper imports from the foreign sector would lower inflation.

Table 6.5: Correlation coefficients between price deflator for Norwegian imports and CLI-CPI (1830-2017)

Lag	1830-1913				1919-1939				1946-2017			
	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF
-2	0.0481	-0.0480	0.1433	0.0543	-0.6884	-0.7659	0.0062	-0.9020	0.3258	-0.1119	0.5046	-0.0211
	(0.6699)	(0.6687)	(0.1989)	(0.6282)	(0.0011)	(0.0001)	(0.9801)	(0.0000)	(0.0063)	(0.3565)	(0.0000)	(0.8621)
-1	-0.0591	0.0396	0.1980	-0.0580	-0.1953	-0.2119	0.4105	-0.2106	0.3914	0.1159	0.6485	-0.0245
	(0.5981)	(0.7223)	(0.0728)	(0.6022)	(0.4229)	(0.3699)	(0.0722)	(0.3729)	(0.0008)	(0.3357)	(0.0000)	(0.8393)
0	0.1511	0.1205	0.3117	0.0485	0.9091	0.8674	0.9137	0.9301	0.5025	0.3845	0.7731	0.0656
	(0.1728)	(0.2749)	(0.0039)	(0.6616)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0009)	(0.0000)	(0.5841)
1	-0.0811	0.0908	0.3154	-0.1665	0.3839	0.3289	0.7284	0.3178	0.5354	0.5291	0.8609	0.0854
	(0.4690)	(0.4144)	(0.0037)	(0.1325)	(0.1047)	(0.1568)	(0.0003)	(0.1721)	(0.0000)	(0.0000)	(0.0000)	(0.4790)
2	0.2174	0.2691	0.4180	0.1065	-0.5170	-0.5101	0.2936	-0.7194	0.5899	0.5236	0.9020	0.1618
	(0.0513)	(0.0145)	(0.0001)	(0.3411)	(0.0234)	(0.0257)	(0.2225)	(0.0005)	(0.0000)	(0.0000)	(0.0000)	(0.1809)

The numbers show the correlation between the cyclical components of the price deflator for Norwegian imports and current, leads [+] and lags [-] of CPI. Lag equal to zero indicates contemporaneous correlation. *p*-values in parentheses.

Table 6.6: Correlation coefficients between GDP per capita and the price deflator for Norwegian imports (1830-2017)

Lag	1830-1913				1919-1939				1946-2017			
	FOD	HP (λ=100)	HP (λ=2500)	CF	FOD	HP (λ=100)	HP (λ=2500)	CF	FOD	HP (λ=100)	HP (λ=2500)	CF
-2	0.1191	0.0398	0.0577	-0.0359	0.2430	0.0815	0.1932	-0.0078	-0.1370	-0.3176	-0.3249	-0.1062
	(0.2895)	(0.7223)	(0.6066)	(0.7490)	(0.3313)	(0.7400)	(0.4280)	(0.9747)	(0.2615)	(0.0074)	(0.0029)	(0.3816)
-1	0.1253	0.2961	0.2427	0.1033	-0.3522	-0.2891	0.1732	-0.4358	-0.0010	-0.1270	-0.3054	0.0858
	(0.2620)	(0.0066)	(0.0271)	(0.3526)	(0.1391)	(0.2164)	(0.4652)	(0.0548)	(0.9936)	(0.2911)	(0.0050)	(0.4767)
0	0.2452	0.4084	0.3379	0.2265	0.2705	0.1859	0.5201	0.1966	0.0972	0.0700	-0.2701	0.0884
	(0.0255)	(0.0001)	(0.0017)	(0.0383)	(0.2487)	(0.4197)	(0.0157)	(0.3930)	(0.4200)	(0.5587)	(0.0130)	(0.4605)
1	0.0627	0.2838	0.2610	0.0299	0.2691	0.2986	0.5481	0.3231	-0.0034	0.1336	-0.2258	-0.2478
	(0.5757)	(0.0093)	(0.0172)	(0.7883)	(0.2653)	(0.2010)	(0.0123)	(0.1646)	(0.9778)	(0.2666)	(0.0401)	(0.0372)
2	0.0643	0.1164	0.1322	-0.0415	0.0950	-0.0369	0.2523	0.0640	-0.0045	0.2336	-0.1629	-0.2073
	(0.5685)	(0.2977)	(0.2364)	(0.7114)	(0.7076)	(0.8807)	(0.2974)	(0.7947)	(0.9708)	(0.0516)	(0.1437)	(0.0851)

The numbers show the correlation between the cyclical components of GDP per capita and current, leads [+] and lags [-] of the price deflator for Norwegian imports. Lag equal to zero indicates contemporaneous correlation. *p*-values in parentheses.

6.4.3 Exchange rates

As seen from the monetary policy model in section 3, changes in the exchange rate can change demand through exports or change supply through imports. To determine if the exchange rate has had an influence on inflation, its correlation against CPI is computed in table 7. As expected, the contractionary monetary policy to bring the currency back to its gold par value during the interwar period likely explains the strong negative correlations. However, from 1979 to 2017 all the contemporaneous correlations are positive, while the price-led [+] correlations are weak negative. Thus, the results are highly ambiguous and the exchange rate does not seem to have had a consistent or significant impact in this period.

Table 6.7: Correlation coefficients between the EER/REER and CPI (1919-1939/1979-2017)

Lag	1830-1913 (Fixed rate)				1919-1939 (EER)				1979-2017 (REER)			
	FOD	HP (λ=100)	HP (λ=2500)	CF	FOD	HP (λ=100)	HP (λ=2500)	CF	FOD	HP (λ=100)	HP (λ=2500)	CF
-2	-	-	-	-	0.3679	0.3495	-0.0559	0.5942	0.2230	0.2694	-0.1335	0.0807
					(0.1330)	(0.1424)	(0.8201)	(0.0073)	(0.1979)	(0.1121)	(0.4375)	(0.6398)
-1	-	-	-	-	0.1292	0.2045	-0.2342	0.4066	0.1424	0.3449	-0.0371	0.1571
					(0.5979)	(0.3871)	(0.3202)	(0.0753)	(0.4004)	(0.0340)	(0.8251)	(0.3463)
0	-	-	-	-	-0.3828	-0.2385	-0.4728	-0.4537	0.2165	0.2961	0.0352	0.2826
					(0.0957)	(0.2977)	(0.0304)	(0.0388)	(0.1916)	(0.0672)	(0.8317)	(0.0813)
1	-	-	-	-	-0.2631	-0.1743	-0.4764	-0.3190	-0.0078	0.0105	-0.0135	-0.0532
					(0.2765)	(0.4623)	(0.0337)	(0.1705)	(0.9636)	(0.9502)	(0.9361)	(0.7513)
2	-	-	-	-	0.1267	-0.2214	-0.4845	0.3097	-0.1676	-0.1974	-0.0482	-0.2626
					(0.6165)	(0.3624)	(0.0355)	(0.1970)	(0.3360)	(0.2485)	(0.7799)	(0.1218)

The numbers show the correlation between the cyclical components of the effective/real effective exchange rate and current, leads [+] and lags [-] of CPI. Lag equal to zero indicates contemporaneous correlation. *p*-values in parentheses. An increase in both exchange rate indices indicates appreciation.

6.4.4 Productivity

Productivity is regarded as the single largest contributor among the supply side factors (Grytten and Hodne, 2002, p.17-18). Earlier analyses have suggested that shifts in productivity could represent a supply side shock that increases output, but lowers inflation. In order to determine the strength and direction of the relationship between productivity and inflation, the correlation coefficients between multifactor productivity and CLI/CPI is computed in table 8.

Increased multifactor productivity implies that higher output has been achieved by a more efficient use of resources. Typical explanation are better technology, human capital and organizational improvements, but also more inclusive economic and political institutions (Acemoglu and Robinson, 2012). Contemporaneous and price-led [+] correlations are most relevant, as the productivity change needs to take place first in order to study its effect.

Table 8 reports that almost every contemporaneous and price-led correlation across all sub-periods since 1900 are negative. The evidence strongly indicates that changes in productivity has historically tended to move in opposite directions of inflation. Thus, it might indicate that increases in productivity generally contributes to lower inflation. This is the most consistent and decisive result of this thesis, suggesting that productivity can offer important information to understand the different developments in short-term output and price cycles.

Table 6.8: Correlation coefficients between MFP and CLI-CPI (1900-2017)

Lag	1900-1913				1919-1939				1946-2017			
	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF
-2	0.4307	0.6225	0.6288	0.5804	0.5316	0.3868	-0.0499	0.7008	0.1401	0.1802	0.3434	0.2906
	(0.1861)	(0.0306)	(0.0285)	(0.0478)	(0.0232)	(0.1018)	(0.8392)	(0.0008)	(0.2508)	(0.0016)	(0.0036)	(0.0147)
-1	-0.0662	0.1184	-0.1043	0.1284	0.1178	0.1608	-0.3512	0.3983	0.0356	-0.0739	0.1917	-0.0578
	(0.8381)	(0.7000)	(0.7345)	(0.6759)	(0.6309)	(0.4984)	(0.1289)	(0.0820)	(0.5433)	(0.5403)	(0.1093)	(0.6319)
0	-0.1523	-0.2547	-0.3236	-0.2078	-0.1513	-0.1701	-0.6034	-0.1572	-0.1539	-0.3554	0.0346	-0.4685
	(0.6193)	(0.3796)	(0.2591)	(0.4760)	(0.5244)	(0.4610)	(0.0038)	(0.4961)	(0.2002)	(0.0022)	(0.7731)	(0.0000)
1	-0.3896	-0.4178	-0.4366	-0.5510	-0.5050	-0.5788	-0.7975	-0.5732	-0.0658	-0.3875	-0.0583	-0.1691
	(0.2106)	(0.1554)	(0.1358)	(0.0510)	(0.0274)	(0.0075)	(0.0000)	(0.0082)	(0.5885)	(0.0008)	(0.6289)	(0.1587)
2	-0.0419	-0.0958	-0.1140	-0.1210	-0.2492	-0.1453	-0.4898	-0.2021	-0.0647	-0.3211	-0.1235	0.1145
	(0.9026)	(0.7670)	(0.7242)	(0.7081)	(0.3187)	(0.5528)	(0.0333)	(0.4068)	(0.5976)	(0.0067)	(0.3083)	(0.3453)

The numbers show the correlation between the cyclical components of MFP and current, leads [+] and lags [-] of CPI. Lag equal to zero indicates contemporaneous correlation. *p*-values in parentheses.

6.4.5 Net migration

The general hypothesis is that significant shifts in net migration could represent a labour supply shock that can move output and inflation in opposite directions. For example, a large increase in the labour force would increase output, but also lead to lower wages, lower production costs, and thus lower prices in the short-term. Throughout the first sub-period and early parts of the second sub-period, large waves of emigration could represent a negative supply shock. Significant return migration towards the end of the second period could also represent a positive supply shock. Lastly, in third sub-period, several waves of almost exponentially increasing immigration could represent a positive labour supply shock.

In order to determine the strength and direction of the relationship between net migration and inflation, the correlation coefficients between the cycle components is computed in table 9. In this analysis, price-led [+] and contemporaneous correlations are most relevant as the migration needs to happen first in order to study its effects. Negative net migration implies emigration, whereas positive net migration implies immigration.

Table 9 reports a clear majority of negative contemporaneous and price-led correlations for the first sub-period. This indicates that inflation increased as more people emigrated and net migration fell. However, these correlation results are a bit weak. The productivity increases which partly led to the emigration, given the results from table 8, could likely distort the results by simultaneously decreasing inflation.

In the second sub-period, all the contemporaneous correlations are positive, but over half the price-led correlations are negative. Given the numerous other shocks in this period it makes sense that net migration was not necessarily a driving factor of the general price level.

In the last sub-period the correlations are almost exclusively negative. The contemporaneous correlations are all negative and close to statistically significant. Half of the price-led cycle correlations are also negative. Notably, all the 2500-lambda HP correlations are negative. Since the growth in immigration has been so incredibly strong, this filter will more correctly allocate more of this growth to the cyclical component than the other filters. Thus, the evidence clearly suggest that net migration and inflation has tended to move in opposite directions. In addition, net migration might contribute to explain the negative co-movement of output and inflation in this period.

Table 6.9: Correlation coefficients between net migration and CLI-CPI for Norway (1836-2017)

Lag	1836-1913				1919-1939				1946-2017			
	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF	FOD	HP (ʎ=100)	HP (ʎ=2500)	CF
-2	0.0567	0.1361	0.0660	0.0362	-0.3509	-0.5772	-0.5519	-0.4515	-0.0407	-0.0726	-0.3051	-0.1797
	(0.6291)	(0.2409)	(0.5711)	(0.7561)	(0.1408)	(0.0097)	(0.0143)	(0.0523)	(0.7400)	(0.5503)	(0.0102)	(0.1366)
-1	0.0875	0.0971	0.0595	-0.0606	0.3031	0.1600	0.0407	0.5248	-0.0408	-0.1543	-0.3188	-0.2025
	(0.4521)	(0.4007)	(0.6072)	(0.6007)	(0.2071)	(0.5004)	(0.8649)	(0.0175)	(0.7374)	(0.1989)	(0.0067)	(0.0903)
0	-0.0835	-0.0153	0.0041	-0.1940	0.2074	0.1489	0.1836	0.4824	-0.0949	-0.1802	-0.3088	-0.1867
	(0.4704)	(0.8939)	(0.9718)	(0.0887)	(0.3804)	(0.5196)	(0.4257)	(0.0268)	(0.4314)	(0.1298)	(0.0083)	(0.1164)
1	0.0418	-0.0235	-0.0016	0.0353	-0.1733	-0.1266	0.1853	0.0794	0.0506	-0.0155	-0.2481	0.1501
	(0.7201)	(0.8391)	(0.9888)	(0.7606)	(0.4780)	(0.5948)	(0.4342)	(0.7394)	(0.6777)	(0.8980)	(0.0369)	(0.2116)
2	-0.0141	-0.0624	-0.0334	0.0755	-0.2610	-0.3798	0.1233	-0.3878	0.0390	0.0602	-0.1867	0.1696
	(0.9044)	(0.5920)	(0.7743)	(0.5169)	(0.2804)	(0.1088)	(0.6151)	(0.1009)	(0.7505)	(0.6205)	(0.1217)	(0.1603)

The numbers show the correlation between the cyclical components of net migration and current, leads [+] and lags [-] of CPI. Lag equal to zero indicates contemporaneous correlation. *p*-values in parentheses.

7. Conclusions

This thesis provides empirical evidence of the short-term co-movement between historical output and prices in Norway from 1830 to 2017. The analysis looks at the correlations between contemporanous, leads and lags in cycle data of real GDP per capita and CLI-CPI time series. The cyclical components are derived from deviations from estimated polynomial trends by the Hodrick-Prescott and Christiano-Fitzgerald filters, in addition to simple annual fluctuations.

The results for the sub-periods prior to WWII are ambigous and non-conclusive as the contemporanous correlations are mixed between positive and negative, or are very close to zero. It is difficult to conlude on a signficant positive or negative relationship between output and prices in these periods. However, the key take-away is that the contemporanous and price-lagged correlations are almost never strong and positive. Contrary theoretical expecations.

After WWII the correlations are strong negative for all the methodologies, indicating a clear negative relationship between output and prices. All the filtered contemporanous correlations and almost all the price-lagged correlations are strong and negative. Even half of the price-led correlations are negative. In opposition to one of the key foundations of inflation targeting, short-term prices and output have tended to move in opposite directions. The correlations does not reveal causality, but may suggest that supply side shocks have been important in the period.

To investigate whether supply side shocks can explain the lack of a significant historical co-movement between output and prices, the same method is applied, looking at cross correlations of cycle data from supply side factors: capital (incl. natural resources), labour and productivity.

The most decisive result from these analyses is that multifactor productivity has clearly been negatively correlated with prices across all the sub-periods since 1900. Suggesting that short-term changes in productivty might have a significant impact on inflation. As increased productivity, and indirectly output, tend to coincide with falling prices, and vice versa.

Changes in the supply of labour is represented by net migration. From 1830-1913 there is a clear majority of negative, but weak correlations against prices. Huge waves of emigration in the period likely represented a negative labour supply shock, increasing prices and wages, but decreasing output. However, the strength of the effect could be distorted by simultaneously increasing productivity which would lower prices. Thus, one could still interpret the weak negative correlations as an indication of labour supply shocks being influential in this period.

During the interwar period, the contemporanous correlations are all positive, while half of the price-led correlations are negative. Thus, it seems labour supply shocks was not a driving factor for inflation in the period. However, the correlations after WWII are almost exclusively negative, and all the filtered contemporanous correlations are strongly negative. Therefore, the evidence may suggest that huge waves of immigration has increased labour supply and indirectly output, while decreasing wages and consequently prices.

Changes in the supply of capital is analysed through import and export prices. The idea was to first determine if export or import prices had an influence on inflation. Then, investigate if the fluctuations in export and import prices were demand-or supply-led. Thus, figuring out if external supply side shocks can explain the lack of co-movement between output and prices.

Import prices has had a strong positive relationship with inflation in all the sub-periods. Thus, it seems clear that import prices has a significant impact on fluctuations in inflation. However, export prices had a strong positive correlation with inflation prior to WWII, but this clearly shifts towards negative correlations afterwards. This can not be explained by changes in the exchange rate, and indicates that the world price of the exported goods have tended to move in the opposite direction of inflation and import prices. This can be very pro-cyclical under an inflation targeting regime, as for example increased export prices have tended to coincide with lower inflation rates. Thus, the central bank would be incentivised to lower the interest rate while increased prices on the exported goods have already generated a positive output gap.

The correlations between output and import prices seems to support this explanation. These are clearly positive prior to WWII, but shifts towards negative correlations afterwards. It seems that while import prices were previously demand-led, after WWII they have been primarly supply-led. This may suggest that supply shocks from imported goods in this period has decreased import prices and consequently inflation. Meanwhile export prices have increased, generating a positive output gap, leading to a negative relationship between output and prices.

Based on the empirical evidence, one may suggest that short-term supply side movements and shocks could contribute to explain the lack of historical co-movement between output and prices. In particular productivity seems to have been very influential in all the sub-periods, while labour supply might also have had some impact. However, supply side shocks seems to be more prominent after WWII. Uniquely, in this period external supply shocks from the foreign sector seems to have played a larger role. Explaining the clearly negative correlations.

