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Short-term Impact of Public Capital Investment

Abstract

The literature on the macroeconomic impact of public capital investment suggests that public capital enhances growth and facilitates private capital formation. Standard vector autoregressive (VAR) models have become the most popular empirical method to examine the effects of public investment, because this method requires few assumptions about how public capital interacts with the economy. However, previous studies did not employ large information sets, or control for the possibility of forward looking economic agents. To test the robustness of previous findings, this study augments the VAR framework with factor analysis of large data sets and includes proxies for economic foresight about future public investment. This study finds that the conventional VAR specification excludes relevant information potentially generating an upward bias in the short-term affect public capital investments have on growth. The response of private capital formation to shocks in public capital is found to be aligned with previous studies. Finally, the results of this study find no strong indication that expectations about future public investments affect private sector activity.

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1. Introduction

The public capital stock is one of the key components in determining the long-term growth prospect of a country (Romp & de Haan, 2007; The Swedish Fiscal Policy Council, 2012). The stock consists of fixed assets such as railroads, hospitals and schools, which provide infrastructure for economic activity in the private sector as well as the production of public goods. Since Aschauer (1989), substantial empirical research has been conducted to determine the economic contribution of public capital. Romp & de Haan (2007) summarised the current state of knowledge and concluded that recent findings suggest that public capital investment stimulates growth.

The more conclusive results of later studies coincide with the development of new econometric models. Most notably, the use of vector autoregression (VAR) models has become prevalent. In comparison to the production function approach premiered by Aschauer (1989), the VAR model stipulates fewer *a priori* assumptions about links between a set of variables. The open-ended structure of VAR models mitigates the problem of reverse causation, which has often been a concern with the production function approach. However several VAR studies estimating the relationship between public capital and macroeconomic variables may have limited use. In essence, policy makers and the private sector might have information not reflected in the typical VAR study. First, the private sector might form and act on the anticipation of public investments rather than acting when the actual investments occur. In Ramey (2011) it is argued that unexpected shocks in government spending are anticipated several quarters before they occur. More generally, private sector anticipation can be attributed to fiscal policy suffering from *implementation lags;* it takes time for a policy decision to be enacted (Blanchard & Perotti, 2002). What is registered as a public investment shock in the VAR framework might be the result of a previous policy decision. To attain an accurate characterisation of public capital investments' contribution to the overall economy, one must account for a possible anticipation effect. To our knowledge, the existence of anticipation effects has not been investigated thoroughly enough in the literature. Second, the typical VAR analysis contains only a subset of the variables policy makers might take into account when deciding the level of public investments. The typical specification includes public capital, private capital, employment and output (Jong-A-Pin & de Haan, 2008). Arguably, policy makers in a given constituency base their public investment decisions on more information. Interest rates, budget balance, level of public capital, and sovereign debt may all affect the course of action. Studies in monetary policy show that additional information from omitted variables can be incorporated into the VAR framework by

using factor analysis. This method, coined factor augmented vector autoregression (FAVAR), has the advantage of allowing the researcher to construct impulse response functions for a large set of variables, without losing degrees of freedom (Bernanke, et al., 2005). Thus it is warranted to investigate whether the detected effects of public capital are robust to the inclusion of more information.

The aim of this paper is twofold. First, it aims to determine the short-term macroeconomic effects of net public capital investments. Second, it aims to investigate if expectations about public capital investment affect private sector activity. Specifically we use different VAR models to register the impact of unexpected shocks between actual and predicted public investment levels, as well as changing expectations about future levels of investment.

The paper is structured as follows. Section 2 contains a theoretical framework explaining how public capital investment affects growth and private investments. Results from previous studies are presented in addition to arguments as to why the anticipation of public capital investment can have a real economic impact. The data set is described in section 3 and hypotheses are formulated in section 4. The sample, which consists of Swedish data, was generated during a time period of institutional transition within the Swedish economy. As a consequence of this institutional transition the data inherited certain restrictions which may blur econometric inference if not properly addressed. We present some remedies for these issues in section 5 methodology. In addition we present the FAVAR technique including an identification strategy and diagnostic tools used to ensure sound econometric properties. Section 6 summaries the main results. Section 7 is a discussion of the internal and external validity of our findings. Section 8 concludes. References and appendix are listed separately.

2. Theoretical Framework and Previous Research

Previous research estimating the effects of public capital investments have focused on answering two questions. First, is there a relationship between investments in the public capital stock and economic growth? Second, does public capital investment complement or substitute private capital investments?[1] Before presenting theoretical and empirical answers to these questions in section 2.2 and 2.3, attention is given to the definition of public capital in section 2.1.

Few papers have investigated if the private sector acts on the anticipation of public investments. As a result no formal theoretical model has been found that can be used as a base for formulating hypotheses on how anticipation about future public investments could affect the economy. Instead we present various arguments on why expectations about public investments may or may not affect economic agents in section 2.4. These arguments are complemented with findings from papers examining the importance of accounting for economic forecast when estimating spending multipliers. Finally, the importance of anticipation in econometric modeling is explained.

2.1 Public Capital Defined

The literature on the macroeconomic role of public capital does not offer a single, distinct definition of public capital. Without accurate definition and measurement, inference on the dynamic effects of public capital investments will be difficult. There is no universal definition of public capital stock, public capital investment and government capital investment. Investment financed via the government's budget and investment by state controlled entities is referred to as a *public investment*. A narrower definition is *government investment* which only includes investment financed directly from the budget of the government at central or lower levels (Gonzalez Alegre, et al., 2008). However, this distinction between public and government investment is not commonly applied. The term public investment is used in a majority of academic papers without specifying if investments from state controlled entities are included or not.

Public capital stock is usually gauged by applying the so-called *perpetual inventory method*. This method entails calculating the value of past investments and making adjustments for capital depreciation to determine a monetary value of the net capital stock. When estimating the dynamic effects of public capital, researchers tend to prefer using the capital stock over outright

[1] From here on the terms public capital investments, net public capital investments and public investments will be

investment levels. The reason for this is simple. Returns to public investments might be diminishing, depending on the size of the current capital stock (Jong-A-Pin & de Haan, 2008). Consequently, the external validity is generally limited for studies using investment levels rather than the public capital stock. Unfortunately, using the public capital stock has other drawbacks. Any measurement of the public capital stock is likely to contain errors as the estimation is based on assumptions of depreciation rates and durability of various asset classes. In terms of data, computation of the capital stock requires long time series of public investments for robustness. The researcher is limited to the amount and quality of data available (Romp & de Haan, 2007). Furthermore, as pointed out by Gupta et al (2011), a dollar invested in public capital does not necessarily translate into one dollar of productive capital stock. In practice this one to one relationship between investment and capital formation is implicitly assumed in most studies. Gupta et al. (2011) is one of the few studies attempting to account for this problem by using the Public Investment Management Index[2] as a proxy for efficiency adjusted public capital. For developing countries, Gupta et al. (2011) finds that conventional methods can overestimate the accumulated capital stock by as much as one half, if attention is not given to the efficiency of public investment.

As previously mentioned, econometric analysis measures public capital in the form of investment or stock, where both metrics are associated with specific drawbacks. Estimating the public capital stock requires judgment calls about depreciation, while solely relying on investment levels ignores the notion of diminishing returns. Our analysis uses the Net Public Capital Formation as metric, which corresponds to the increase of the monetary value of the public capital stock in each period.