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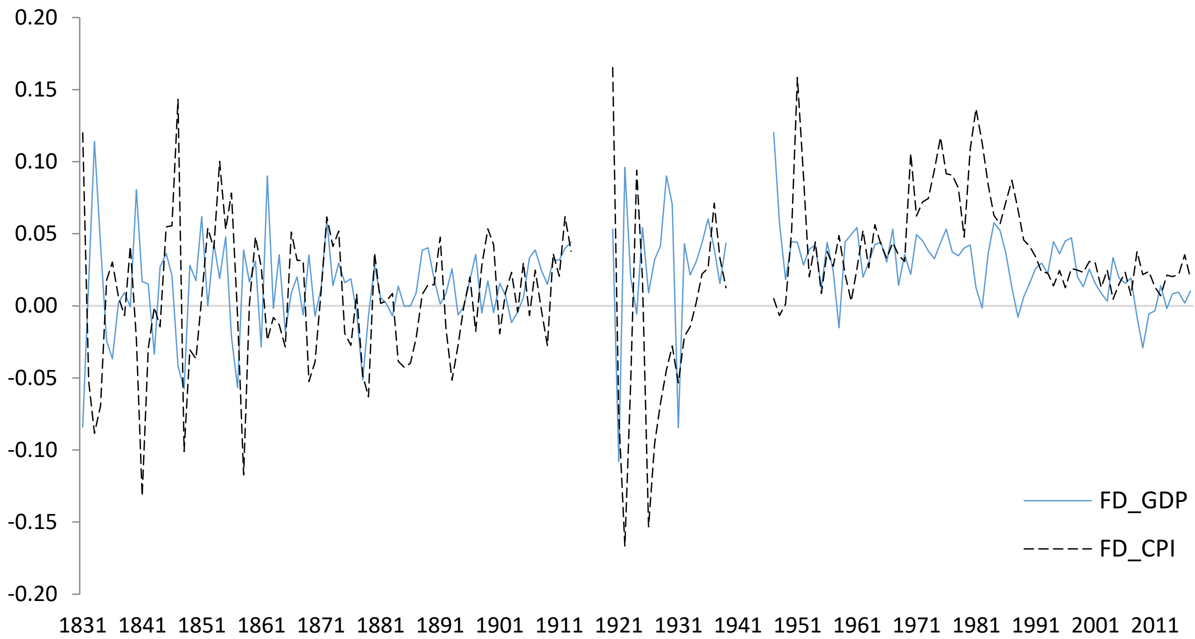
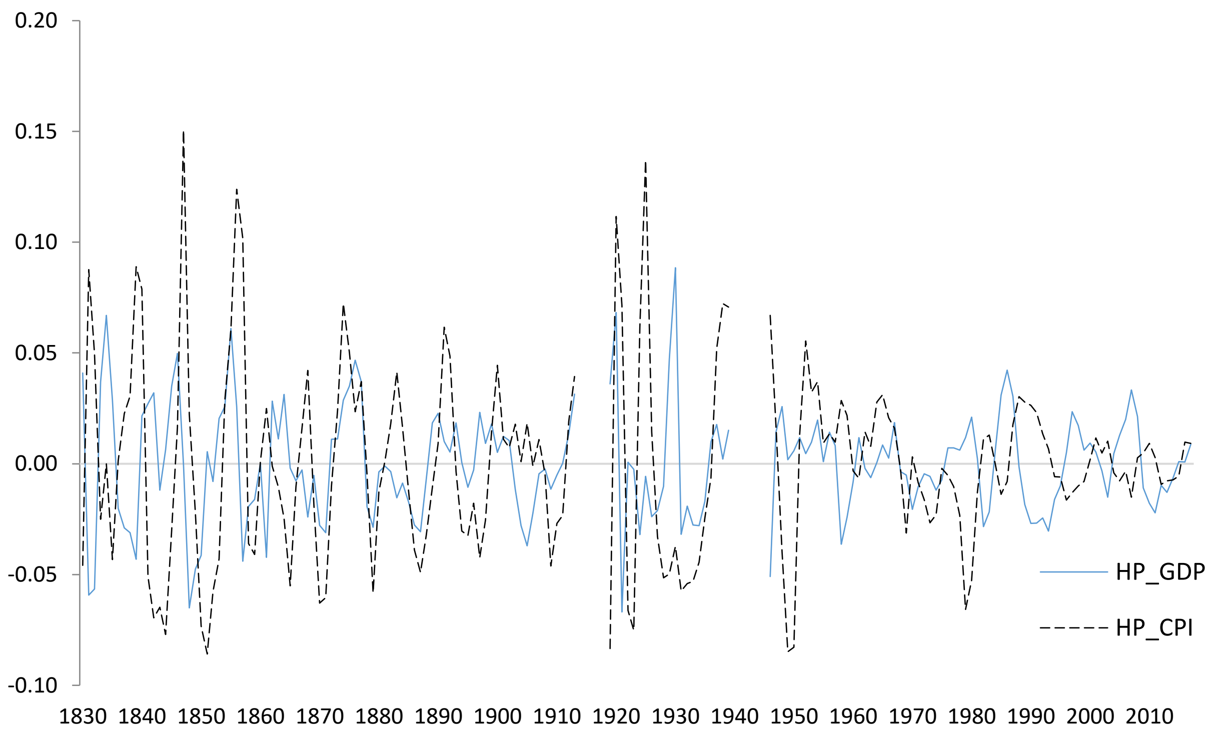
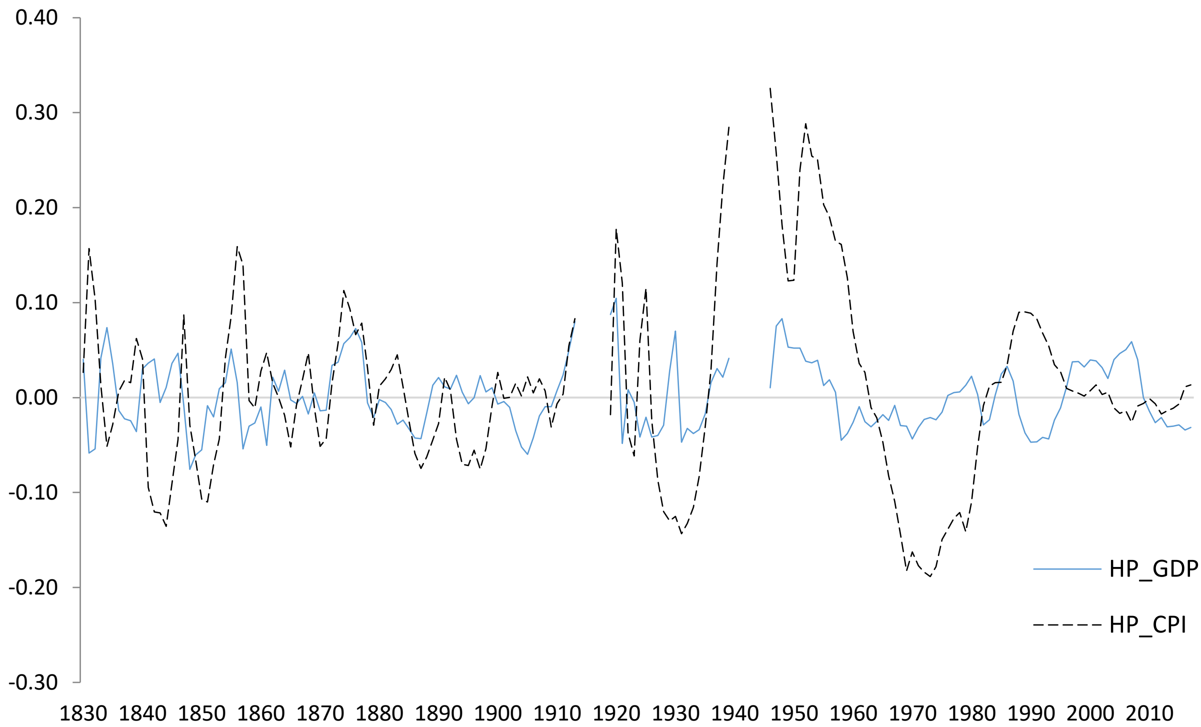
Appendix



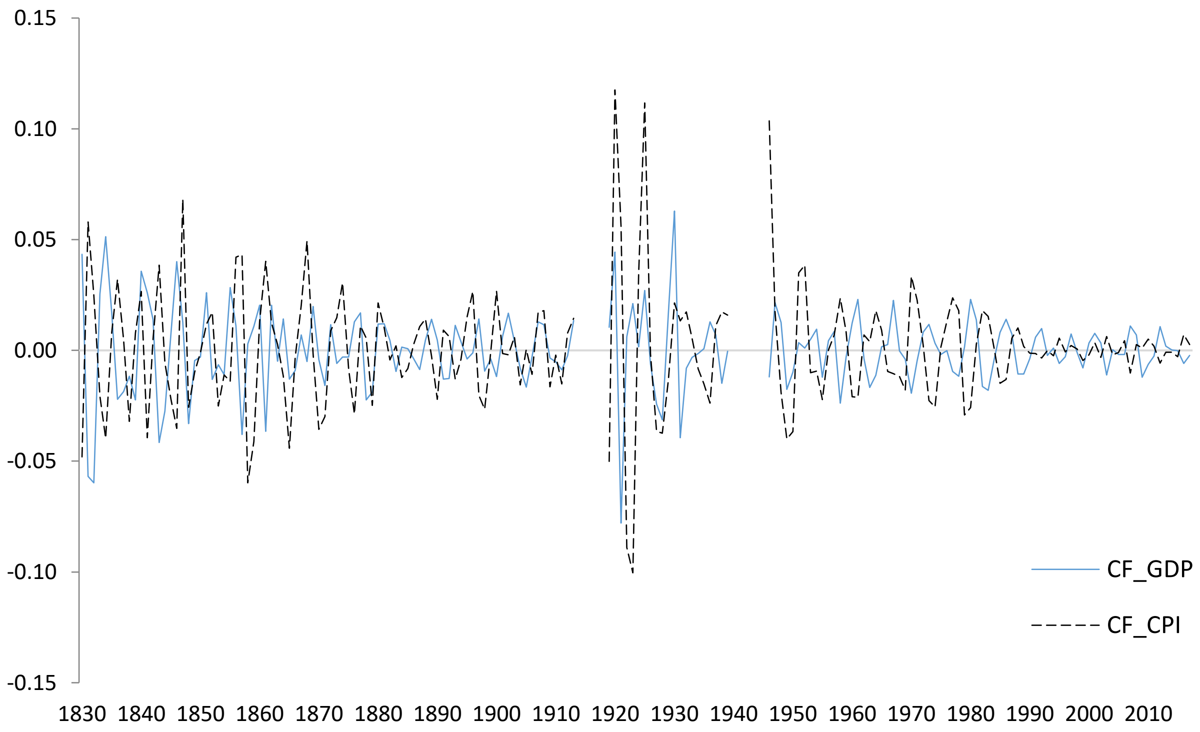
Graph A.1: Annual fluctuations in GDP per capita in fixed prices and CLI/CPI 1830-2017. Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



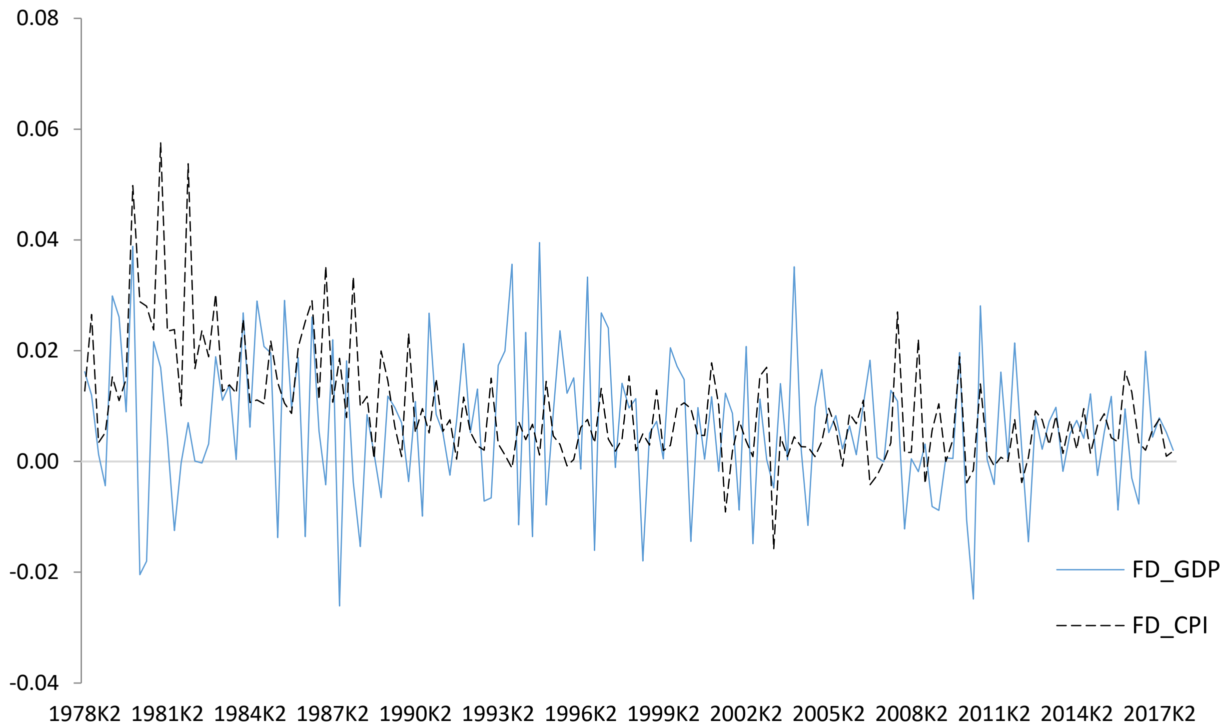
Graph A.2: GDP per capita in fixed prices and CLI/CPI 1830-2017 estimated by the Hodrick-Prescott filter (ʎ=100). Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



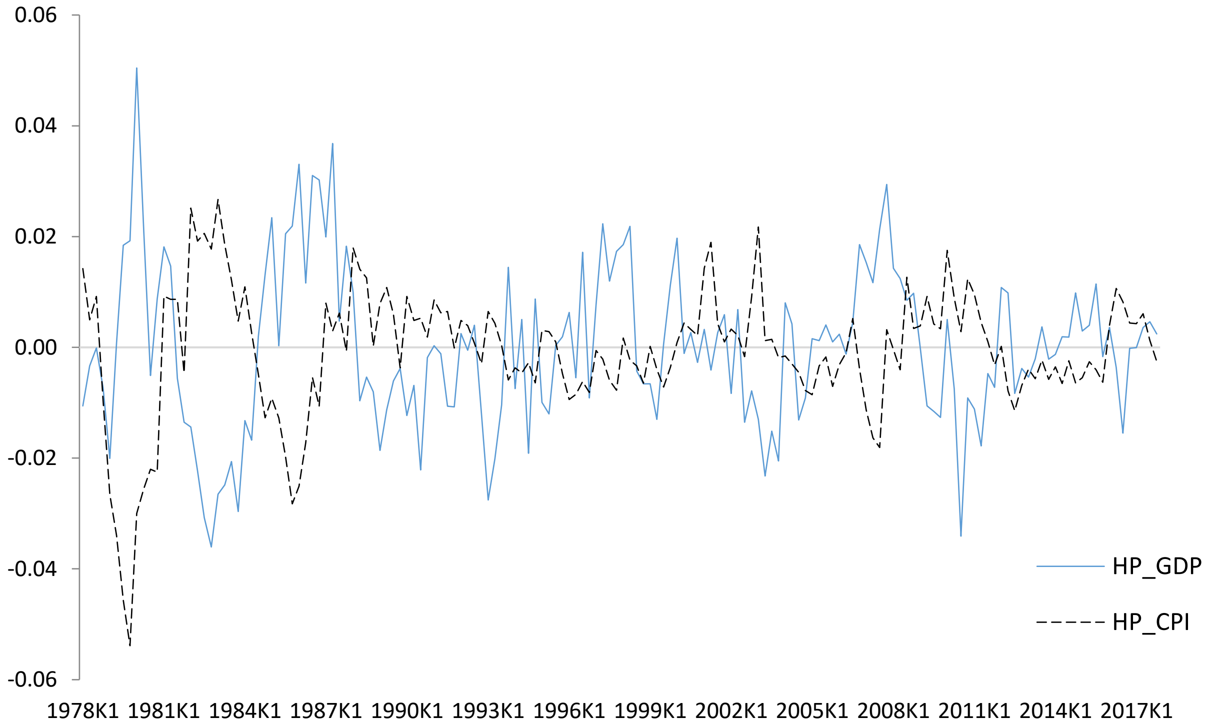
Graph A.3: GDP per capita in fixed prices and CLI/CPI 1830-2017 estimated by the Hodrick-Prescott filter (λ=2500). Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



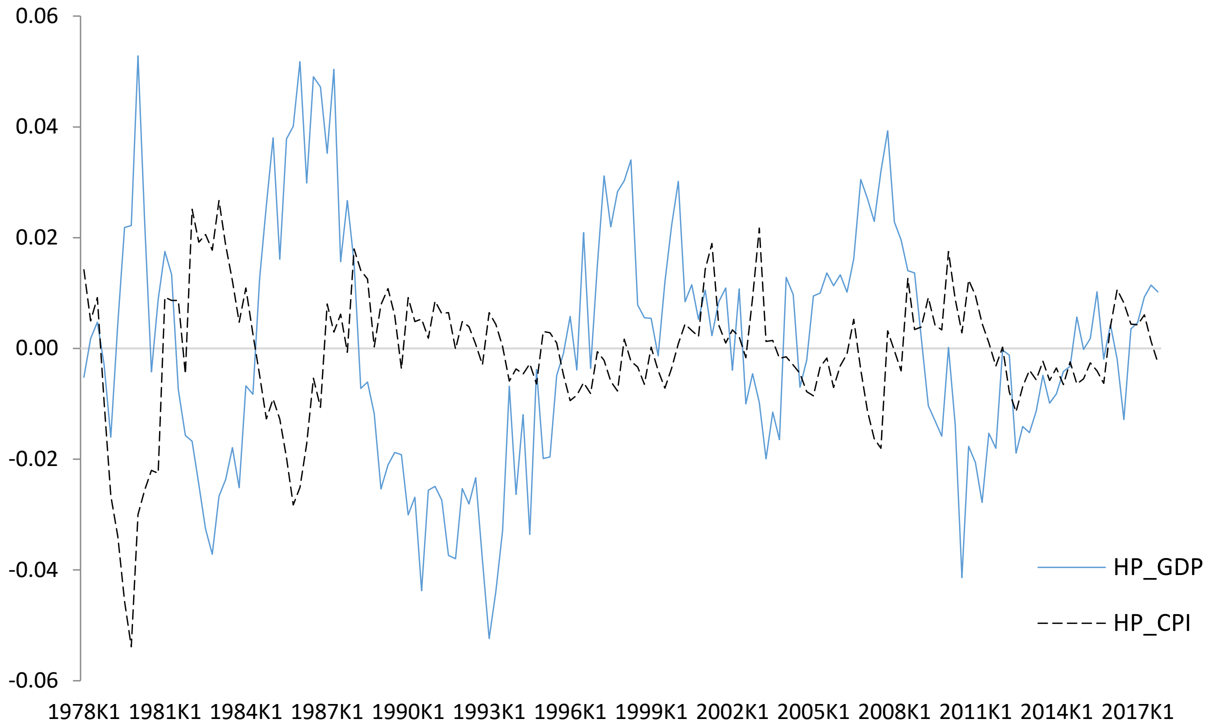
Graph A.4: GDP per capita in fixed prices and CLI/CPI 1830-2017 estimated by the Christiano-Fitzgerald band pass filter allowing periodic components between two and seven years.
Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



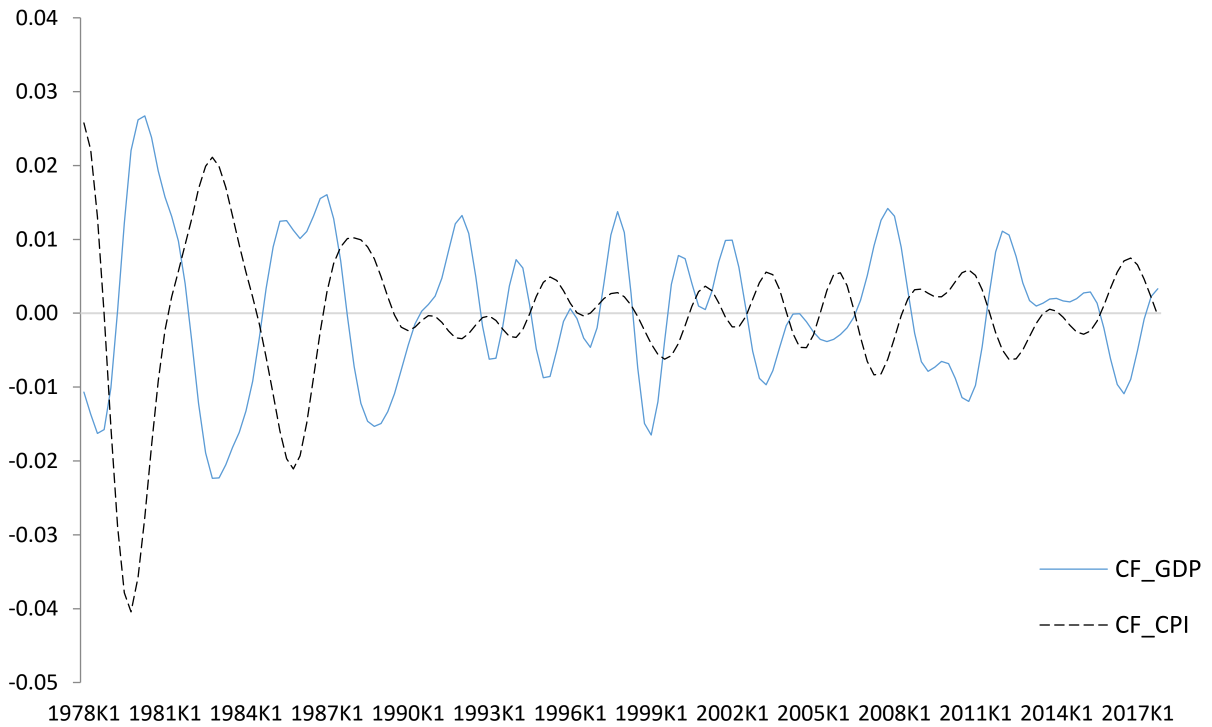
Graph A.5: Annual fluctuations in quarterly GDP in fixed prices and quarterly CPI 1978Q1-2017Q4. Sources: Grytten 2004a, 92-93. Norges Bank 2019. Statistics Norway 2019.



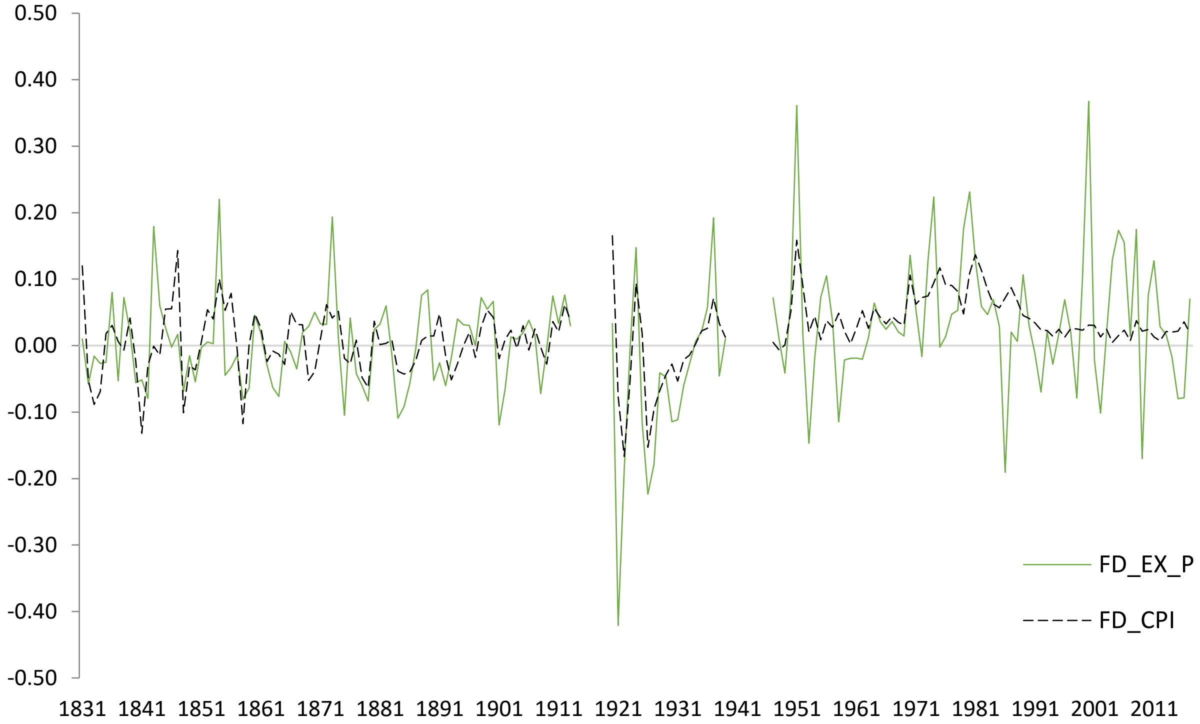
Graph A.6: Quarterly GDP in fixed prices and quarterly CPI 1978Q1-2017Q4 estimated by the Hodrick-Prescott filter (λ=100). Sources: Grytten 2004a, 92-93. Norges Bank 2019. Statistics Norway 2019.



Graph A.7: Quarterly GDP in fixed prices and quarterly CPI 1978Q1-2017Q4 estimated by the Hodrick-Prescott filter (λ=2500). Sources: Grytten 2004a, 92-93. Norges Bank 2019. Statistics Norway 2019.



Graph A.8: GDP per capita in fixed prices and CPI 1978Q1-2017Q4 estimated by the Christiano-Fitzgerald band pass filter allowing periodic components between 8 and 28 quarters.
Sources: Grytten 2004a, 92-93. Norges Bank 2019. Statistics Norway 2019.



Graph A.9: Annual fluctuations in export prices and CLI/CPI 1830-2017.
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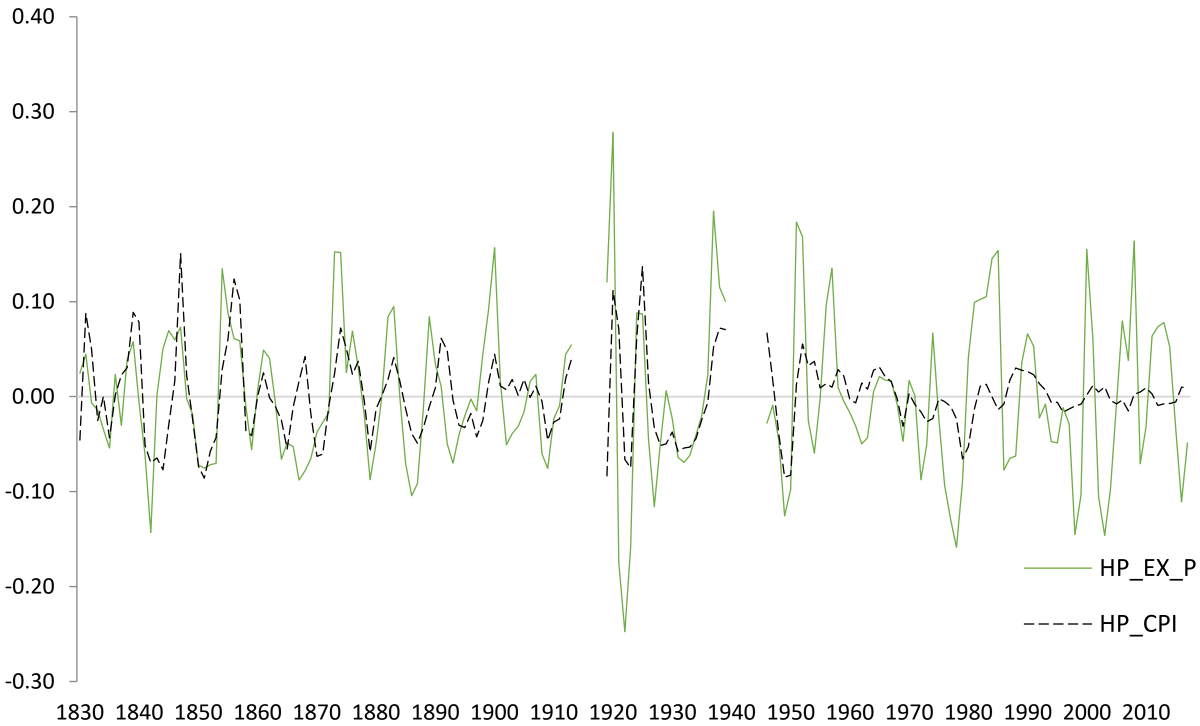

Graph A.10: Export price and CPI cycles 1830-2017 estimated by the Hodrick-Prescott filter (ʎ=100).
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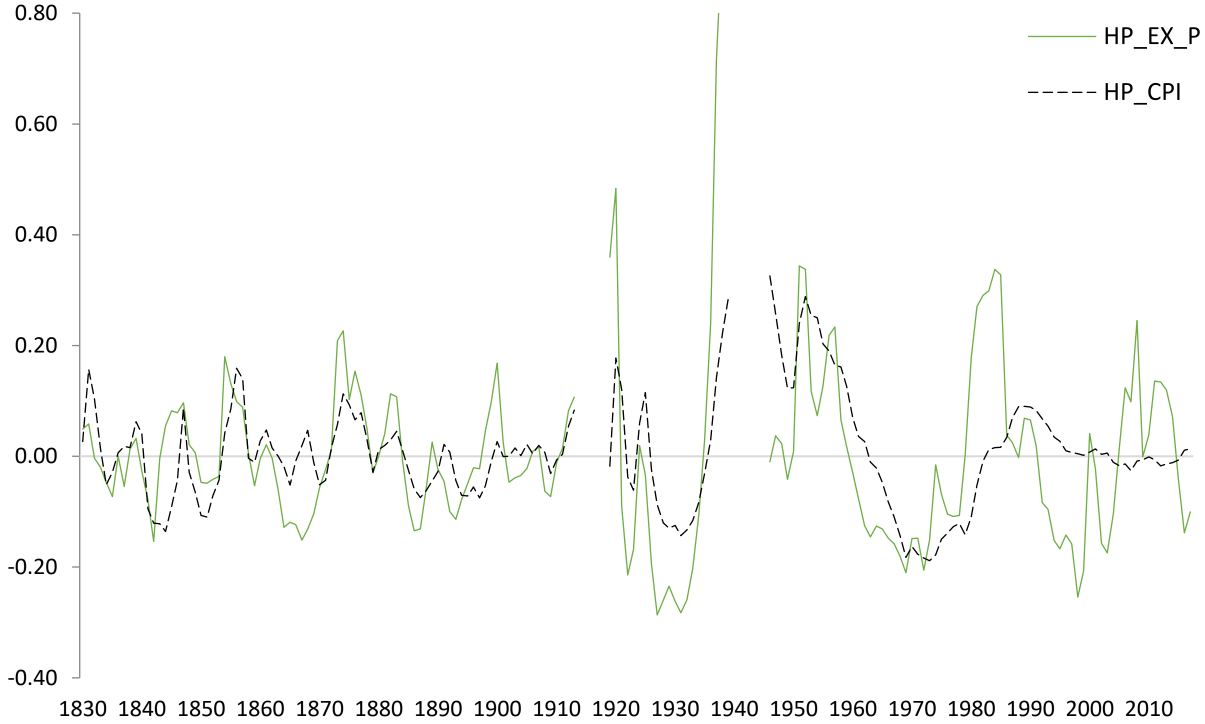

Graph A.11: Export price and CPI cycles 1830-2017 estimated by the Hodrick-Prescott filter (λ=2500).
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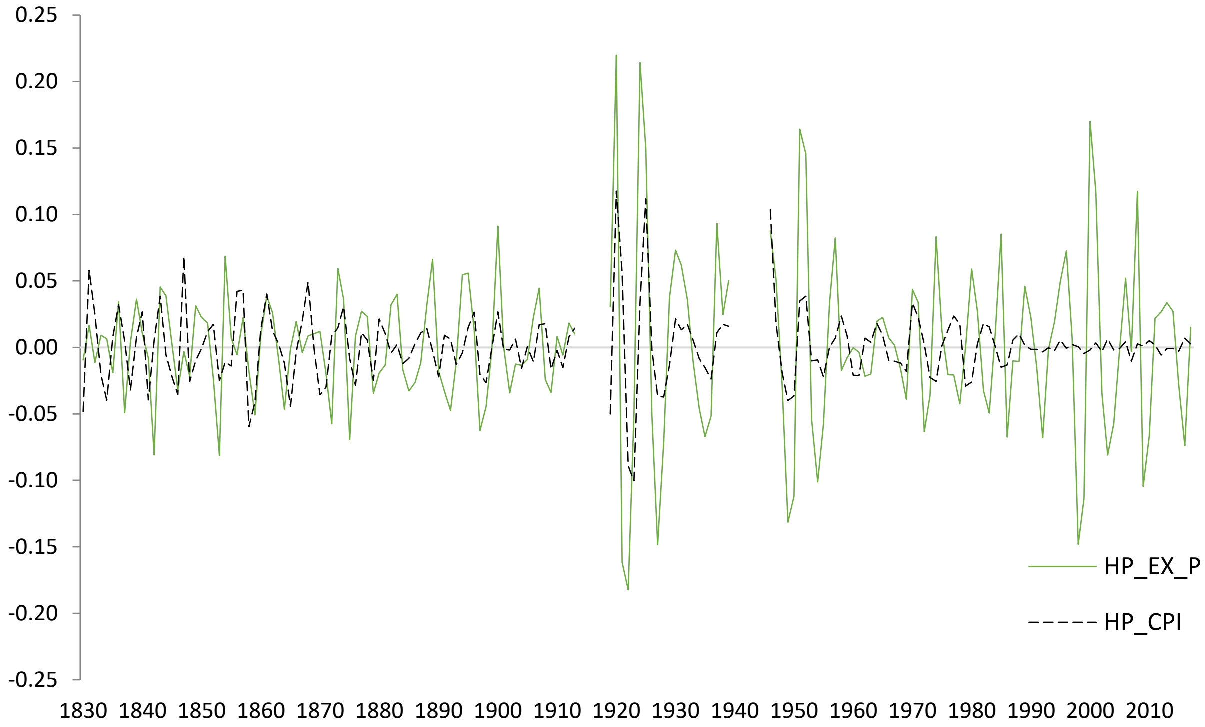