2.2 Theory about the Role of Public Capital

Production functions, cost functions and theory grounded in new economic geography have been used to theoretically explain the link between public capital and growth. Whether public capital investment complement or substitute private capital is in theory linked to production costs, taxes, exchange rates, public debt and marginal productivity of capital (Romp & de Haan, 2007).

[2] The PIMI is composed of 17 indicators measuring the effectiveness in four phases of a public investment. 1) project appraisal 2) project selection 3) project implementation and 4) project evaluation.

Modern international trade theory, mainly new economic geography, offers a line of reasoning as to why public capital may spur economic growth. In essence, firms locate in the largest market possible in order to utilize economies of scale and to minimize trade costs. By investing in transport infrastructure the market grows (due to reduced transport costs) which makes it easier for companies to cluster. In turn, the clustering effect allows firms to utilize economies of scale which spurs growth (Krugman, 1991).

In neoclassical theory, the production function maps the relationship between output and a set of inputs. In this framework public capital is either modelled as a direct input or as indirect determinant of total factor productivity. The direct input approach is justified on the assumption that public capital, especially infrastructure, is used in nearly all forms of production. Building roads may also reduce the cost of production for the private sector, thereby increasing total factor productivity. However, as argued by Duggal et al. (1999), simply augmenting the production function with public capital is not consistent with standard marginal productivity theory, i.e. a factor of production is paid equal to its marginal product[3]. If public capital as factor input is to be compensated based upon its marginal product, the unit cost of capital must be determined by the market mechanism. This assumption is uncertain considering that public capital is often financed by general taxes and debt issuance, hence making it hard for the individual firm to determine the unit cost of capital.

The impact of public investments on growth can also be explained by cost functions. As stated previously, public investment may lower the cost of production for the private sector, which in turn may increase output. The cost function approach is an attempt to formalize the idea of cost reduction into a theoretical framework. While overcoming some of the difficulties of the production function, e.g. satisfying marginal productivity theory and more flexible functional form (Duggal et al, 1999), it also suffers from major drawbacks. Cost functions often contain second order cross-products of input variables, creating a multicollinearity problem which makes the assumption of *ceteris paribus* implausible (Romp & de Haan, 2007).

There are different theories as to why public capital investment may crowd-in or crowd-out private investments. If investment in public capital increases the productivity of private capital, or lowers the cost of production, a complementarity effect between public and private capital should exist. A simple example of a crowding-in effect is if a new highway expands the capacity of nearby factories, increasing the return to private investments, which in turn boosts demand.

[3] (PreserveArticles.com, u.d.)

On the other hand, if public investments are financed through increased government debt or taxes, several adverse effects could occur. First, distortionary taxes could dampen economic activity, thereby lowering the expected net return of private capital. Second, increased sovereign debt could raise concerns about fiscal sustainability, affecting the market risk premium. Third, the relative price between goods produced at home and abroad may be altered if public investment temporarily raises aggregate demand. Boasted aggregate demand will raise the price of domestic goods, making imported goods relatively cheaper[4]. If the intratemporal substitution between domestic and private goods is high, the temporary boost of increased demand could be reversed, thereby lowering the incentives of domestic actors to invest (Agenor & Dodson, 2005). Furthermore, if the government borrows in the domestic market interest rates may rise. The credit available for private agents might also be reduced (Afonso & St Aubyn, 2006).

The discussion above indicates that that there might be various relationships between public investments and private capital formation. Noticeably, many research papers using the production function or cost function approach do not account for the negative effects associated with financing public investments. Besides crowding-out private activity, taxes or high sovereign debt could hamper growth directly (Reinhart & Rogoff, 2010; Romer & Romer, 2011). By using a VAR structure augmented with factor analysis we can single out those theories which seem to have an effect on the data.

2.3 Econometric Models and Empirical Findings

Aschauer (1989) pioneered the use of the neoclassical production approach[5] to estimate the returns on public capital investments. Public capital investments were found to be a strong determinant of economic growth. By regressing changes in GDP on private capital, public capital labor inputs and other variables, Aschauer calculated that an increase in the public capital stock by 10 percent would raise productivity by almost four percent. The results were subsequently criticized for being implausibly high, and plagued with econometric difficulties. Reverse causation, spurious regression, and incorrect handling of unit roots, are the econometric complications that have been associated with the production function based research. Most of these problems are direct consequences of the requirement to impose *a priori* assumptions about causality (Romp & de Haan, 2007).

[4] Given that the nominal exchange rate does not adjust to offset this effect.
[5] Private and public capital is seen as separate inputs in the production function.

Demetriades & Mamuneas (2000) use a quadratic cost function, and data from 12 OECD countries, to calculate the elasticity between public infrastructure capital and output supply. Public infrastructure investment is found to have a positive effect on output supply in all countries examined. The output response to a 1 % increase in public capital increases output ranges from 2.06 % in Norway, to 0.36 % in the United Kingdom.

As previously mentioned, the production function approach assumes a predetermined causal order relating public capital to economic growth, ignoring any notion of reverse causation, i.e. that economic growth or private investment may spur public investment. Over the last two decades, the use of vector autoregressive models has increased in popularity. The popularity of VAR's stems from the ability to capture dynamic effects between different variables, using fewer a priori assumptions. The more flexible structure is advantageous when the causal order of the variables, and the time-horizon of the potential effects, is theoretically unclear.

The body of empirical evidence from VAR studies indicates a positive relationship between public capital investments and economic growth (Romp & de Haan, 2007). Kamps (2004) and Mittnik & Neumann (2001) studies the relationship between growth and public capital, using a standard set of four variables reflecting output, labor input, private capital and public capital. The two studies arrive at similar results; public capital investments have a positive effect on GDP. In Mittnik & Neumann (2001) the positive results were found to be enhanced in countries with high ratios of public consumption relative to public capital investments. The evidence in Kamps' (2004) study points toward significant positive effects of public capital on GDP in the OECD area. A feedback effect, where GDP affects public capital is also detected. In comparison, Afonso & St Aubyns (2006) study yields mixed results. In some countries, public investments are shown to have a detrimental effect on GDP.

The results from studies investigating crowding-in and crowding-out effects are generally indicative of crowding-in effects on private capital formation. However, the results are more varied than the studies on GDP growth (Romp & de Haan, 2007). Mittnik & Neumann (2001) find crowding-in effects in three of the six OECD-countries examined, and insignificant results for the other three. Pereira (2001) finds crowding-in effects in his study on the US, whereas Afonso & St Aubyn (2006) attain mixed results for the 17 industrialized countries in their study. The results in Hunt (2012) are also inconclusive, with instances of crowding-in as well as crowding-out for different regions.

2.4 Economic Foresight

Economic agents who forecast policy changes can be a source of econometric complication. In essence, economic agents can use and act on a larger information set than the econometrician can observe (Ramey, 2011). The differing information sets can be attributed to inside lags and outside lags. An inside lag is the amount time that passes from when a policy is suggested to when it is passed. An outside lag is the amount of time between passing and actually implementing a policy (Leeper, et al., 2012). For example, a decision on the construction of a new highway is likely to be preceded by several years of planning and discussion (inside lag), and followed by several years of construction work until the road is finished (outside lag). If inside and outside lags are not properly addressed, a vector autoregression might not capture shocks accurately. Inaccurately estimated shocks will yield inaccurately timed responses in the VAR system.

Depending on the research question, several different solutions have been proposed to solve the foresight problem. Methods include the narrative approach, conditioning on asset prices and direct estimation of a dynamic stochastic general equilibrium model (Leeper, et al., 2012). The narrative approach is the focus of this paper.