Graph A.12: Export price and CPI cycles 1830-2017 estimated by the Christiano-Fitzgerald band pass filter allowing periodic components between two and seven years.
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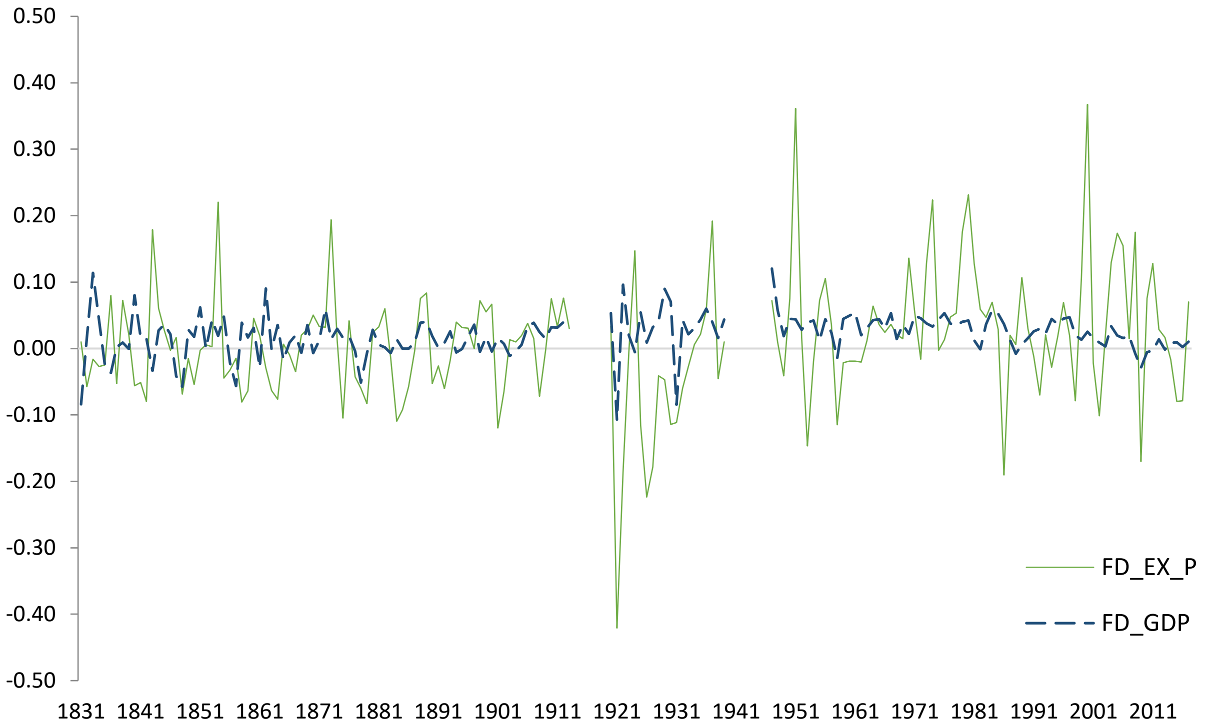
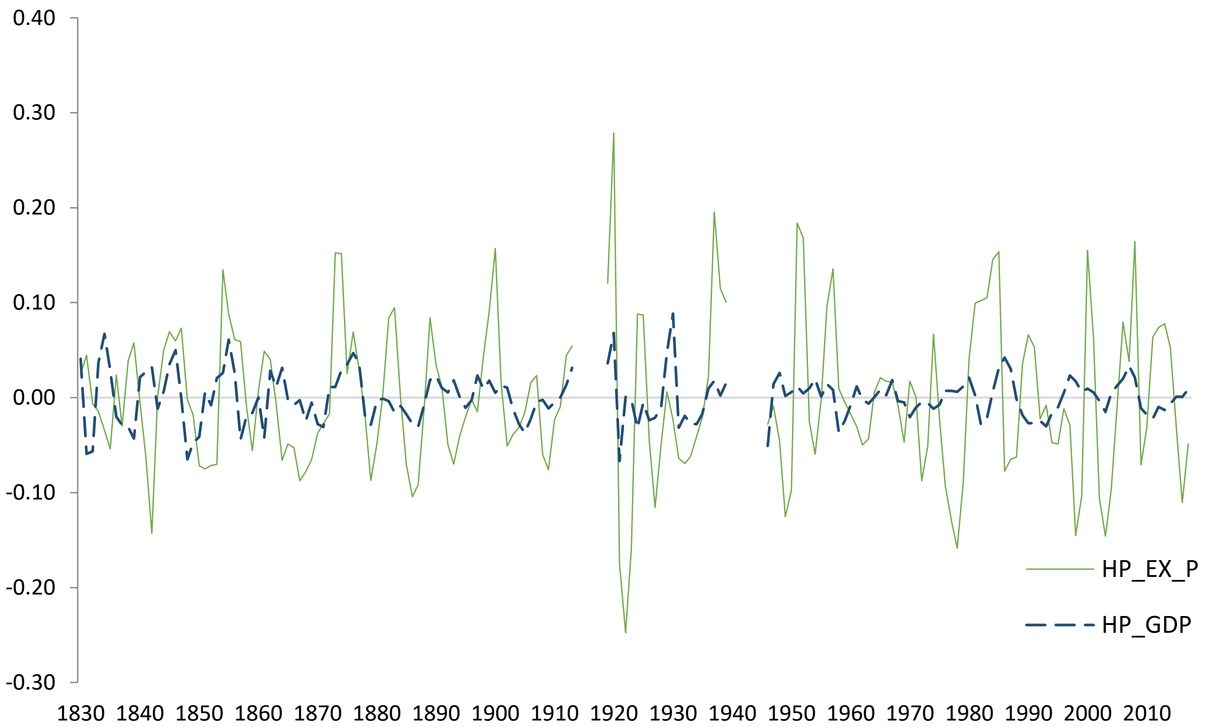
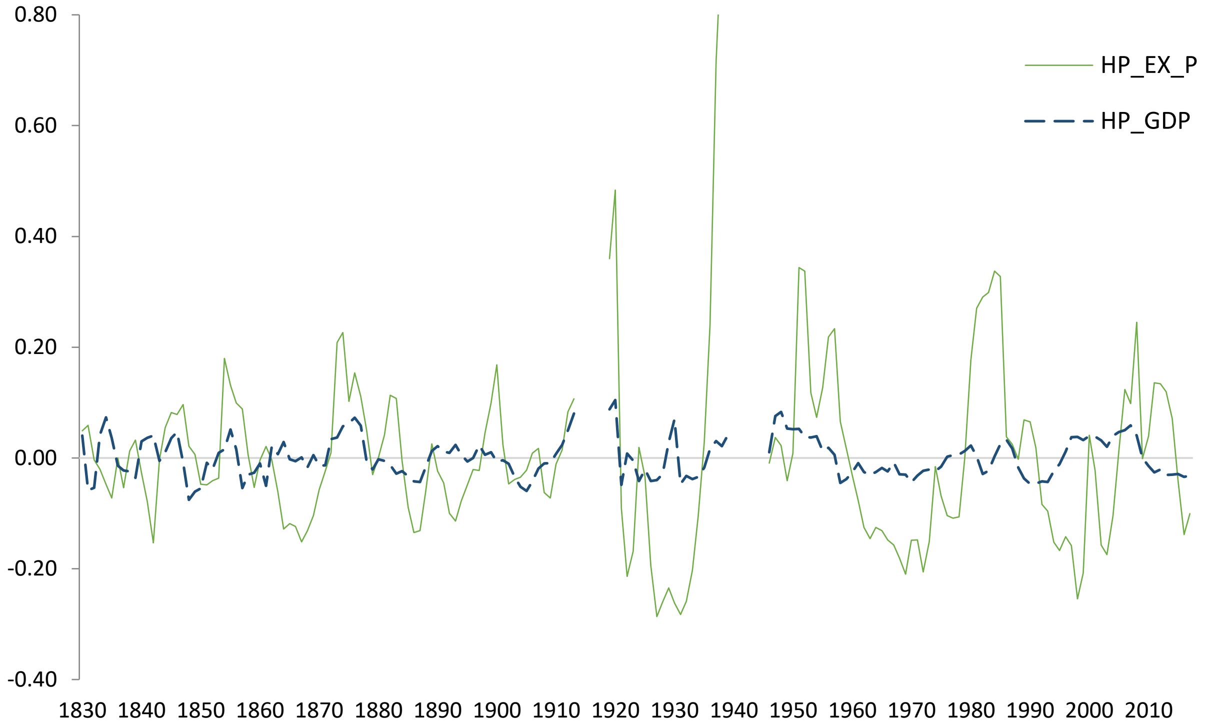


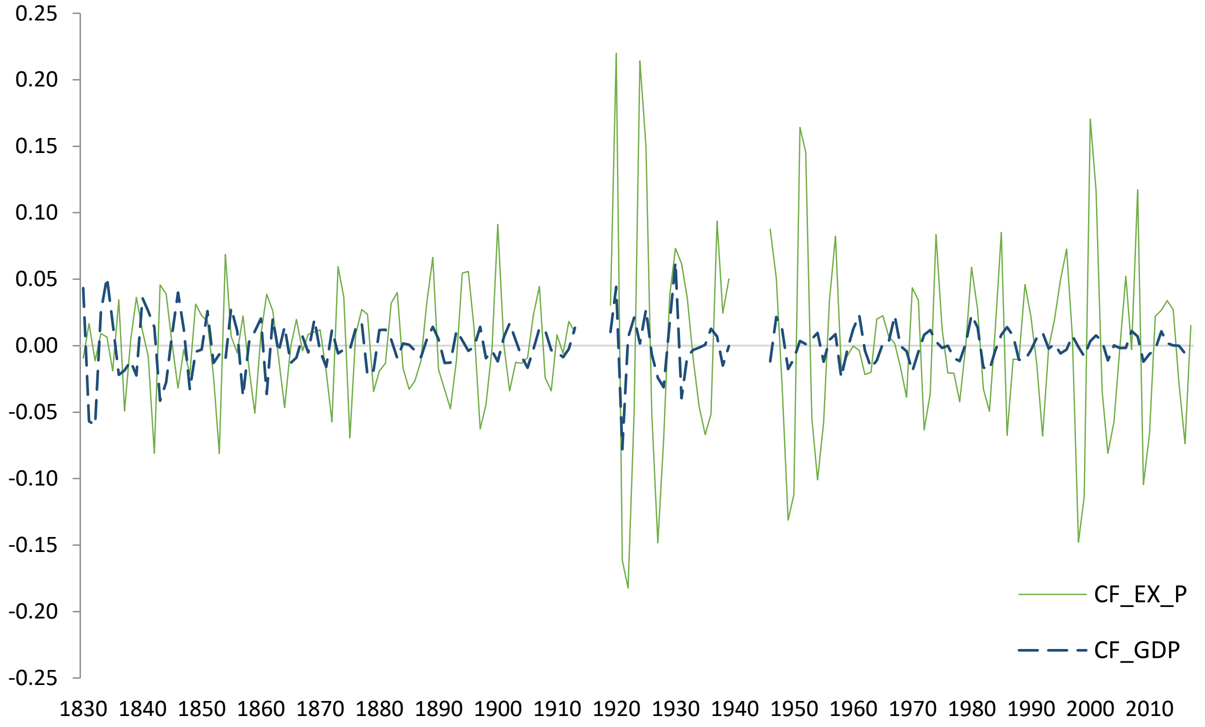
Graph A.13: Annual fluctuations in GDP per capita in fixed prices and export prices 1830-2017. Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



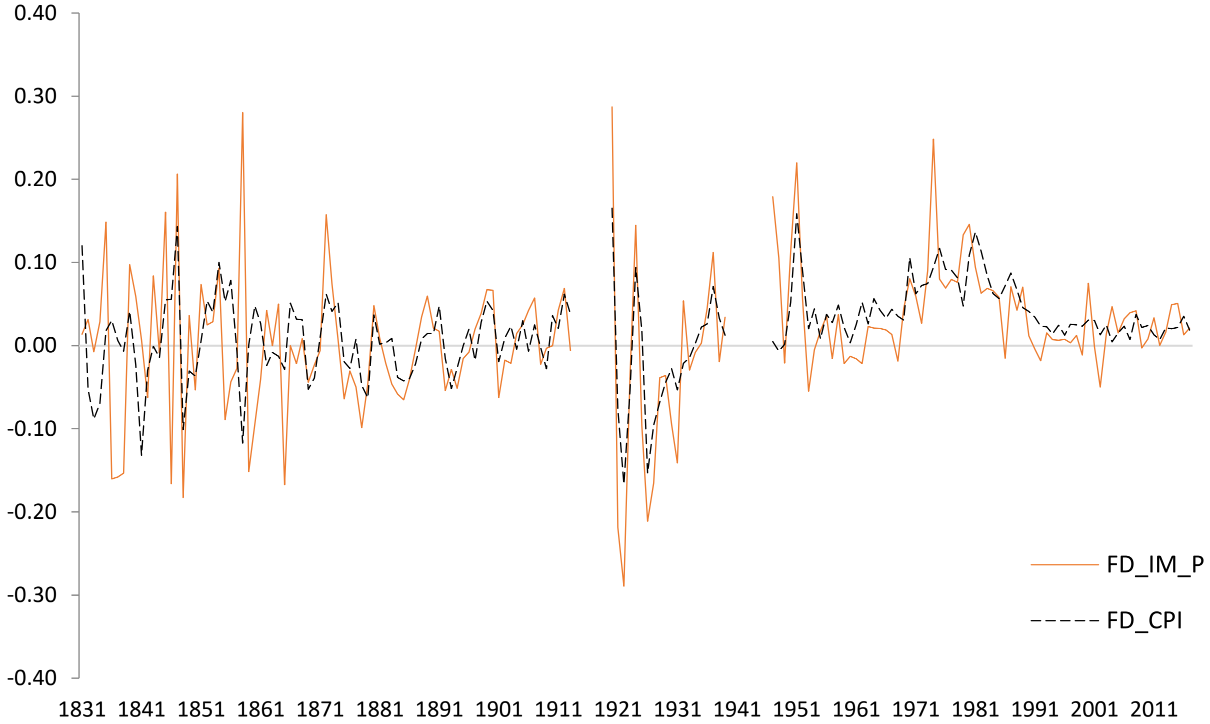
Graph A.14: GDP per capita in fixed prices and export price cycles 1830-2017 estimated by the Hodrick-Prescott filter (λ=100). Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



Graph A.15: GDP per capita in fixed prices and export price cycles 1830-2017 estimated by the Hodrick-Prescott filter (ʎ=2500). Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



Graph A.16: GDP per capita in fixed prices and export price cycles 1830-2017 estimated by the Christiano-Fitzgerald band pass filter allowing periodic components between two and seven years. Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



Graph A.17: Annual fluctuations in import prices and CLI/CPI 1830-2017.
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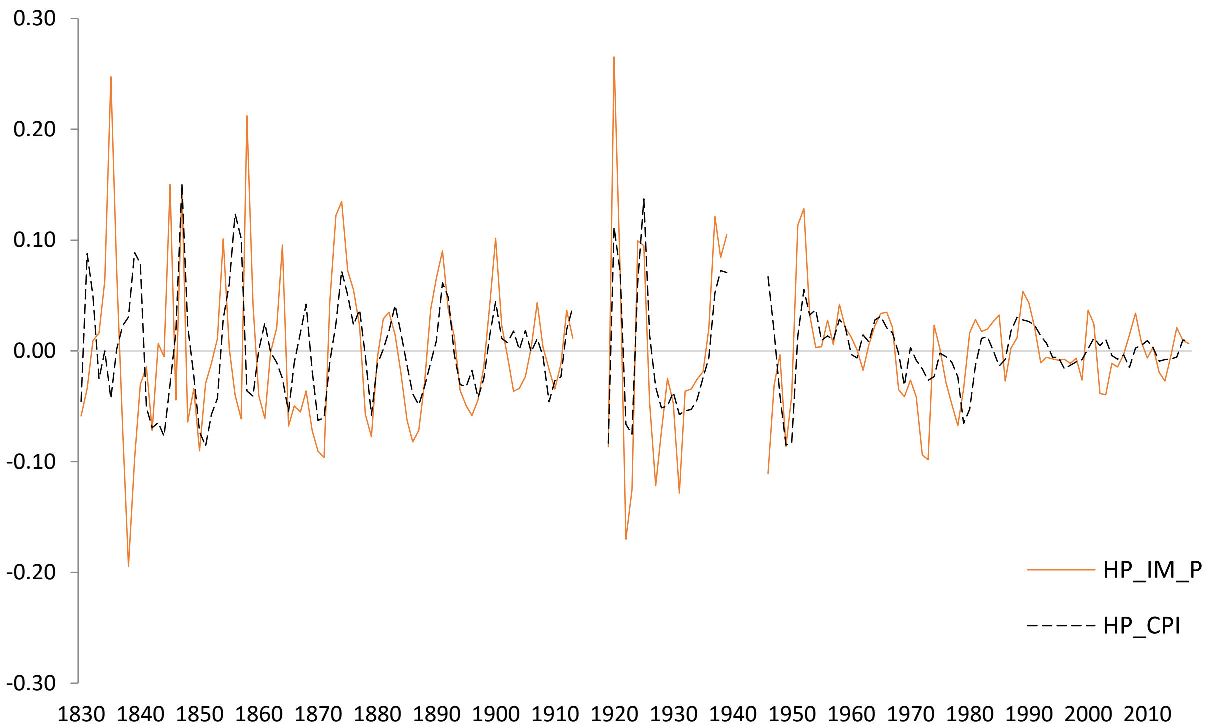

Graph A.18: Import price and CPI cycles 1830-2017 estimated by the Hodrick-Prescott filter (ʎ=100).
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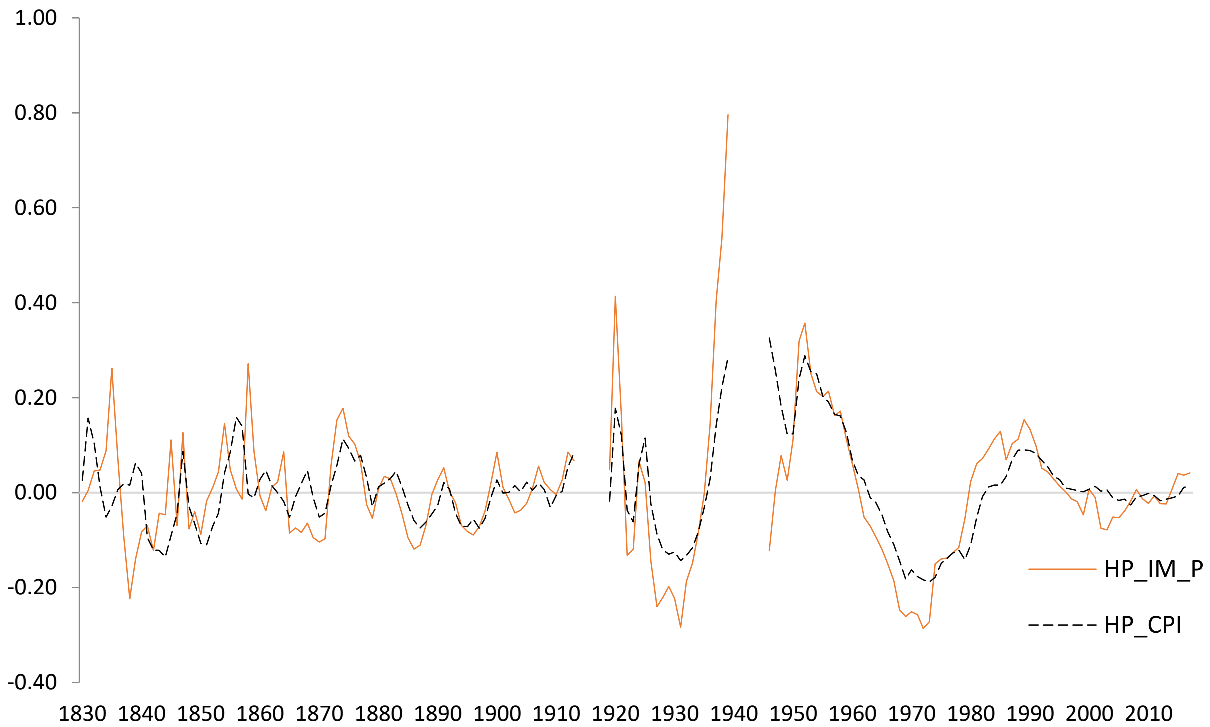

Graph A.19: Import price and CPI cycles 1830-2017 estimated by the Hodrick-Prescott filter (λ=2500).
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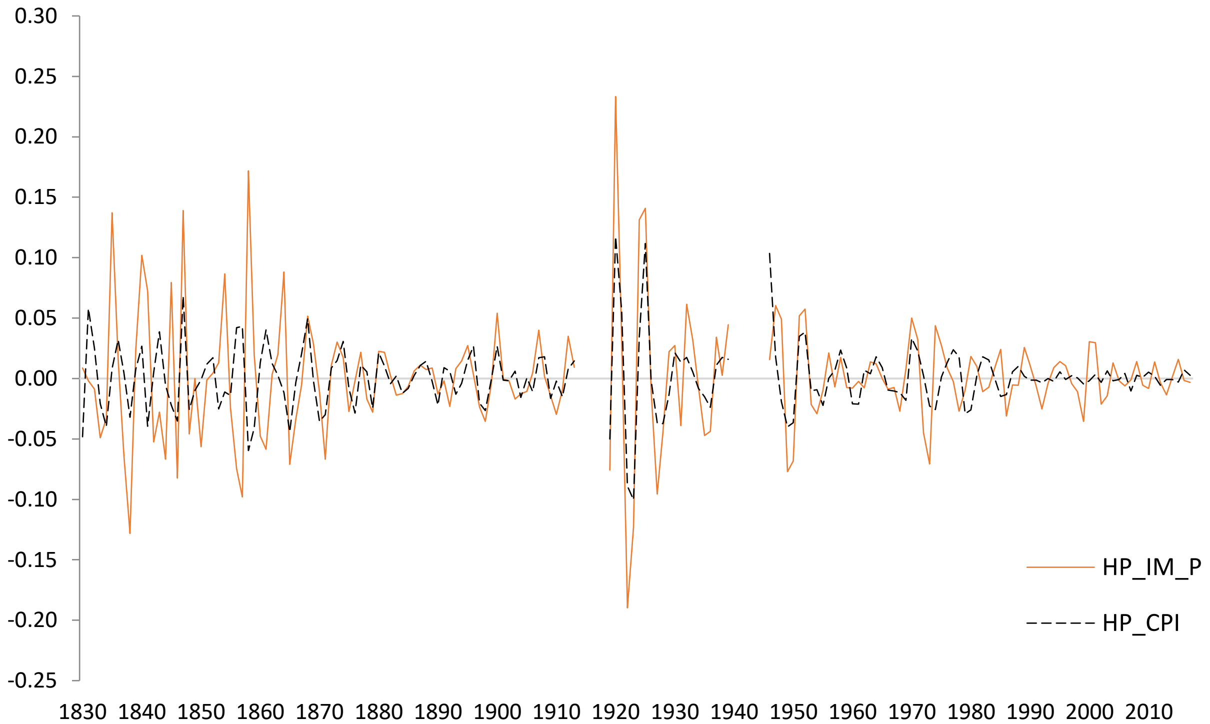
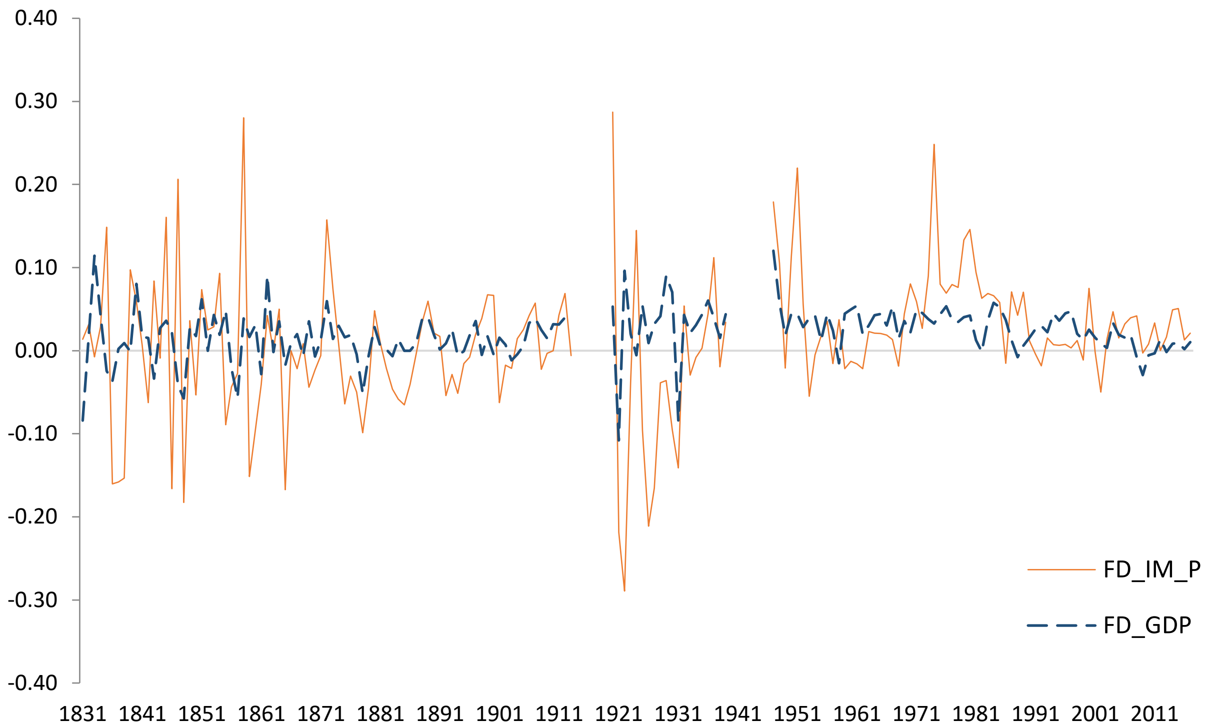
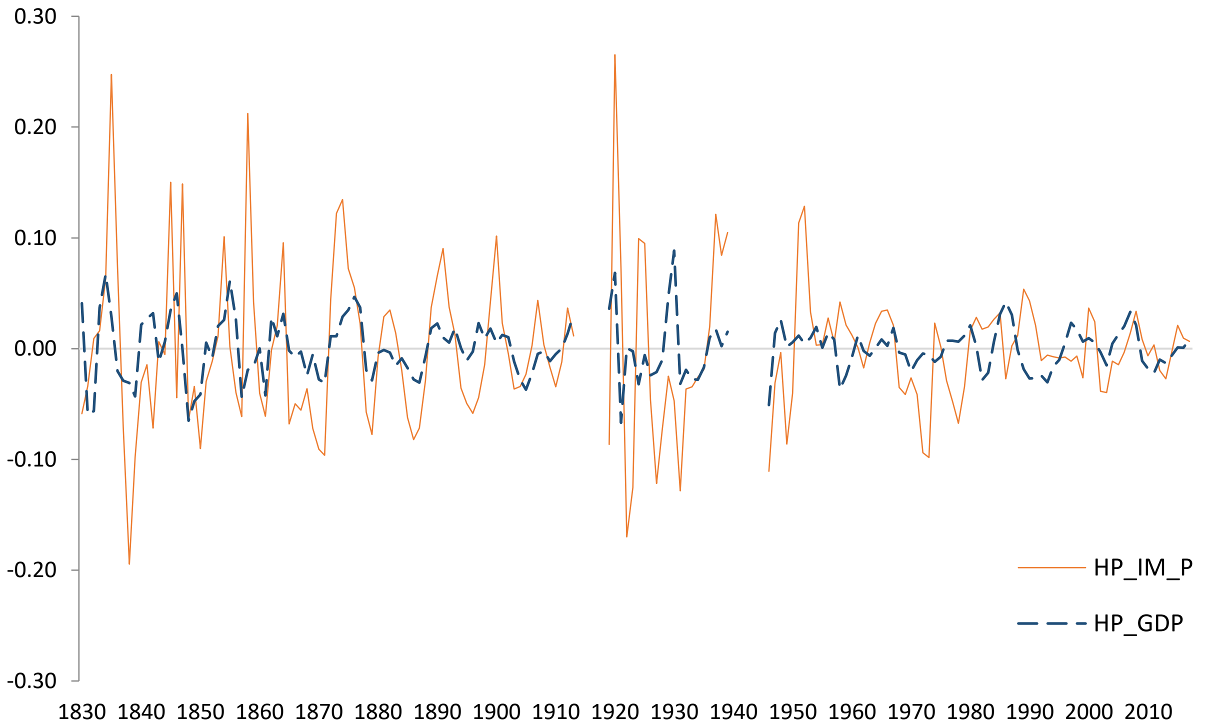


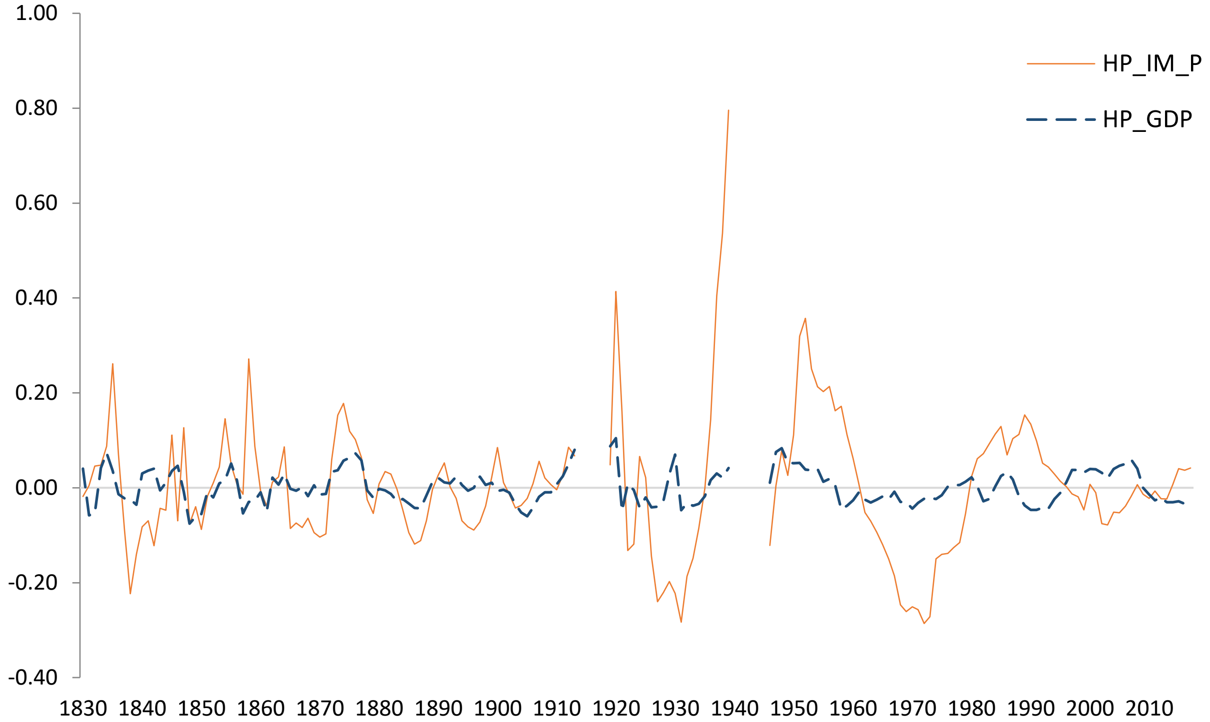
Graph A.20: Import price and CPI cycles 1830-2017 estimated by the Christiano-Fitzgerald band pass filter allowing periodic components between two and seven years.
Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



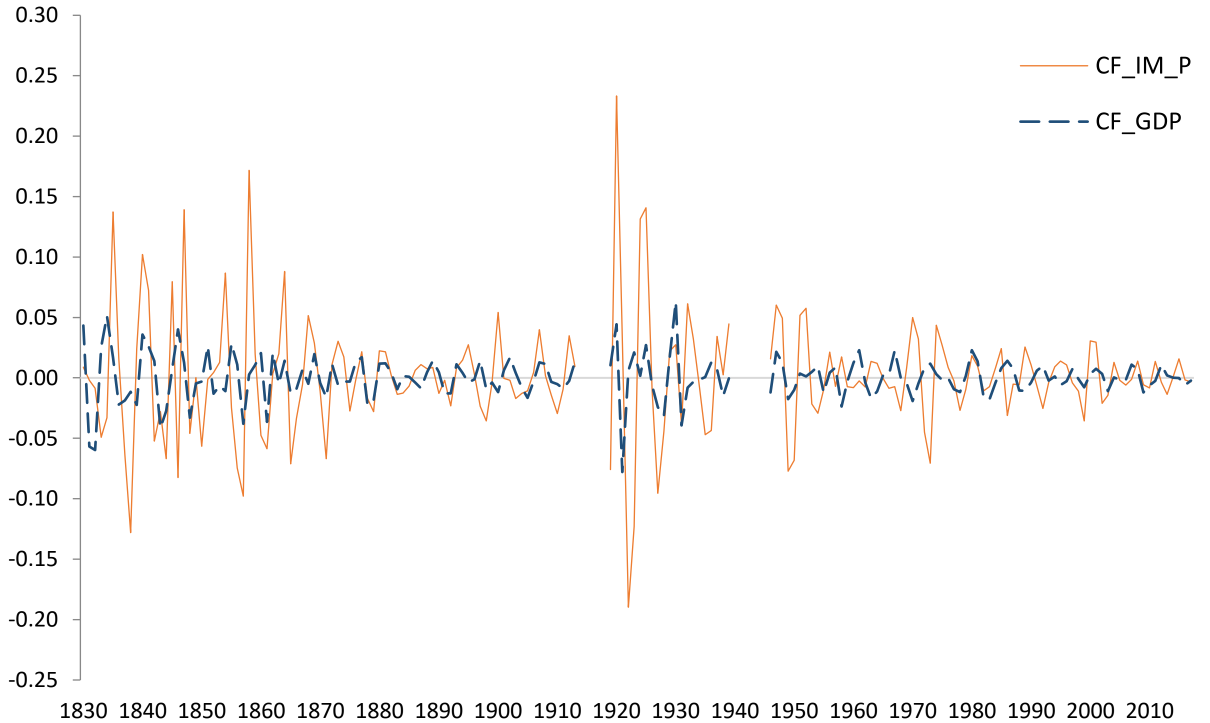
Graph A.21: Annual Fluctuations in GDP per capita in fixed prices and import prices 1830-2017. Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



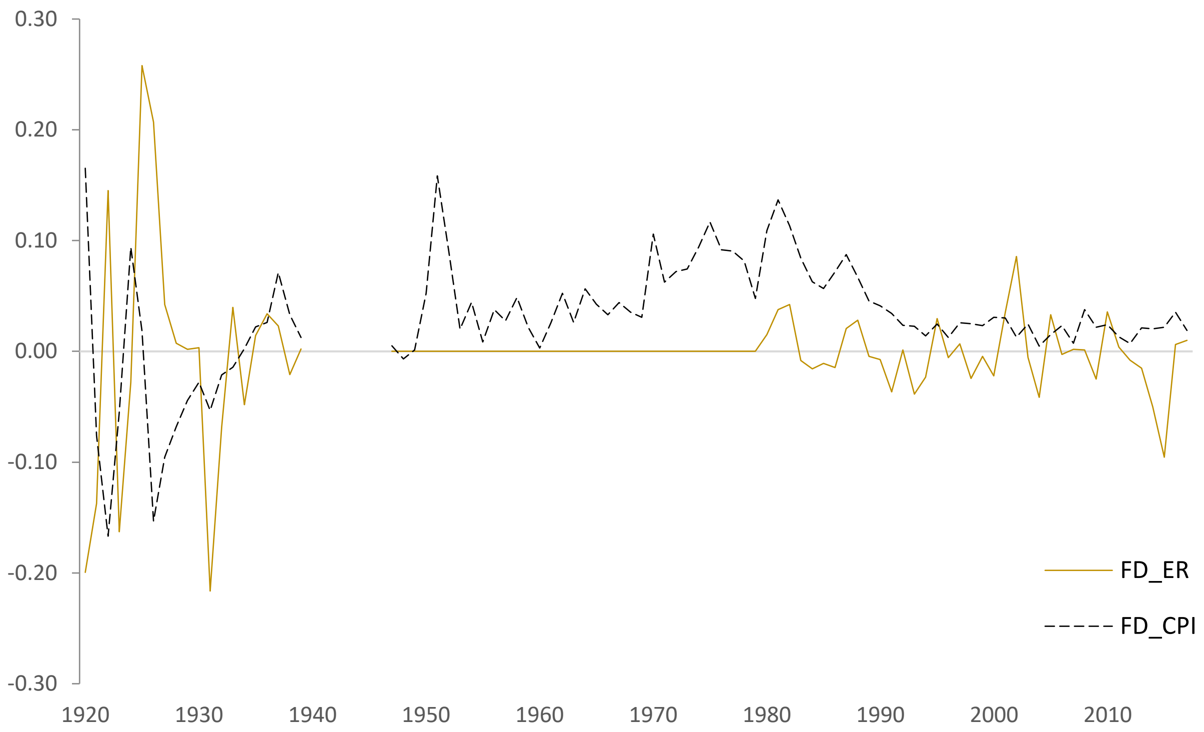
Graph A.22: GDP per capita in fixed prices and import price cycles 1830-2017 estimated by the Hodrick-Prescott filter (λ=100). Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



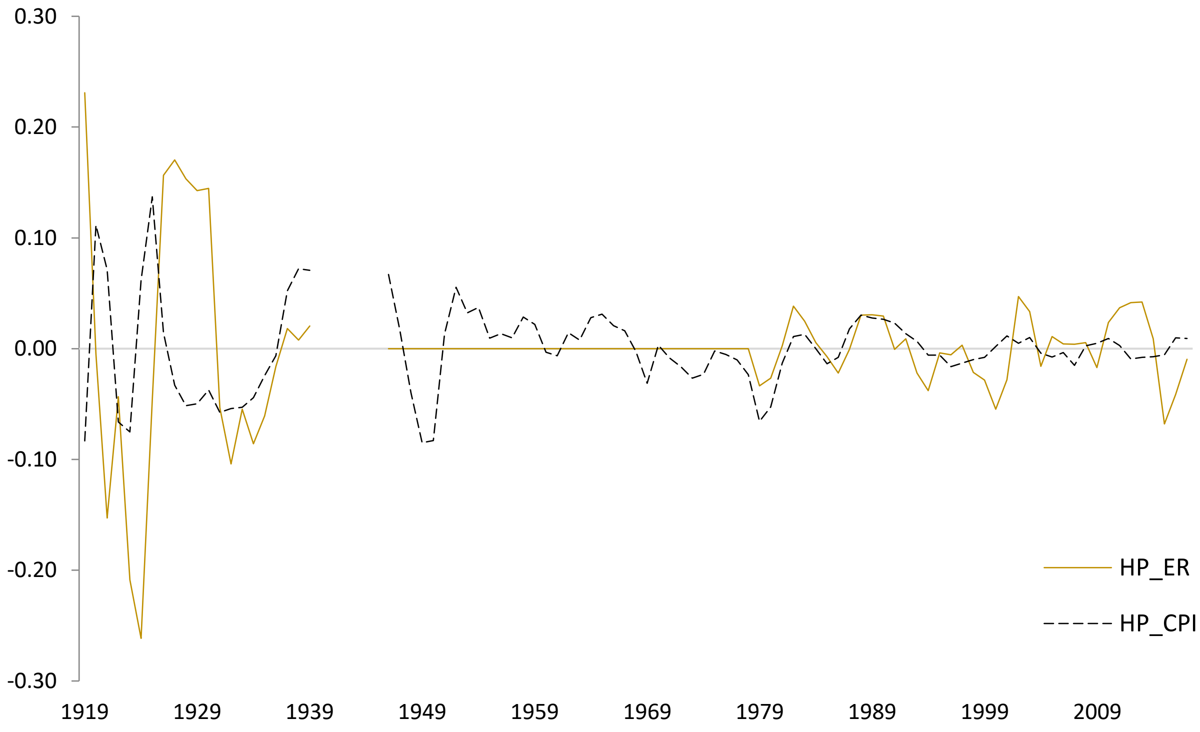
Graph A.23: GDP per capita in fixed prices and import price cycles 1830-2017 estimated by the Hodrick-Prescott filter (λ=2500). Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