The narrative approach can be traced back to Friedman, Jacobson & Schwartz (1963). Originally, it entailed using non-statistical sources, for example historical newspapers which captured the ideas and processes that led up to economic decisions (Romer & Romer, 1989). In Ramey & Shapiro (1998), information from *Business Week* is used to detect expectations about future increases in defence spending which may affect aggregate demand. This is done by isolating three dates that signal significant military build-ups (the North Korean invasion of South Korea in June 25, 1950, an attack on army barracks in Vietnam on February 7, 1965, and the Soviet invasion of Afghanistan on December 24, 1974). As military build-ups are driven by unexpected geopolitical events the authors argue that dates can be seen as exogenous shocks to other macroeconomic variables. By creating a dummy variable based on these dates they estimate the effects of military build ups on key macroeconomic variables as GDP. Expanding on this idea, Ramey (2012) created a "news" series based on quantitative information[6] from periodicals to capture changes in the present value of government spending based on unexpected changes in foreign policy. Under the assumption that the series is exogenous, Ramey identifies shocks to government spending as a shock in the news variable, using a normal vector autoregressive framework. Using this method,

[6] Primarily from *Business Week, The New York Times* and *The Washington Post.*

coined Expected VAR (EVAR), Ramey finds that private spending declines in response to increases in government spending. Studies using the narrative approach tend to have discrepancies between theoretical and empirical information flows. Narrative news variables, while seen as exogenous, are more likely to be instruments (Leeper, et al., 2012).

This study extrapolates the narrative approach into the domain of public investment. Just as shocks in anticipation of government consumption can stimulate private sector output, the private sector may adjust the capital stock in response to anticipated increases in the public capital. For example, infrastructure projects may spur investment in housing and real estate, and motivate expansion of nearby commercial facilities. Anticipating major public construction projects, construction firms can invest in machinery and equipment.

Short-term forecasts about public investment levels are likely to be more accurate than long-term prognoses. This stems from the inherit difficulty in predicting the long-term development of factors affecting the forecast such as macroeconomic conditions, political will, and government finances. If the private sector forms and acts on the anticipation of public investments short-term prognoses should have the biggest impact.

A model which does not take into account the potential effects of increases in anticipated public investment is at risk of ignoring the immediate response to a policy innovation. This paper accounts for this potential effect by incorporating prognoses about public investment into the econometric framework.

3. Data

Time-series data from 1970 to 2011 on macro-economic aggregates for Sweden is retrieved from the European Commission's Database on Economic and Financial Affairs (AMECO). The data from Sweden has been generated under certain circumstances which need to be addressed. From 1970 to 1991 the data series is in the form of *public investments* i.e. it includes investments made directly by the government and government controlled entities. From 1991 onwards the time-series data gradually changes from public investments to *government investments* i.e. investments only directly financed from the government budget. This shift is in part attributed to a bill signed in 1991 by the Swedish parliament that allows municipalities to form private companies. As a result, many middle- and large-sized municipalities created companies to run local electricity, water and sewage operations. After 1991 Sweden also experienced several corporatizations of state institutions. Notable examples were the transformations of the energy provider Vattenfall, and the telecommunication network provider Telia (previously Televerket), into legal entities operating in the private sector. Investments by these new enterprises are classified as private[7]. As disaggregated data is scarce, it is difficult to adjust the time-series to reflect the entire time period. Another accounting issue is that one of the major infrastructure investments during 1990's, the construction of the Öresund Bridge, is not included in the data set. The Öresund Bridge which connects Sweden and Denmark was financed by a private company jointly owned by the Swedish and Danish governments. Given the bridge's strategic importance and cost, roughly 35 billion SEK (Lundquist & Winter, 2003) excluding it from the data set might distort subsequent findings. It can also be that the private sector might have made investments based on the assumption that the bridge would be built.

A related institutional change, accentuated from the 1990's onwards, is the emergence of the private sector into traditional public sector domains, such as education, healthcare, and transport infrastructure. The increased activity of the private sector in these fields may have affected the complementarity or substitutability between private and public capital. If private investments increasingly replaced public investments after 1991, the dynamic effects of public capital investments might differ between 1971-1991 and 1992-2011.

[7] However, theoretically these investments are still classified as public, the companies are still owned by the government.

In addition to the AMECO data, Swedish budget bills[8] are used to create two present value series for the expected value of public investments. The first series is based on investments planned in the near future. We have named this variable NPV Public Investment. The second time series reflects the present value of public investments expected a period later[9]. This variable is coined NPV-2 Public Investment. The discount rate used to calculate these net present value series is based on the interest rate from Swedish treasury bills with one month duration. The data is collected from the Swedish Central Bank. Bonds with other durations were used as data was not available for the entire time period.

One important event related to our sample is the change in the budget process from 1996 onwards. Before 1996, the budget year did not coincide with the calendar year but instead stretched from July to June. In this regime, the Budget Bill stipulates a tentative budget proposal whereas the Spring Fiscal Policy Bill adjusts and finalizes the budget. After 1996 the opposite relationship is true, the Spring Fiscal Policy Bill indicates the trajectory of government spending whereas the Budget Bill finalized the government budget. The regime switch has implications for the calculation of the net present value series. During the earlier regime, the forecast for upcoming public investments were much closer in time than in the latter budget structure.

In addition the NPV variables, a time series consisting of deviations between actual and forecasted investments is created. These deviations can be viewed as a shock to the expected value of the public capital stock. The shock can be caused by a variety of factors. One main ingredient could relate to the difference between planning and execution of public investments. The central government decides on the level of public investments while the actual implementation is carried out by government agencies[10]. Any difference between planning and execution will result in an anticipation shock. Moreover, local governments account for roughly half of public investment. The central government can only forecast their investment level, and does not dictate the actual investment level. Other factors relating to deviations between actual and projected investment levels could be changing prices, and the inherit uncertainty in making forecasts. The creation of the Public Investment Shock series yields another instrument which can be used in the analysis if expectations about public capital investment affect private sector activity.

[8] The Budget Bill and the Spring Fiscal Policy Bill.
[9] The terms "near future" and "one period later" is made explicit in the methodology section.
[10] The discussion is based on Swedish conditions.

The government budget bills are typically published in less frequent intervals than newspapers or other periodicals. As an information channel the budget bills are clearly restricted compared to internet websites or TV news channels. The private sector is likely to form expectations about future government policies from information sources which are published more frequently than the Budget Bill or the Spring Fiscal Policy Bill. However, using the government bills still has some merit in the form of coverage and reliability. Newspapers and or prominent internet sites do by and large not provide quantifiable information about future Swedish public investment levels. Multi-year prognosis of public investments, included in recent budget bills, is less likely in other information sources. Any rational attempt to estimate the changes in public investment levels should include consultation of the Spring Fiscal Policy Bills and Budget Bills since they are, except when there is a shift of power in the government, issued by the policy makers themselves. Hence, information contained in the government budget bills is likely to be more reliable than other sources.

4. Hypotheses

As previously stated, the aim of this paper is to answer two main questions. First, what are the short-term[11] macroeconomic effects of net public investments? Second, do expectations about public capital investment affect private sector activity? To answer these two questions seven hypotheses have been formulated. Four of them are related to the first question and the last three relate to our second inquiry. Previous research indicates that public investments are likely to crowd in private investments and spur growth, but the results are not conclusive. Studies estimating the output multiplier to government spending highlight that anticipation effects exists, but give no hint about how they matter in a public investment context. Given this background, the hypotheses are as follows:

Hypothesis 1 (H1): Public and private capital investments are complements in the short-term.