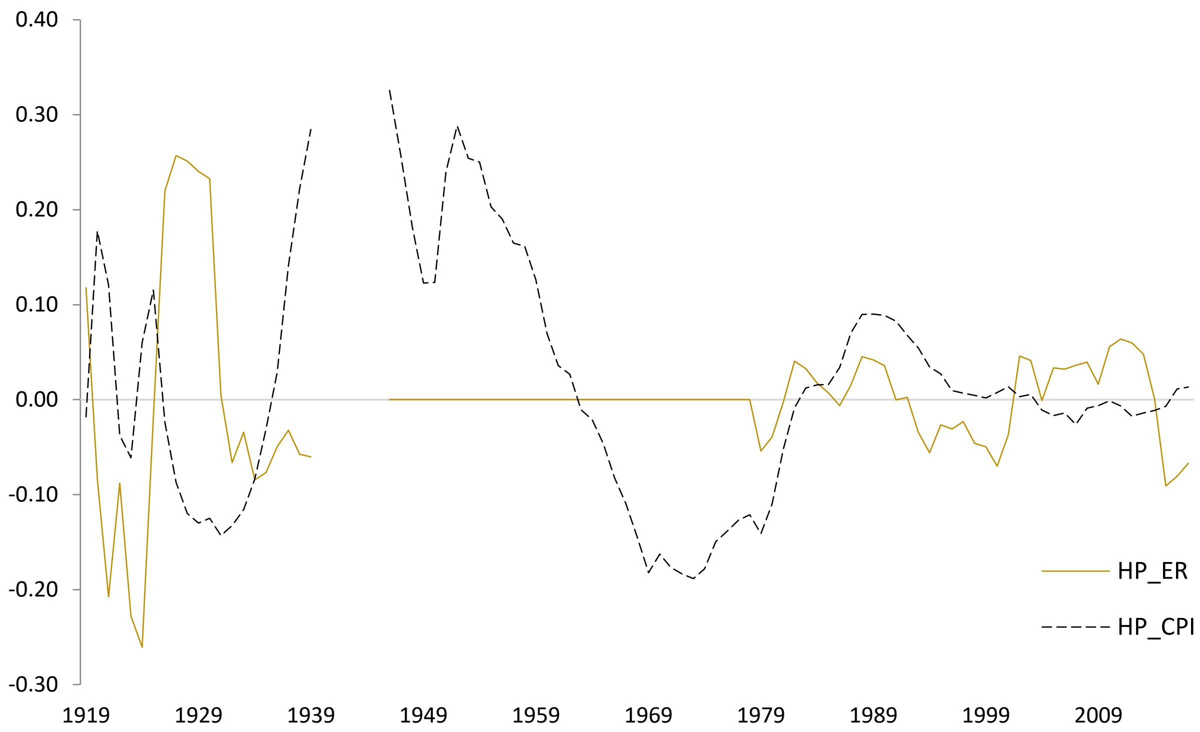
Graph A.24: GDP per capita in fixed prices and import price cycles 1830-2017 estimated by the Christiano-Fitzgerald band pass filter allowing periodic components between two and seven years.
Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019.



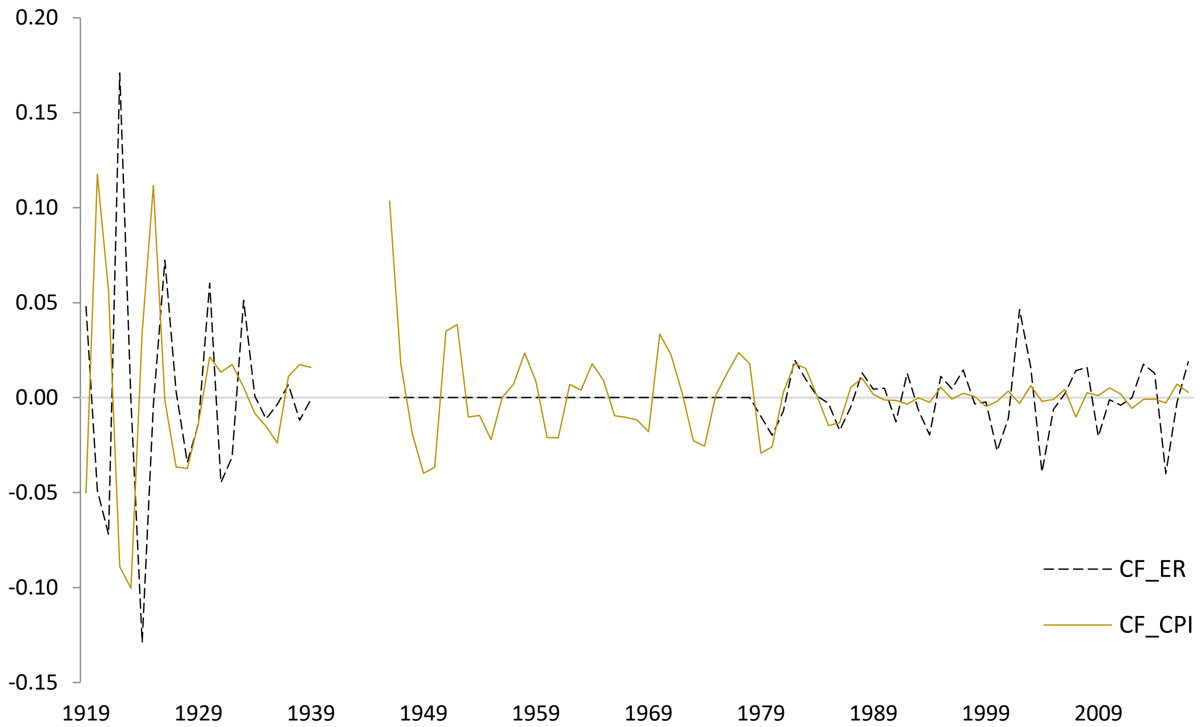
Graph A.25: Annual Fluctuations in exchanges rates and CPI 1919-2017.
Sources: Klovland 1998. World Bank 2019



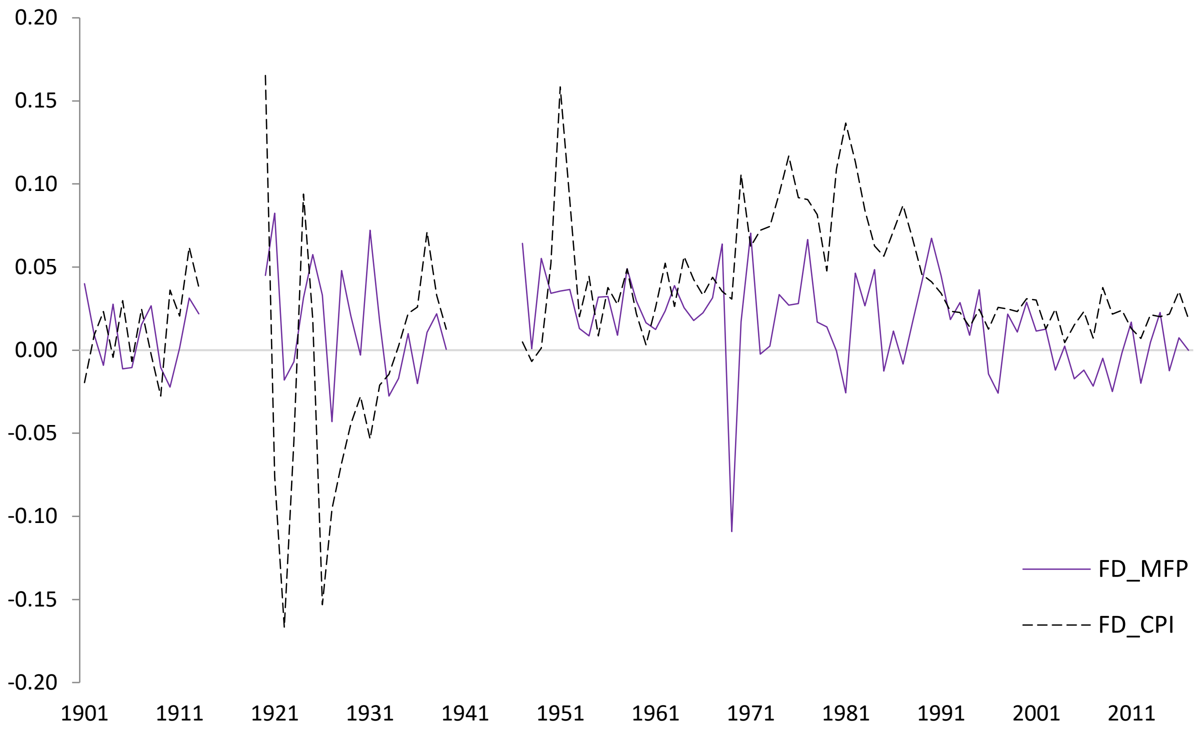
Graph A.26: Exchange rate and CPI cycles 1919-2017 estimated by the Hodrick-Prescott filter (λ=100)
Sources: Klovland 1998. World Bank 2019



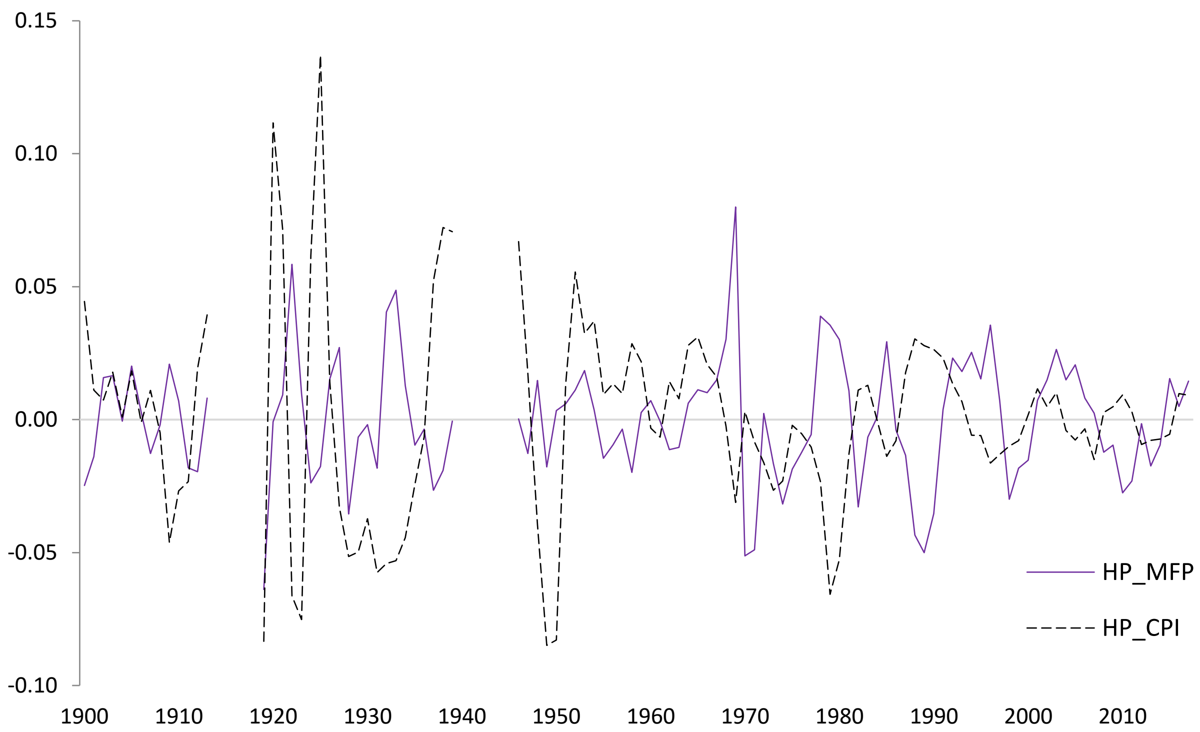
Graph A.27: Exchange rate and CPI cycles 1919-2017 estimated by the Hodrick-Prescott filter (λ=2500)
Sources: Klovland 1998. World Bank 2019.



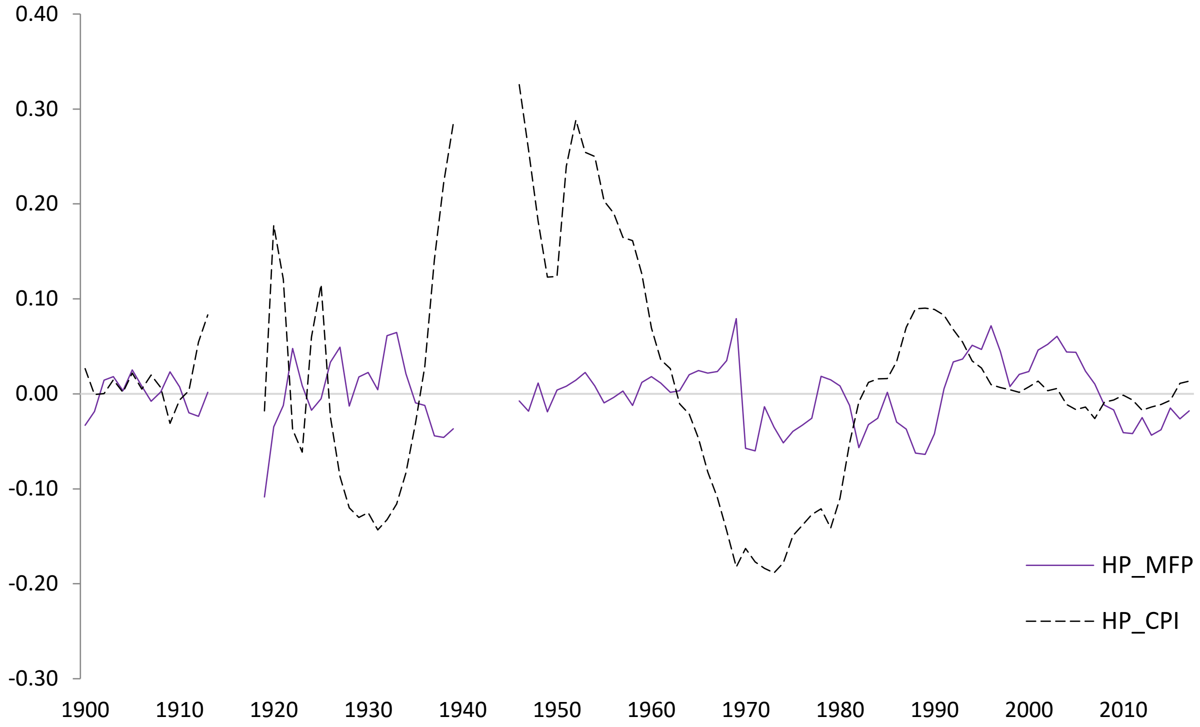
Graph A.28: Exchange rate and CPI cycles 1919-2017 estimated by the Christiano-Fitzgerald band pass filter allowing periodic components between two and seven years. Sources: Klovland 1998. World Bank 2019.



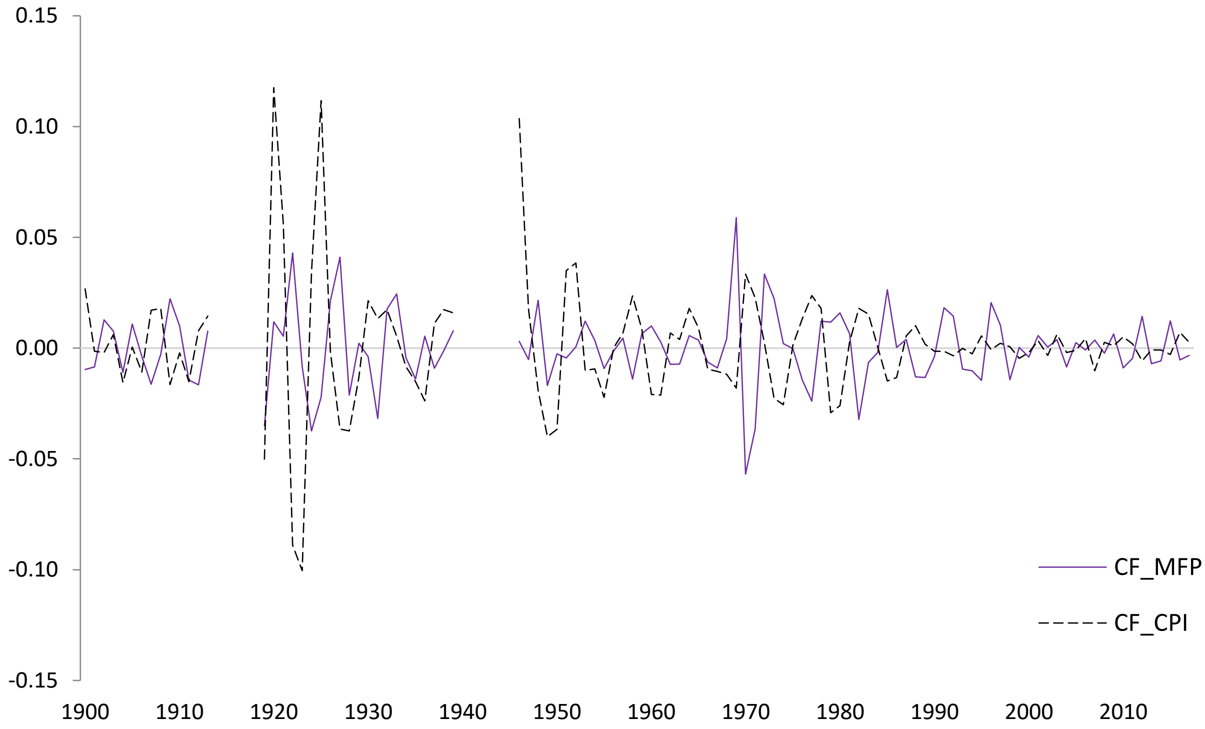
Graph A.29: Annual Fluctuations in multifactor productivity and CPI 1900-2017.
Sources: Grytten 2004a, 92-93. Grytten 2004a, 92-93. Norges Bank 2019. Statistics Norway 2019.



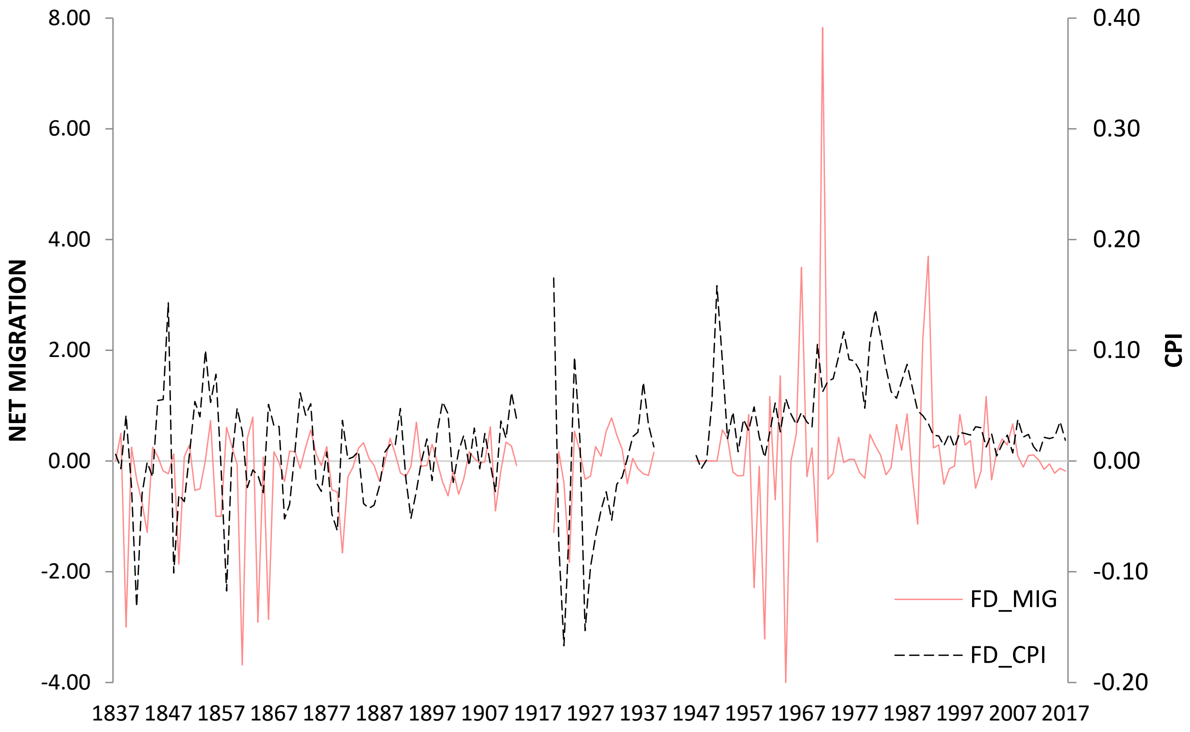
Graph A.30: Multifactor productivity and CPI cycles 1900-2017 estimated by the Hodrick-Prescott filter (λ=100).
Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019. Statistics Norway 2019.



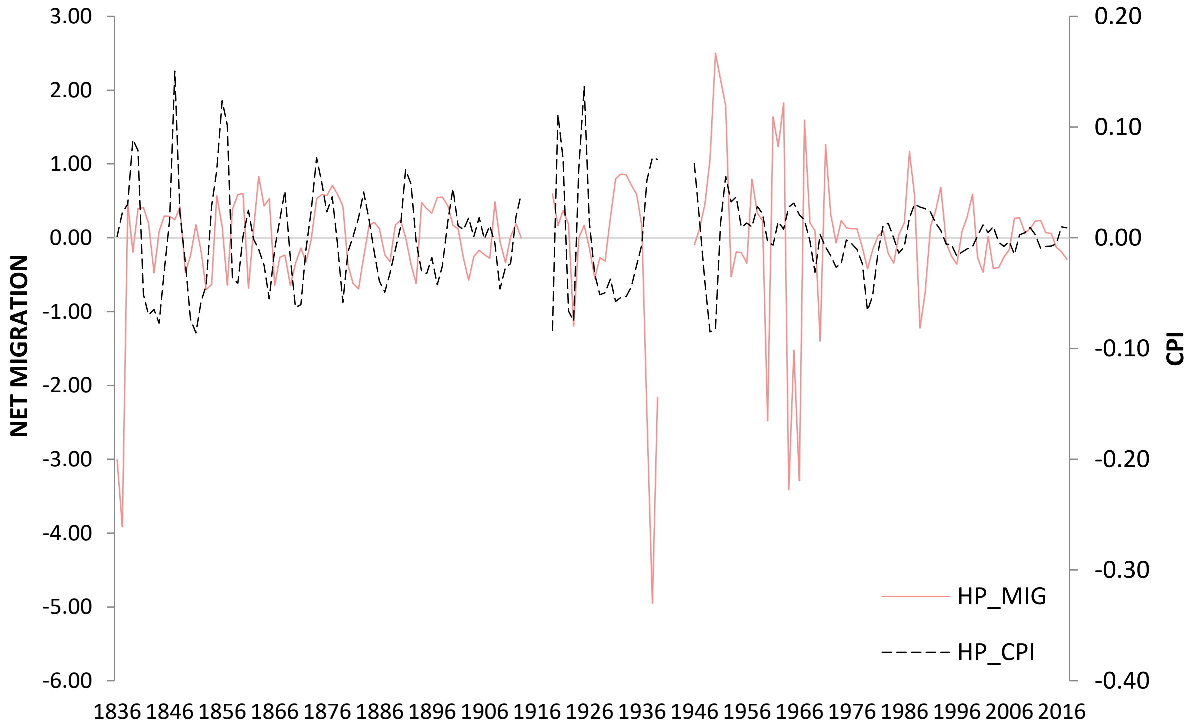
Graph A.31: Multifactor productivity and CPI cycles 1900-2017 estimated by the Hodrick-Prescott filter (λ=2500). Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019. Statistics Norway 2019.



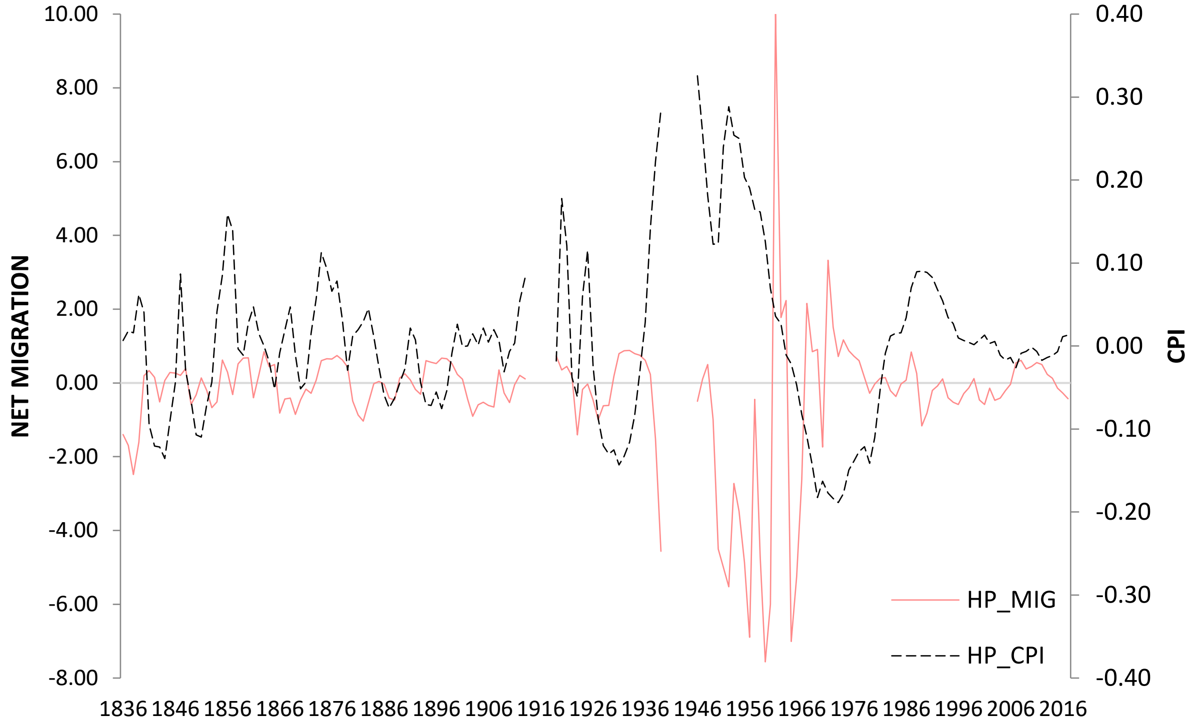
Graph A.32: Multifactor productivity and CPI cycles 1900-2017 estimated by the Christiano-Fitzgerald band pass filter allowing periodic components between two and seven years.
Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019. Statistics Norway 2019.



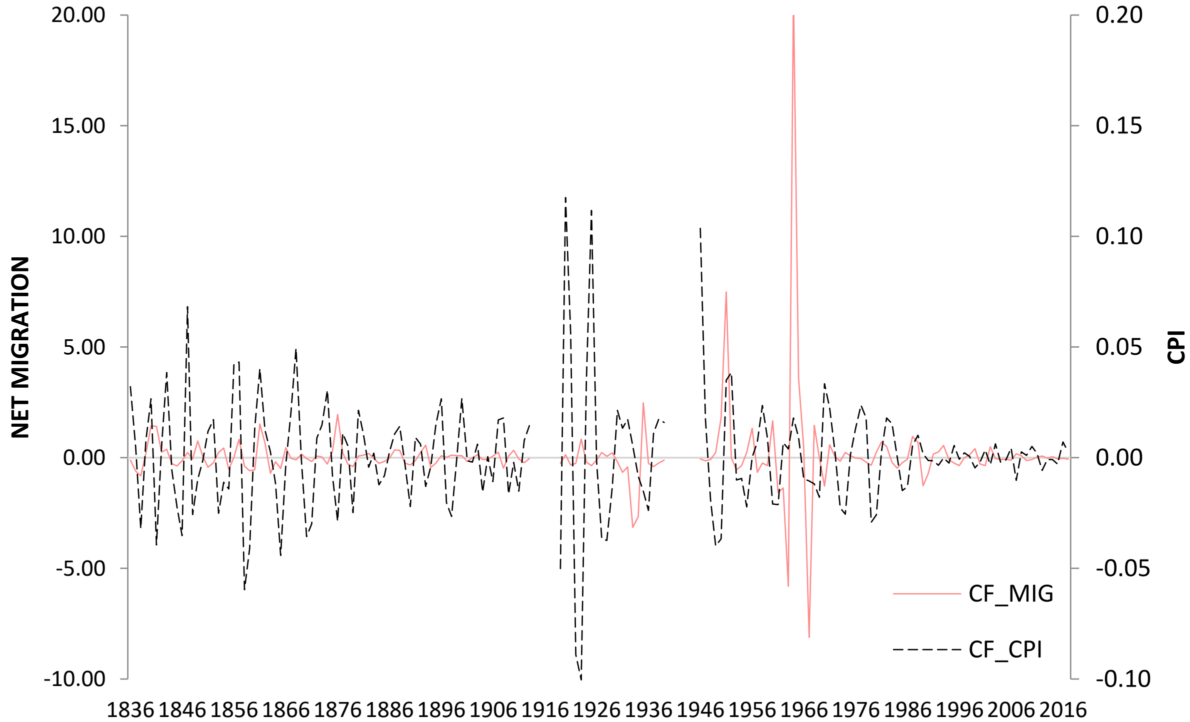
Graph A.33: Annual Fluctuations in net migration and CPI 1836-2017.
Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019. Statistics Norway, 2019..



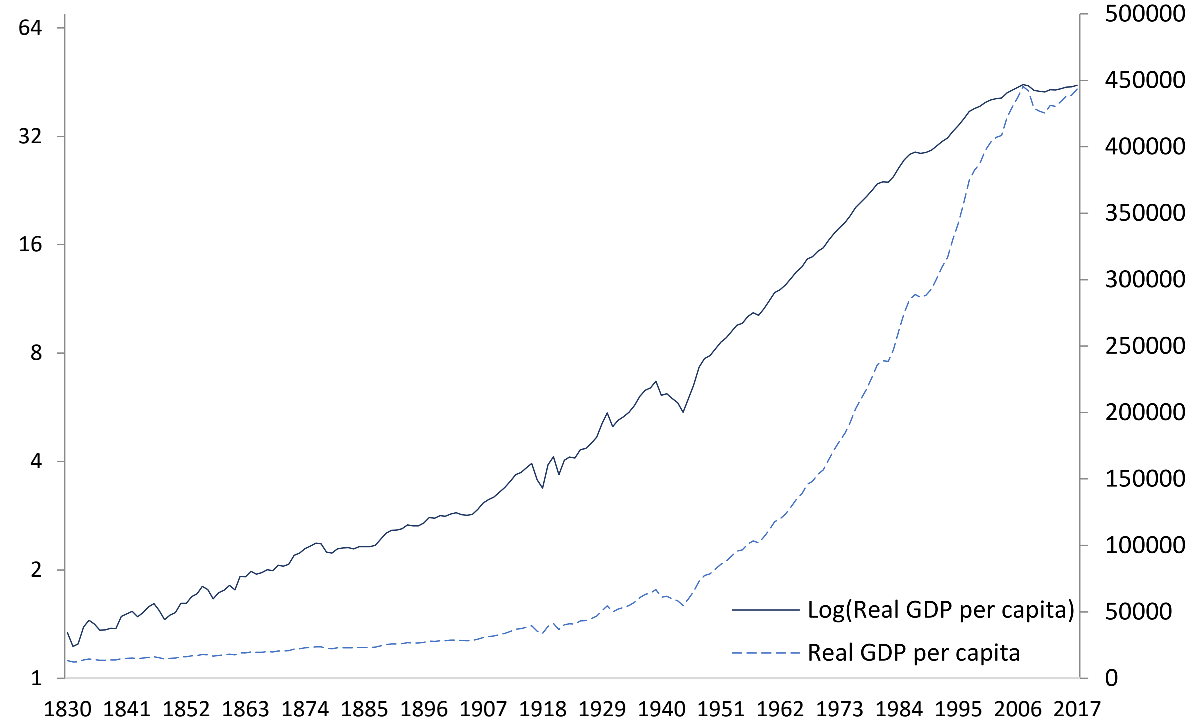
Graph A.34: Net Migration and CPI cycles 1836-2017 estimated by the Hodrick-Prescott filter (λ=100).
Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019. Statistics Norway, 2019.



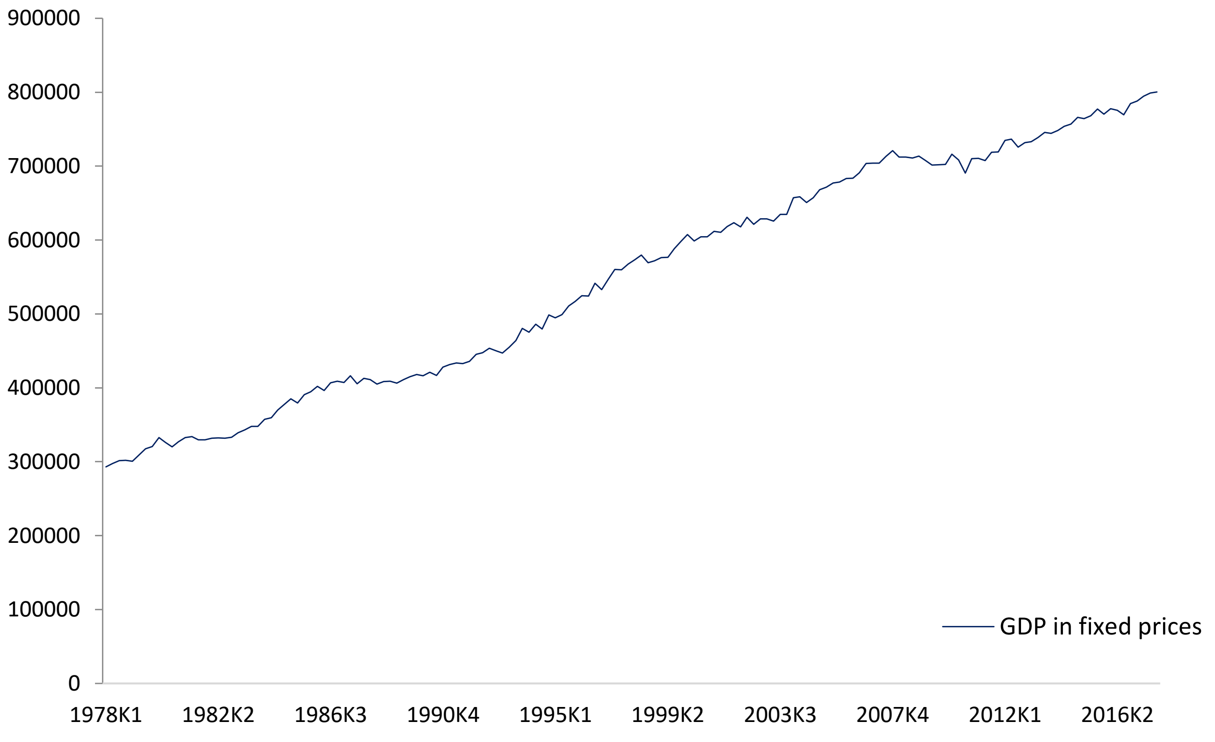
Graph A.35: Net Migration and CPI cycles 1836-2017 estimated by the Hodrick-Prescott filter (λ=2500).
Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019. Statistics Norway, 2019.