H_o = Public capital investment decrease or has no effect on private capital investment in the short-term.

H_1 = Public capital investment increase private capital investment in the short-term.

[11] Short-term is defined as 8 years.

Hypothesis 2 (H2): Public capital investments crowd-out private capital investments in the short-term.

H_o = Public capital investment increase or has no effect on private capital investment in the short-term.

H_1 = Public capital investment decrease private capital investment in the short-term.

By using the vector autoregressive studies it is possible that an impulse response function will give support to (H1) for a certain time period and (H2) for another. If so, it can be hard to conclude whether public capital primarily complements or substitutes private capital in the short-term.

Hypothesis 3 (H3): Public capital investments increase GDP in the short-term.

H_o = Public capital investment decrease or has no affect on GDP in the short-term

H_1 = Public capital investment increase GDP in the short-term.

Hypothesis 4 (H4): Public capital investments decrease GDP in the short-term.

H_o = Public capital investment increase or has no affect on GDP in the short-term.

H_1 = Public capital investment decrease GDP in the short-term.

Among several macroeconomic variables (H1) to (H4) only involve GDP and private capital investments. Since we are using VAR models augmented with factor analysis we will be able to generate impulse response function for a larger set of variables. Still, lack of theoretical models complicates hypothesis formulation about how public investments relate to the other variables, for example domestic demand or the consumer price index. Response from these and other variables will aid the analysis, but the affect public investments have on GDP and private investments will be the main tools to answering question 1.

Hypothesis 5 (H5): The private sector acts on the anticipation of additional net public capital investments.

H_o = The private sector does not respond to changes in the net present value of public capital investments.

H_1 = The private sector responds to changes in the net present value of public capital investments.

As for question 1, lack of previous research cause difficulties in formulating specific hypothesis about how the private sector is likely to react. The impulse response function of private capital formation and the business cycle indicator will be the main variables of interest in evaluating hypothesis 5.

Given that the null hypothesis of H5 is rejected, hypothesis 6 can be tested.

Hypothesis 6 (H6): The private sector reacts stronger to raised expectations about higher public investments in the short-term than in the intermediate-term.

H_o = Private capital investments increase or decrease less or stay the same to raised expectations about public investments in the short-term than in the intermediate-term.

H_1 = Private capital investments increase or decrease more to raised expectations about public investments in the short-term than in the intermediate-term

As argued in the theoretical framework, forecasts about investments closer in time are likely more accurate than long-term prognoses. We therefore expect the private sector, if there is an anticipation effect, to react stronger to news about additional public investments in the near future.

Hypothesis 7 (H7): Deviations between actual and anticipated public investment has a macroeconomic effect.

H_o = Deviations between actual and anticipated public investment has no macroeconomic effect.

H_1 = Private capital investments increase or decrease less or stay the same to raised expectations about public investments in the short-term than in the intermediate-term.

A priori reasoning of whether these shocks will stimulate or diminish private sector activity is troublesome since we cannot pinpoint the underlying reason for these shocks themselves. Hypothesis 7 is therefore of general character.

5. Methodology

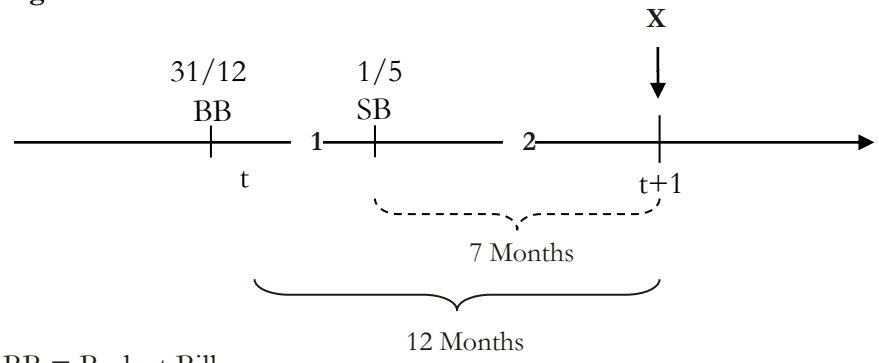
Section 5.1 of the methodology section contains a more detailed description of how the NPV series for public investments are calculated. The econometric model of this paper, FAVAR, is explained in section 5.2. To test the hypotheses different econometric specifications are formulated in section 5.3. The specifications are tested for cointegration, lag length and unit roots to ensure sound econometric properties.

5.1 NPV Public Investment

The difference between the two net present value series is that they differ in timing. NPV Public Investment captures the anticipated value of public investments occurring roughly one year ahead of time. NPV-2 Public Investment is the equivalent measure for public investments expected in two years. The series is based on two observations per annum while the statistics from AMECO is based on yearly data. To make the entire data set comparable the NPV series have to be transformed into annual data. Moreover, the change in budget procedure from 1996 leads to a slightly different computation of the net present value of public investments 1996-2011 compared to 1970-1995.

Figure 1 and figure 2 give an overview of how NPV Public Investment is created during 1970-1995 and 1996-2011, respectively.

Figure 1: Calculation NPV 1970 – 1996



BB = Budget Bill

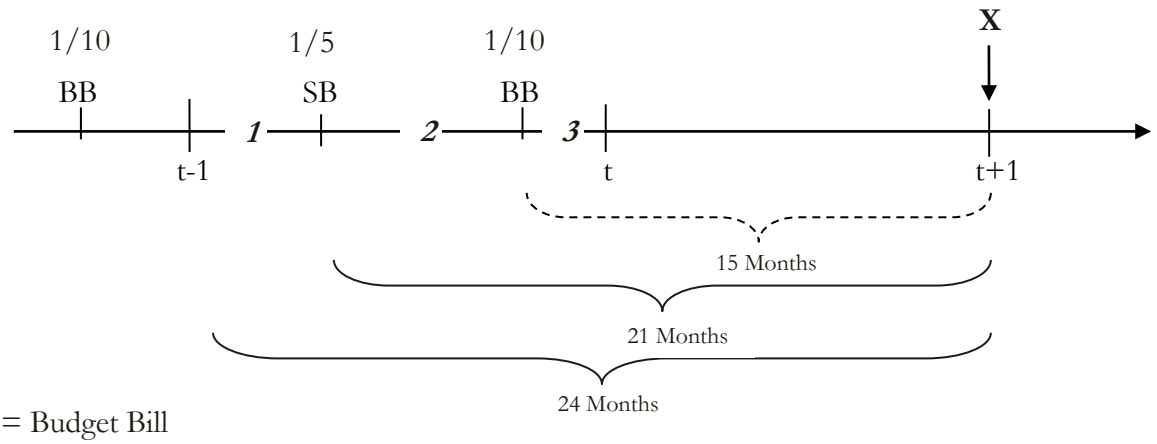
SB = Spring Fiscal Policy Bill

X = Stochastic Variable: Forecast Public Investment

1 = Time period when forecast is based on the Budget Bill

2 = Time period when forecast is based on the Spring Fiscal Policy

Figure 2: Calculation NPV 1996 – 2011



BB = Budget Bill

SB = Spring Fiscal Policy Bill

X = Stochastic variable: Forecast public investment

1 = Forecast based on the Budget Bill from year t-2

2 = Forecast based on the Spring Fiscal Policy Bill year t-1

3 = Forecast based on the Budget Bill year t-1

In both budget regimes investments are assumed to occur at the end of each year. During 1970-1995 we assume that the Budget Bill is released 31/12 while the Spring Fiscal Policy Bill is published in the beginning of May[12]. For 1996 to 2011 the equivalent dates are the 1st of May and the 1st of October. The numbers **1, 2,** and **3** indicate different information sets about the level of future public investments. For example, in figure 1, information set **1** is the time period when the most accurate forecast about upcoming public investment is based on the Budget Bill. When the Spring Fiscal Policy Budget Bill is released expectations change and information set 2 contains the most accurate prognoses. Given this structure, the expected value of public investments will change twice in a given year during 1970-1995. The yearly estimate is calculated by weighing the prognoses depending on the duration, within a given year, they represent the most current information. For example, in figure 1 the prognosis belonging to information set **1** will be adjusted by a factor of $\frac{1}{3}$ while the forecast from information set **2** is given a weight of $\frac{2}{3}$. In other words, information set **1** contains the most accurate information during the course of four months while information set **2** does it for eight months. Yearly estimates for NPV Public Investment during 1996 to 2011 are calculated analogously.

[12] The time of publication for the Budget Bill and the Spring Fiscal Policy Bill during 1970-1995 differs somewhat between years. The Budget Bill is typically issued around the beginning of January or late December. The Spring Fiscal Policy Bill is issued in April or May. For 1996 to 2011 the Budget Bill was released in late September and the Spring Fiscal Policy Bill in April.

As a consequence of the change in the budget regime, the present value is calculated based on different time frames for 1970-1995 compared to 1996-2011. Public investments are scheduled closer in time from the release of the budget bills in the former period compared to the later period. Furthermore, expectations are updated twice a year 1970-1995 compared to three times per annum 1996-2011. Another discrepancy is that occasional assumptions are needed about information set **1** in figure 2. Normally, information about planned public investments in year t+1 is based on the Budget Bill published in year t-2. If the budget bill in year t-2 does not contain this data, an assumption is made that the investment level in t+1 will be equivalent to public investments planned in period t.

NPV-2 Public Investment is calculated according to the same formula as NPV Public Investment. The single computational difference is that NPV-2 Public Investment only includes public investment intended two periods ahead of the last government bill.

5.2 Factor Augmented Vector Autoregression – FAVAR

This study uses Factor Augmented Vector Autoregression (FAVAR) to estimate the macroeconomic response to Net Public Capital Formation, NPV of Public Investment, and Public Investment Shocks. The basic feature of the FAVAR system used in this study is to extract a factor from a large set of data representing the economy, and augment the VAR system with that factor. FAVAR possesses a number of features that are advantageous to this study. First, it allows the researcher to exploit a large pool of data. The policy variables of interest are likely to be influenced by several macroeconomic conditions. Conventional VAR's are typically restricted to a small number of variables, for reasons of parsimony and to preserve degrees of freedom. Relating the policy variable only to a few other variables, conventional VAR's may therefore exaggerate causal relations as they fail to capture co-movements of variables related to the policy variable of interest. Second, FAVAR allows for impulse response functions for all variables used, including those used to extract factors. This grants the researcher the opportunity to investigate the results of many different variables, which may be interesting to the policy-maker. Impulse response functions from a conventional VAR are restricted to a smaller set of variables. Third, FAVAR accommodates concerns for the accuracy of single time-series of economic aggregates. For example, GDP is not an absolute reflection of economic activity, and employment is not an absolute reflection of the labor market. FAVAR, using a broader set of

information than conventional VAR's, can mitigate some of the ambiguity associated with the selection of variables.

Previous use of FAVAR (Bernanke et al., 2005; Mönch, 2008; Mumtaz & Surico, 2009; Stock & Watson, 2005) has focused on the dynamic effects of short-term interest rates. We extend this method to estimating the effects of Net Public Capital Formation, NPV of Public Investment, and Public Investment Shocks. Y_t is an M x 1 vector of the main variables of interest. X_t is a Z x 1 vector of variables used to extract F_t, a K x 1 vector of factors used to estimate joint dynamics with Y_t. Z is larger than M and M is larger than K. The joint dynamics of Y_t and F_t is described by the following equation (Bernanke, et al., 2005):

$$\begin{bmatrix} F_t \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1} \\ Y_{t-1} \end{bmatrix} + v_t \quad (1)$$

Where $\Phi(L)$ is a lag polynomial. If the terms of $\Phi(L)$ relating the main variables Y_t to F_{t-1} are not zero, a normal VAR will lead to biased estimates. If the terms are all zero, the model is a conventional VAR. The factor is unobservable, and therefore equation 1 cannot be directly estimated. The relation between X_t, the factor F_t, and the observed variables Y_t is assumed to be as follows:

$$X_t = \lambda^f F_t + \lambda^y Y_t + \varepsilon_t \quad (2)$$

Where λ^f is a Z x K matrix of factor loadings and λ^y is a Z x M matrix of factor loadings. In equation 2, X_t can be interpreted as macro-economic indicators which one by one are insufficient as indicators of macroeconomic development, but which conditional on Y_t are noisy macroeconomic indicators. Both F_t and Y_t affect the dynamics of X_t. We use a two-step principal components approach in which the first step involves extracting the factor loadings, and the second step incorporates the factor loadings in a VAR.

5.3 Specification and Diagnostics

To test the hypotheses and the robustness of subsequent findings, six different econometric models are specified. The baseline model[13] contains four variables; Net Public Capital Formation, Net Private Capital Formation, GDP, and Aggregate Hours Worked. This model is aligned with

[13] Baseline VAR.

the VAR specification used in most previous studies (Jong-A-Pin & de Haan, 2008). Specification *FAVAR (I)* tests the robustness of the baseline model by expanding the information set through factor analysis. In practice a factor representing the macroeconomic environment is added to the variables in the first model. The factor is created using 20 variables which are presented in appendix B2. *FAVAR (II)* augments the previous model by adding a variable for the Net Present Value of Public Investment (NPV). To preserve degrees of freedom, *FAVAR (III)* moves two variables of *FAVAR (II)*, Aggregate Hours Worked and Net Public Capital Formation, to the pool of factor-extracting variables. In theory, the results of these specifications should be qualitatively the same. However, it is worthwhile to empirically test if the findings overlap. In *FAVAR (IV)*, NPV-2 Public Investment replaces NPV Public Investment to determine if the time perspective in prognoses matter for the private sector. Finally, *FAVAR (V)* replaces NPV-2 with Public Investment Shock, to determine whether deviations from forecasted public investment have an effect on private capital formation.

Specifications *FAVAR (I)*, *FAVAR (III)* and *FAVAR (V)*[14] are used on the full sample and two subsamples[15] to determine if the institutional transition during the 1990's affects the underlying relationships between the variables. Table 1 gives an overview of the different specifications.