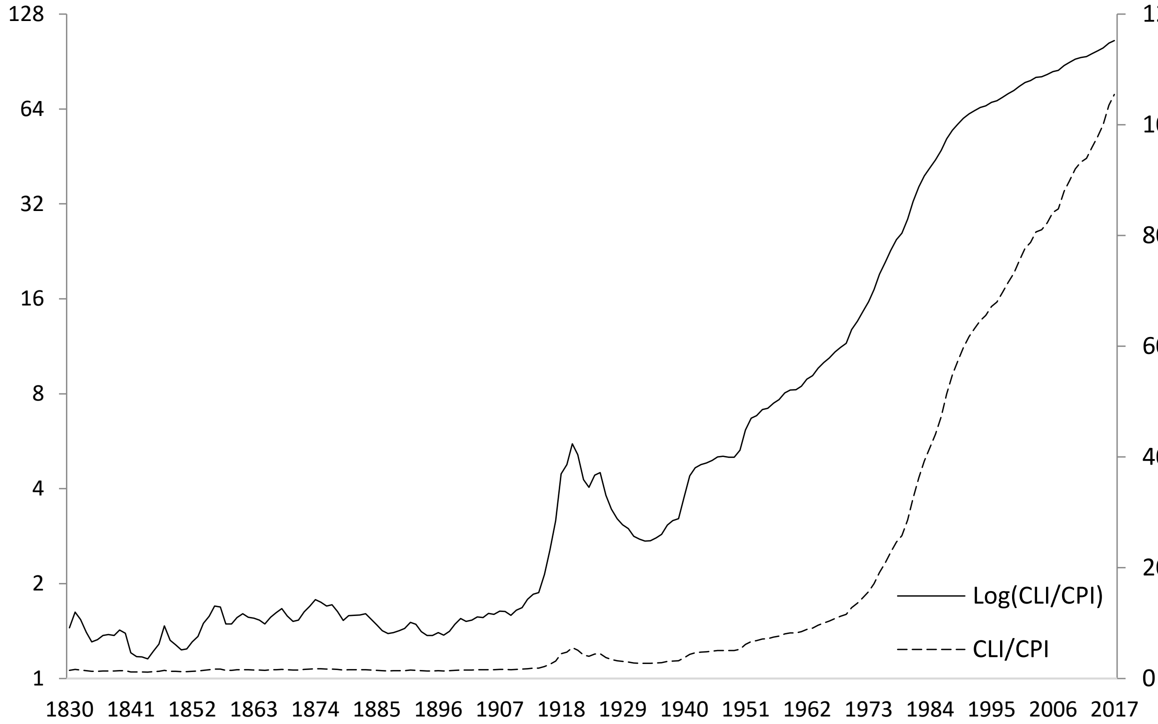
Graph A.36: Net migration and CPI cycles 1836-2017 estimated by the Christiano-Fitzgerald band pass filter allowing periodic components between two and seven years.
Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019. Statistics Norway, 2019.



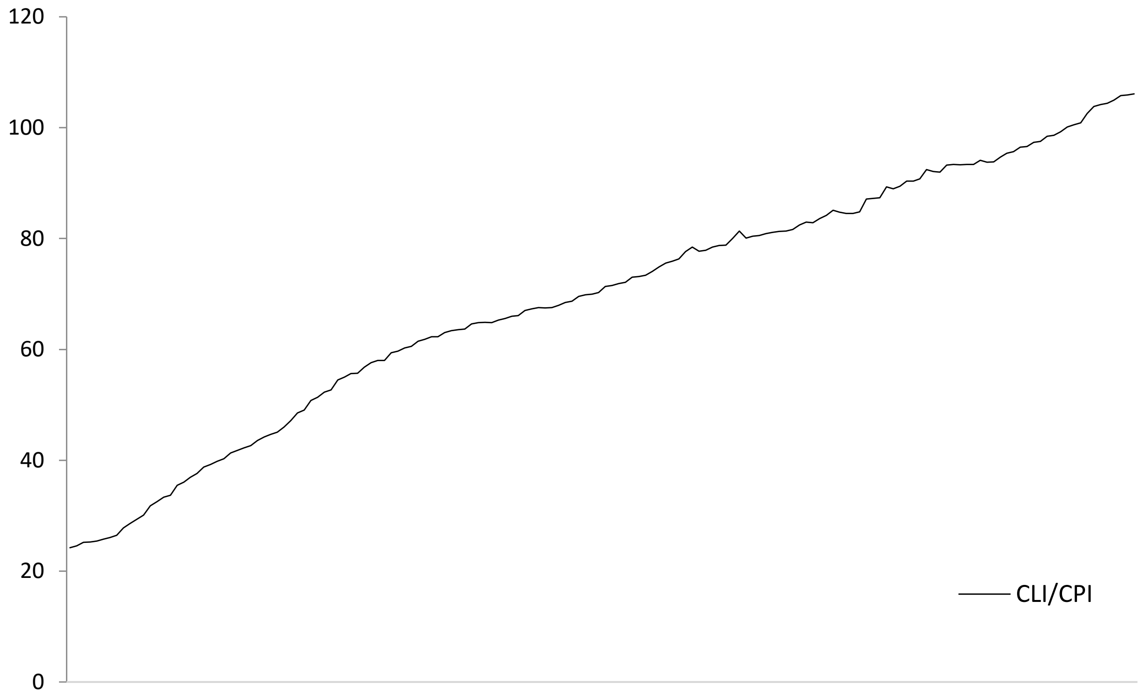
Graph A.37: Gross domestic product per capita in fixed prices (NOK) 1830-2017.
Sources: Grytten 2004a, 92-93. Norges Bank 2019.



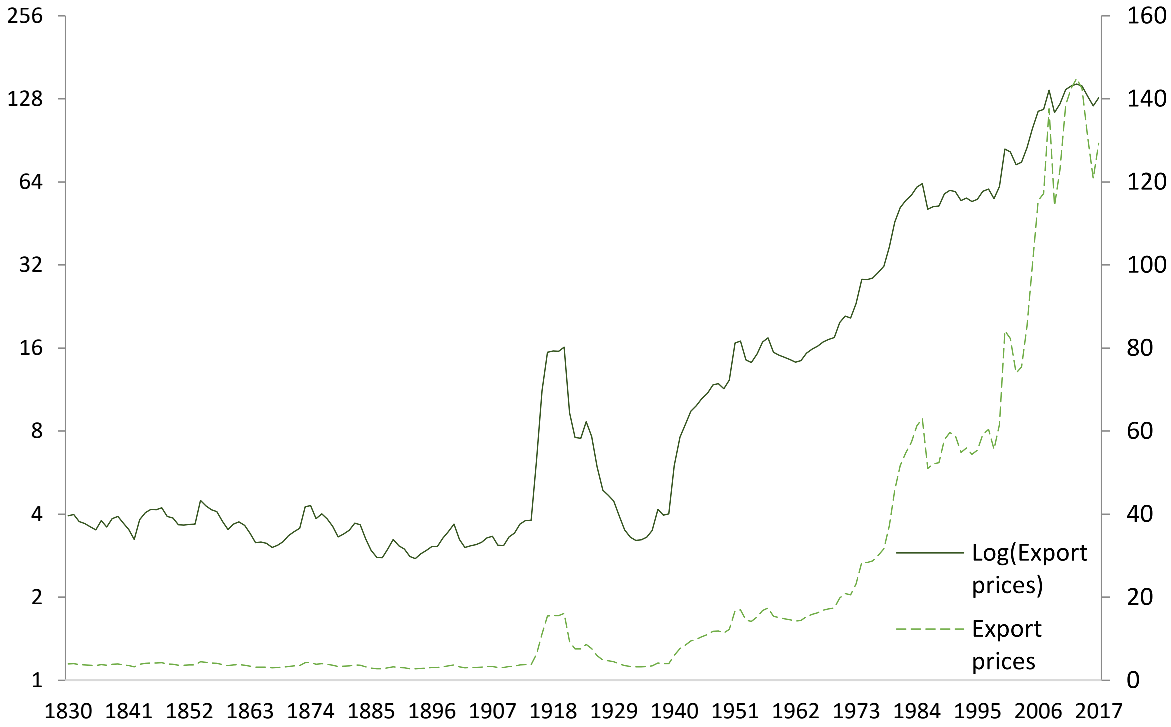
Graph A.38: Quarterly gross domestic product in fixed prices (NOKm) 1830-2017. Sources: Statistics Norway, 2019.



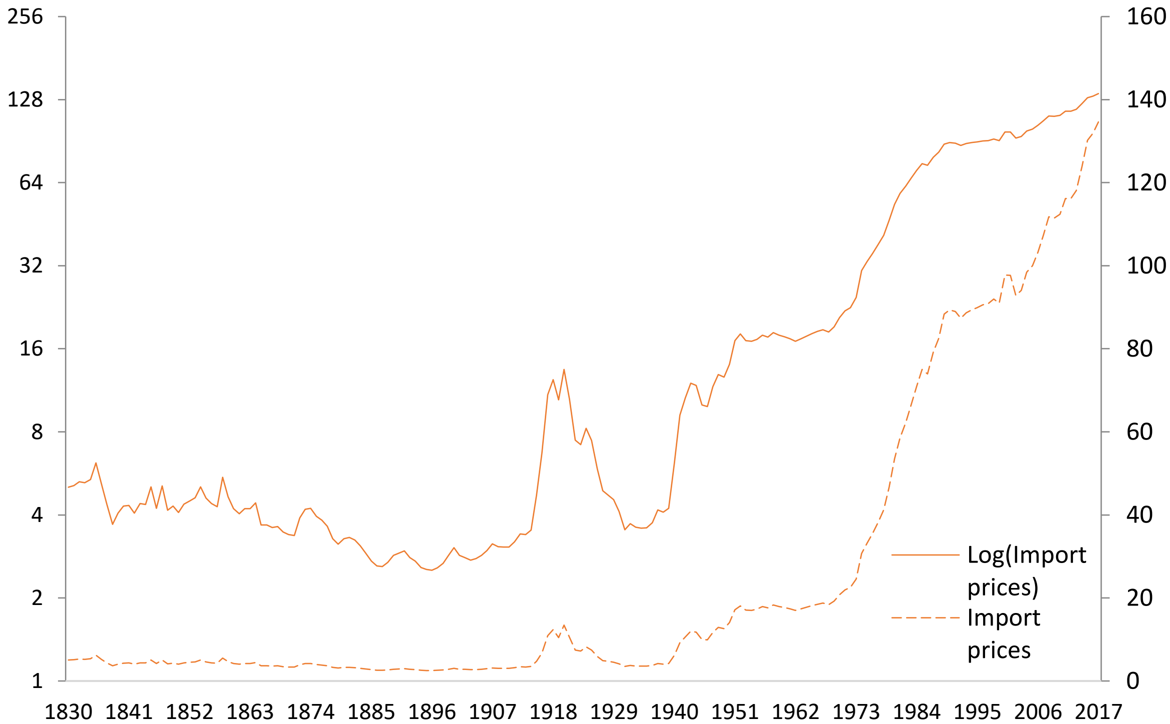
Graph A.39: Cost of living/Consumer price index 1830-2017.
Sources: Grytten 2004b, 92-93. Norges Bank 2019.



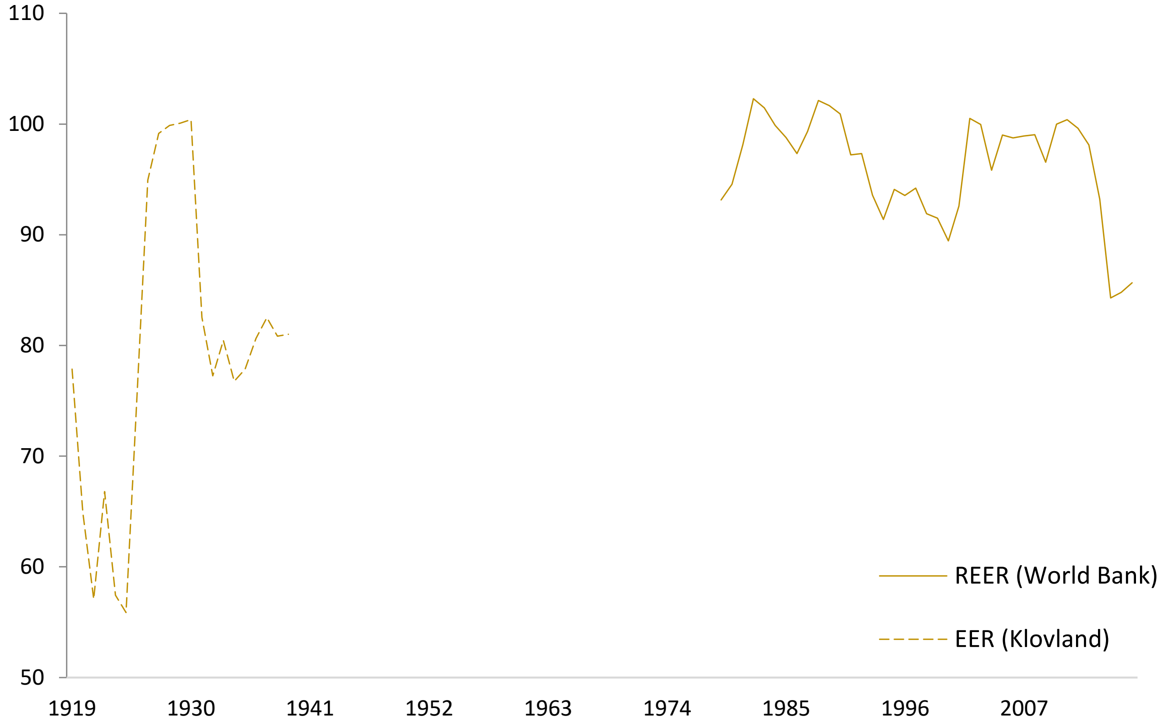
Graph A.40: Quarterly consumer price index 1978Q1-2017Q4. Sources: Statistics Norway, 2019



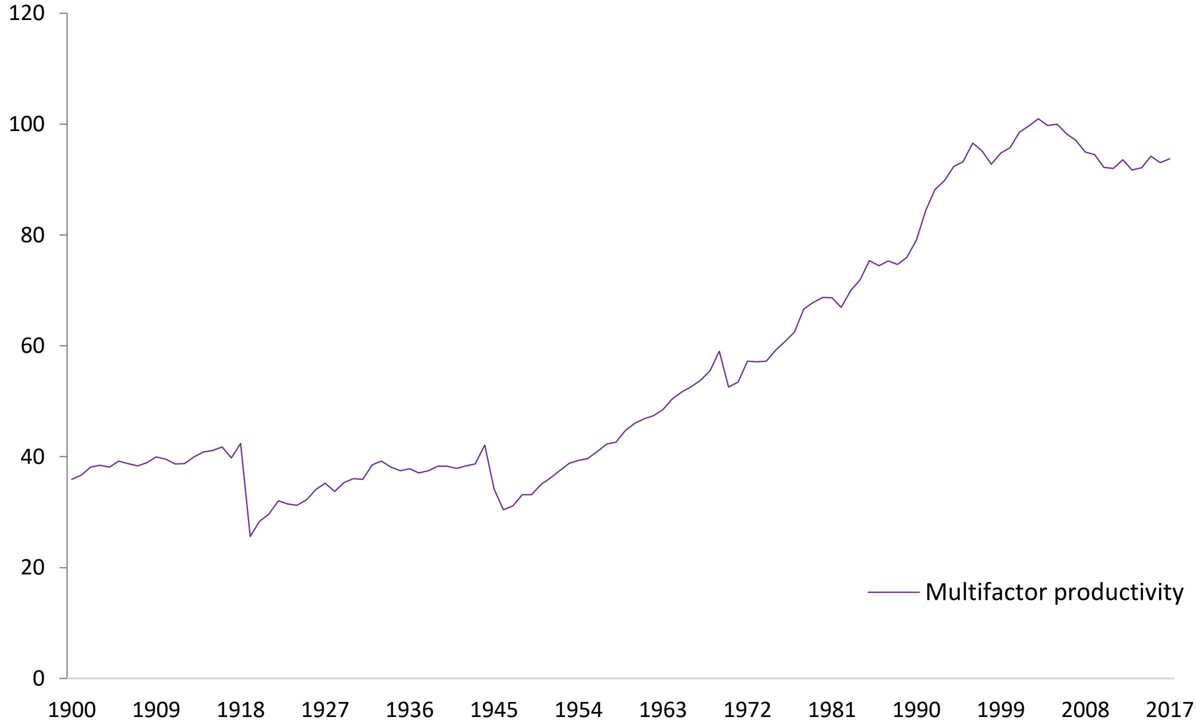
Graph A.41: Price deflator for Norwegian exports 1830-2017.
Sources: Grytten 2004b, 281-284. Norges Bank 2019.



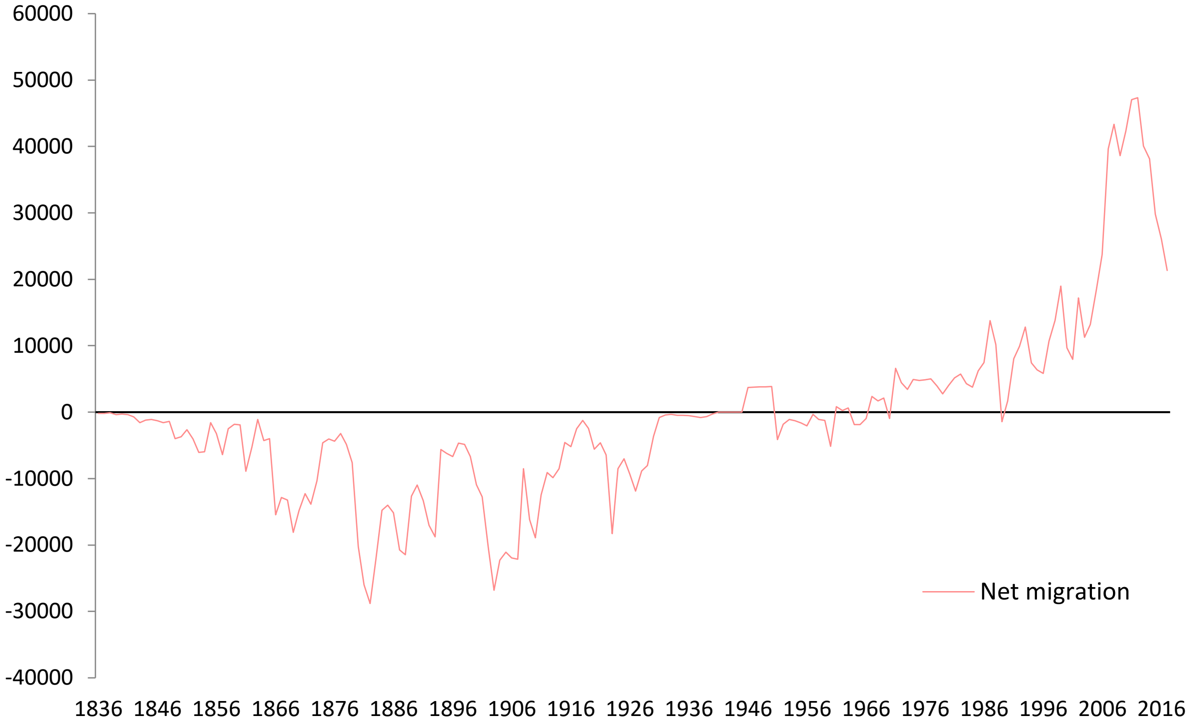
Graph A.42: Price deflator for Norwegian imports 1830-2017.
Sources: Grytten 2004b, 281-284. Norges Bank 2019.



Graph A.43: Effective exchange rate 1919-1939 and real effective exchange rate 1979-2017 for Norway.
Sources: Klovland, 1998. World Bank, 2019.



Graph A.44: Multifactor productivity index (2005=100) for Norway 1900-2017.
Sources: Grytten 2004a, 92-93. Grytten 2004b, 285. Norges Bank 2019. Statistics Norway, 2019.



Graph A.45: Net migration from/to Norway 1836-2017.
Sources: Statistics Norway, 2019.