Table 1: Econometric Specifications

Specification	Variables	Time-Period
1: Baseline VAR	Net Public Capital Formation, Net Private Capital Formation, Aggregate Hours Worked, GDP	1972-2011
2: FAVAR (I)	Net Public Capital Formation, Net Private Capital Formation, Aggregate Hours Worked, GDP, Macroeconomic Factor	1972-2011 1972-1991 1991-2011
3: FAVAR (II)	Net Public Capital Formation, Net Private Capital Formation, Aggregate Hours Worked, GDP, Macroeconomic Factor, NPV Public Investment	1972-2011
4: FAVAR (III)	Net Private Capital Formation, GDP, Macroeconomic Factor, NPV Public Investment	1972-2011 1972 -1991 1992-2011
5: FAVAR (IV)	Net Private Capital Formation, GDP, Macroeconomic Factor, NPV-2 Public Investment	1987-2011

[14] Baseline VAR, FAVAR (I), FAVAR (II), FAVAR (III), FAVAR (IV) and FAVAR (V) is also referred to as specification 1, 2,3,4,5 and 6.
[15] Data from 1972-1991 and 1992-2011

6: FAVAR (V)	Net Private Capital Formation, GDP, Macroeconomic Factor, public investment shock	1972-2011 1972-1991 1992-2011

Cholesky decomposition is used to identify the above VAR and FAVAR systems. This requires restrictions about which variables that can affect each other contemporaneously. Table 2 show the ordering of the variables within each specification. A variable has a contemporaneous effect on those variables which have a lower ordering. For example, a variable ordered second (indicated by 2 in the table) affect variables ordered third, fourth, fifth etc.[16] contemporaneously while it affects the variable ordered first with a lag.

Table 2: Ordering of Variables

Variable	Specification					
	S1	S2	S3	S4	S5	S6
GDP	3	4	5	4	4	4
Net Private Capital Formation	2	3	4	3	3	3
Net Public Capital Formation	1	2	3	F	F	F
Aggregate Hours Worked	4	5	6	F	F	F
Macroeconomic Factor	-	1	1	1	1	1
NPV Public Investment	-	-	2	2	-	-
NPV-2 Public Investment	-	-	-	-	2	-
Public Investment Shocks	-	-	-	-	-	2

Notes: F marks variables moved from independent variables to the pool of factor-extracting variables.

The Macroeconomic Factor is ordered first in all FAVAR specifications. The factor is ordered first because it reflects the current economic environment. In particular it includes interest rates and taxes, components which are likely to interact with the economy instantaneously. The policy variable of interest is always ordered second (besides in the baseline model, where there is no factor) before Net Public Capital Formation, GDP and the other main variables. In specification 2: FAVAR (I)[17] the motivation for this ordering is straightforward. The Net Public Capital Formation in a given period is by large predetermined by the preceding budget bill. The formation of public capital should therefore not respond to private investments or GDP shocks which occur after the budget has been set. However, as mentioned in section 3, the

[16] Indicated by 3,4,5 etc. in table 2.
[17] The policy variable is in this specification is the Net Public Capital Formation.

implementation of public investment is carried out by government agencies. Given this structure it is likely that the Net Public Capital Formation is contemporaneously influenced by interest rates and the business cycle i.e. the Macroeconomic factor. Moreover, roughly half of public investment is done by local governments, who may respond to the current economic state, expressed by the Macroeconomic Factor.

NPV of Public Investment is ordered second, since we want to investigate potential immediate effects on Private Capital Formation. The Macroeconomic Factor accounts for contemporaneous effects on NPV Public Investment.

Public Investment Shocks are also ordered before the Private Capital Stock and GDP but after the Macroeconomic Factor. The choice of ordering can be motivated by the way the Public Investment Shocks is constructed. The Public Capital Investment shock is the result of a discrepancy between forecasted and actual public investments. The forecasted component is set before the investment shock materialize. A prognosis made in period t-1 about public investments in period t can naturally not be affected by actual GDP and private capital formation at time t. The second component, actual public capital investment, is ordered before private capital and GDP, for reasons given earlier in this section. Hence, the deviation cannot be assumed to be unaffected by the current macroeconomic state.

To compare and analyze results, impulse response functions are generated for all specifications. The variable with factor loadings is ordered first in each specification, and only responds to the main variables with a lag. However, in estimating the impulse responses, we do not have to assume the same about the idiosyncratic movements of individual factor variables. Before estimation, we whether factor variables which will react *fast* or *slow* to a shock in the policy variable[18]. Appendix B.5 contains a summary of the variables defined as fast or slow.

VAR and FAVAR systems are stable if the included time series are stationary. Stationarity is induced on the variables through different transformations. More specifically, depending on whether the original time series is trend or difference stationary this paper uses log-difference or the Hodrick Prescott (HP) filter to induce stationarity. Table B.1 and table B.2 sum up the findings from unit root tests before and after transformations. Beside Public investment shocks and the Business cycle indicator, all variables contain a unit root in level form. Those time series

[18] Fast is equivalent to a contemporaneous reaction and slow is a synonymous to a lagged response to shocks in the policy variable.

that showcase a clear trend[19] are transformed by using the HP filter. The other variables are changed by log-differencing. After transformation the Dickey-fuller test rejects the null hypothesis of a unit root for all variables on 5 % significance level[20] indicating that the transformed time series are stationary. Using the Engle-Granger methodology each specification is tested for cointegration in level values, however no such relationship is found. Hence, there is no need to estimate a vector error correction model (VECM) instead of the normal VAR system.

The lag-length of the VAR and FAVAR systems is selected based on Akaike, Hannan-Quinn and Schwartz' Bayesian Information Criterion (see table B.4). The results indicate an optimal lag-length of 1 for the baseline model as well as the augmented models.

6. Findings

The impulse response functions (IRF) for the different specifications can be found in Appendix A. The IRFs are measured in standard deviation units. Tables (A.1) and (A.2.1) compares the results of a conventional four-variable VAR system with an identical system augmented with factor analysis. Since the factor loadings are not zero the FAVAR system in (A.2.1) has higher informational content than the baseline VAR. While the impulse response functions are qualitatively similar, the higher informational content increases the robustness of the findings, motivating the use of FAVAR in investigating the hypotheses of this paper.

Hypothesis 1: Public and private capital investments are complements in the short-term.

The results in (A.2.1) indicate that a positive shock in Net Public Capital Formation is followed by an increase in Net Private Capital Formation. Controlling for NPV Public Investment in (A.3.3) yields similar results. However, the results differ when the sample is divided into two periods. For 1972 – 1991 (A.2.3) public capital complements private capital, whereas no effect is found during 1992 -2011 (A.2.5). Hence, the null hypothesis can only be rejected at a 10 % significance level for 1972 – 2011 and 1972-1991. Overall the evidence indicate that public capital investment may increase private capital investment in the short-term.

Hypothesis 2: Public and private capital investments are substitutes in the short-term

[19] Via visual inspection.
[20] When using one lag. For multiple lags the null hypothesis of a unit root could not be reject for NPV public investment.

Looking at (A.2.1; A.2.3; A.2.5; A.3.3) does not support the hypothesis that public and private capital investments are substitutes in the short-term.

Hypothesis 3: Public capital investments increase GDP in the short-term

Public capital investment does not seem to affect GDP in any time period (A.2.1; A.2.3; A.2.5). Controlling for the anticipation effect does not change this finding (A.3.3). The null hypothesis that public capital investment decrease or has no effect on GDP in the short-term cannot be rejected at 10 % significance level.

Hypothesis 4: Public capital investments decrease GDP in the short-term

A one standard deviation shock in the Net Public Capital Formation does not affect GDP in the short-term (A.2.1; A.2.3; A.2.5; A.3.3). The null hypothesis cannot be rejected at conventional significance levels.

Hypothesis 5: The private sector forms and acts on the anticipation of public investment

The results in table (A.3.1; A.3.2; A.4.1-A.4.6) are indicative that macroeconomic variables are correlated with changes in the net present value of public investment. Interestingly Government Debt, Unemployment and GDP are statistically different from zero on a 10 % significance level for the entire sample (A.3.1; A.3.2; A.4.1; A.4.2). For Government Debt and Unemployment this is also true for the time period 1972-1991 (A.4.3; A.4.4). For the private sector, a positive effect (10 % significance level) on Net Private Capital Formation is found for 1972-1991. However, the null hypothesis that the private sector does not respond to changes in NPV Public Investment cannot be rejected for the entire sample.

Hypothesis 6: The private sector reacts stronger to raised expectations about higher public investments in the short-term than in the intermediate-term.

The findings related to this hypothesis are found in (A.4.5; A.4.6; A.5.1; A.5.2). From these tables it is not possible to reject the null hypothesis. The results imply that shocks to the NPV of public investments are associated with negative fluctuations in GDP and temporarily higher unemployment.

Hypothesis 7: Deviations between actual and anticipated public investment affects macroeconomic sentiment

Surveying (A.6.1-A.6.6) the responses of most macroeconomic aggregates are weak and insignificant. However, Government Debt as % of GDP tends to be significantly different from zero. Overall, the null hypothesis is not rejected.

Institutional Change

Running the same specifications using only data on the time-period 1972-1991, the results are similar to those of the full sample period. The confidence bands are typically wider, which is only to be expected given the smaller sample size. Unlike the full-sample specifications, there appears to be a positive response of private capital formation to a positive shock in anticipated public investment, and a somewhat more positive response of macro-economic aggregates to unanticipated public capital investments. The results on the subsample period 1992-2011 vary more than the earlier sub-sample. The response of private capital formation to a shock in public capital is insignificant; instead the aggregate hours worked show an immediate increase following a public capital shock. Since the response of Unemployment is insignificant, rather than negative as in the full-sample system, there is further indication of different labor market effects in the latter sample period. Unlike the full-sample system, the response of various variables reflecting output and the labor market, to shocks in NPV Public Investment, are insignificant. The responses to a positive impulse in Public Investment Shock are very similar to the full-period system.

7. Discussion

The first aim of this study is to determine the short-term macroeconomic effects of net public capital investments. The empirical result for the full sample indicates that a positive impulse in net public capital formation increases private capital formation in the short-term. However, the results differ between the two subsamples. For the period 1992-2011, private capital formation does not increase in response to a positive shock in public capital. Changed composition of public investment after the 1990's is one possible reason as to why public capital investment does not spur private sector investment. Another plausible explanation is diminishing returns to increases in the public capital stock. Arguably, heavy investment in public capital during the

1970s and 1980s lowered the marginal benefit of additional capital during subsequent decades in terms of complementarity with private capital. In contrast to other studies, we do not find a positive relationship between public capital and GDP. Again, diminishing returns on public capital could be part of the explanation. Interestingly, the reaction of GDP to a shock in public capital formation is almost positive on a 10 % significance level in the baseline VAR (A.1). When additional information is included via factor analysis (A.2.1) this pattern disappears. Variables omitted in the standard VAR specification may lead to an overstatement of the positive effect public capital has on GDP. Still, it is important to point out that we are looking at short-term effects and not long-term relationships. As previously mentioned, public capital is likely a key component in determining the long-term growth prospect of a country.

When considering the entire sample our findings indicate that a shock to private capital has a positive effect on public capital formation see (A.4.8). This two-way causality between public and private capital highlights the importance of using a flexible econometric structure in this line of empirical research. A production function framework would typically have required stricter assumptions about the way in which causality runs.

The second aim of this study is to investigate if expectations about public capital investment affect private sector activity. Overall the empirical analysis cannot conclude that expectations about public investments affect the private sector. Expectations may still matter as indicated by an immediate increase in private capital formation from news about higher NPV for future public investments during the period 1972-1991. The reason why this effect is only found in one subsample may be attributed to the institutional changes described in section 3. The number of components in public investments is fewer in the sample 1992-2011 compared to the time-series 1971-1992. The latter subsample does not include sectors such as telecommunications and energy production. Due to increased private sector involvement in areas such as healthcare and infrastructure, the remaining components are, to an increasing degree, substitutable with private investment. Furthermore, the NPV of public investment in the subsample 1972-1991 is based on forecasts with shorter time-frame than most of the NPV calculations in the 1992-2011 sample. Shorter time-horizons may entail a higher degree of accuracy and shorter inside-lag, which also can explain the stronger response of the private sector during 1972-1991.

The empirical findings do not suggest that timing errors exist in estimating the response to policies about public capital investments. There are two main reasons for this conclusion: First, the impulse response functions of public capital formation and forecasted public investment are

dissimilar, and often insignificant. Thus, it is hard to compare the moving-average pattern of the two variables. Second, the affect of public capital shocks on private capital formation appears to be immediate, a finding that negates the notion of a timing error.

7.1 Internal Validity

The narrative approach has previously been used to investigate the macroeconomic response to shocks in anticipated government spending. Our narrative approach, using budget bills to create a variable consisting of the net present value of future public investments, is different in several ways. The NPV Public Investment[21] cannot be ascribed the same degree of exogeneity as Ramey's new series. Ramey's series measures the impact of future government spending as a result of military emergencies, events that are seemingly unrelated to the development of the economy. Even if the information set is expanded using factor analysis, our NPV Public Investment is likely to be correlated with economic variables that we cannot account for. Furthermore, the variation in Ramey's news variable is much larger than in our net present value series. Lack of variation may be one explanation for the weak private sector response to shocks in NPV Public Investment and Public Investment Shocks. If the data set had included the cost for the Öresund Bridge our findings might have been different. Moreover, it is not plausible that prognoses about future public investments are equally relevant to all industries in the private sector. Intuitively, firms benefiting from major transport infrastructure projects should be most responsive to increases in the public capital stock. More sophisticated methods may prove that expectations about public investments affect certain segments within the private sector.

This paper has discussed inside and outside lags as a source of econometric complications, since the exact time-period of policy innovations in public capital formation cannot be captured precisely. The narrative approach used to create the NPV variables in this study does not solve the issues of inside and outside lag. Instead it offers an alternative temporal identification of public capital policy innovations.

The FAVAR approach enables the inclusion of more variables without losing degrees of freedom compared to normal VAR systems. As theory dictates, public capital may affect macroeconomic aggregates through different channels. GDP growth could be stifled from taxes used to finance a new highway, while the highway itself integrates markets and reduces trade costs which should enhance output. Internal validity is strengthened when the econometric model can account for

[21] Or NPV-2 Public Investment

several interdependencies without losing statistical power. Nevertheless FAVAR is no cure against omitted variable biases as the researcher still defines the universe in which the variables are to be selected from.

Identification of the FAVAR system is based on Cholesky decomposition. A higher degree of flexibility could have been achieved by using a structural FAVAR. While the method requires the same number of restrictions as a Cholesky-identified FAVAR, the researcher is permitted more choices in modeling the temporal dependencies among the included variables. Given apt economic reasoning a structural FAVAR would have led to an identified system which is more aligned with theory than a normal FAVAR. Internal validity could of course also decrease if the researcher's skill is not up to par.

There is always a risk that measurement errors in the data could affect findings. As the data has been retrieved from AMECO, The Swedish Central Bank and official government budgets we assume most of these errors to be minor. As net public capital investment is not efficiency-adjusted, the critique levied by Gupta, et al., (2011) is still valid. One dollar invested does not necessarily become one dollar of productive capital. This is especially problematic for studies using data from developing countries (Gupta, et al., 2011). Since we are using data from Sweden, part of this problem should be mitigated.

Gradual shifts in the composition of public investment, and increased competition of the private sector in traditionally government dominated areas of economic activity, complicates the analysis of time series data. A trade off exists between sample size and the actuality of the data.

7.2 External Validity

In this study, we have used data from Sweden. Since countries vary over several dimensions[22], which could influence the effect of public capital, extrapolation of results between countries is problematic. Similarly, there are time-specific aspects which make extrapolation of results from

[22] For example stage of economic development, demographics, size of public capital stock, quality of institutions and so forth.

one period to another difficult. Examples of such aspects are the size of the public capital stock, institutional changes, and the composition of trade and industry that vary over time.
Countries invest in public capital with different goals. A developed country may select investments meant to increase social welfare, for example by investing in hospitals, parks and housing. A developing country might be more concerned with economic growth and thereby inclined to invest in infrastructure and energy.

8. Conclusion

This paper examines the macroeconomic response to net public capital investment, prognoses about future public capital investments and deviations between actual and forecasted public investments. The latter two variables are innovations of this paper. They are used in different vector autoregressive models to determine if expectations about public capital investment affect private sector activity. Using Swedish data from 1971-2011 it is not possible to conclude that the private sector reacts to changes in expectations about public investment levels.

The standard VAR specification used to estimate the effects of public capital includes the following variables: net public capital formation, net private capital formation, GDP, and aggregate hours worked. This is arguably only a subset of the variables policy makers evaluate when determining the level of public investments. To determine if the results from this specification is robust to the inclusion of more information we detect the short-term macroeconomic effects of net public capital investments by augmenting the standard VAR with factor analysis. The results show no short-term positive effect between public capital investments and output, a finding which contradicts most of the previous literature. Public capital formation is found to have a positive effect on private capital formation, a result that coincides with the majority of earlier work. Positive factor loadings in our FAVAR models indicate that valid information is left out of the standard VAR specification.

To investigate whether institutional changes in Sweden after the 1990s has affected our findings we created two subsamples consisting of data from the time period 1971-1991 and 1992-2011. The findings from 1971 - 1991 mostly overlap with the results from the entire sample. One major difference is that news about future public investments has a positive effect on private capital formation. The second subsample yields more dispersed results. Public capital formation does not have an affect on private capital formation, which is statistically different from zero using a

10 % significance level. Altogether, these results indicate a weaker reaction from the private sector to public investment policies in the last two decades

Further research about the effects of public capital investment should account for country-specific institutional changes to avoid drawing inaccurate inference. Moreover, an alternative way to estimate potential anticipation effects is to construct the forecast variable using news sources to identify major public investment projects. Finally, inclusion of factor analysis in VAR systems should be considered to avoid exaggerated inference.

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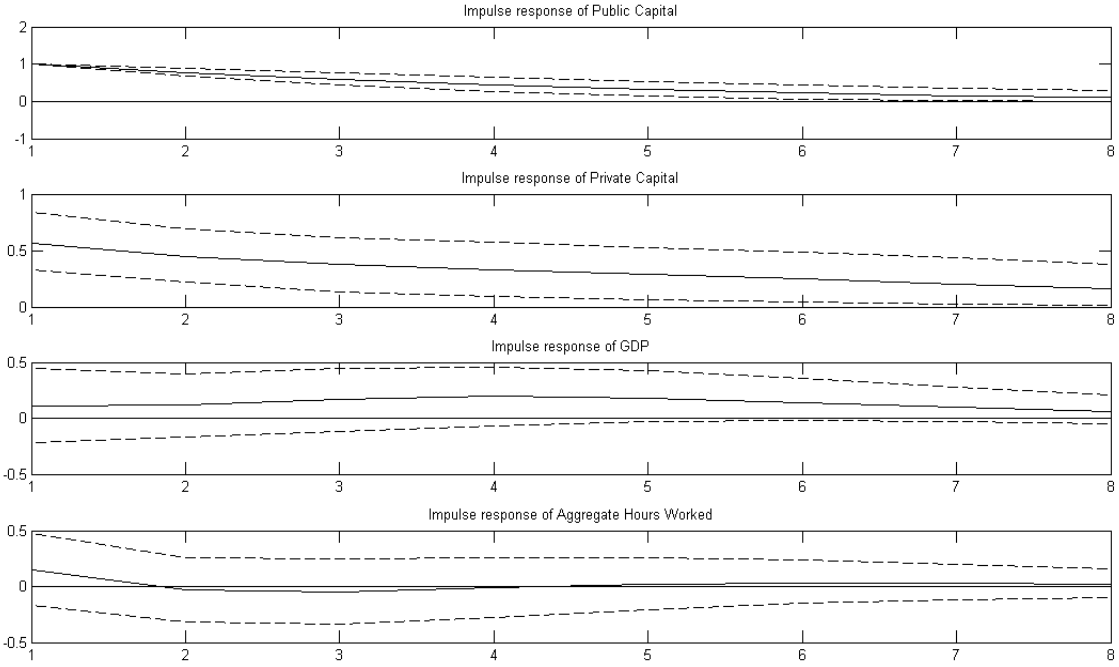
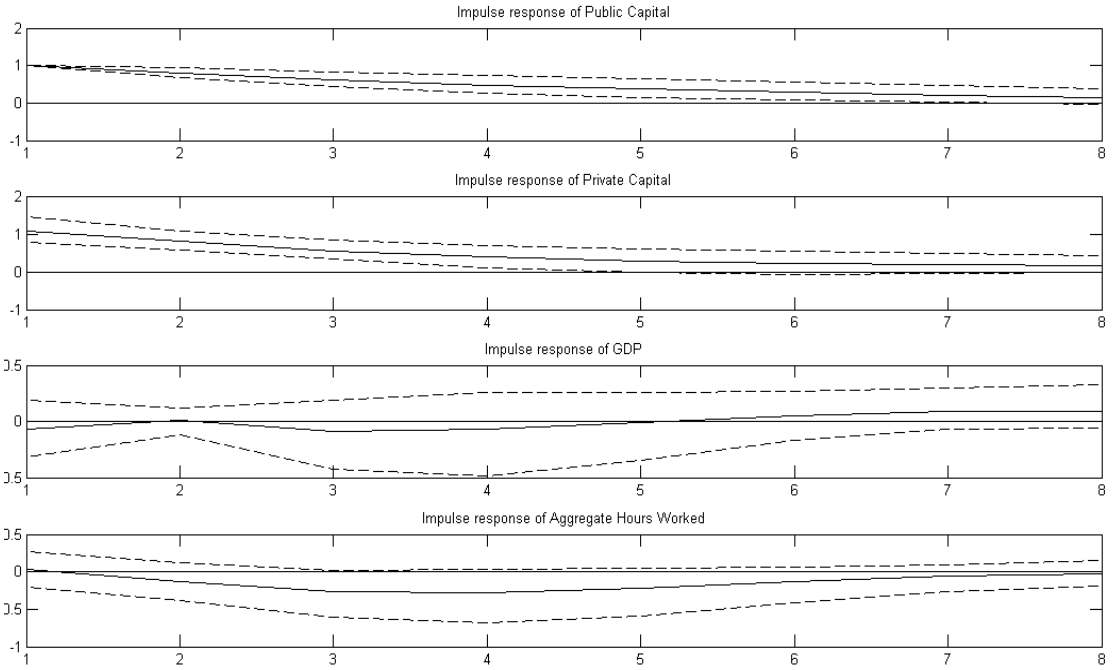
Appendix A – Empirical Findings

A.1 IRF Baseline VAR. Time Period: 1972-2011



A.2.1 IRF FAVAR (I) Main Variables. Time Period: 1972-2011



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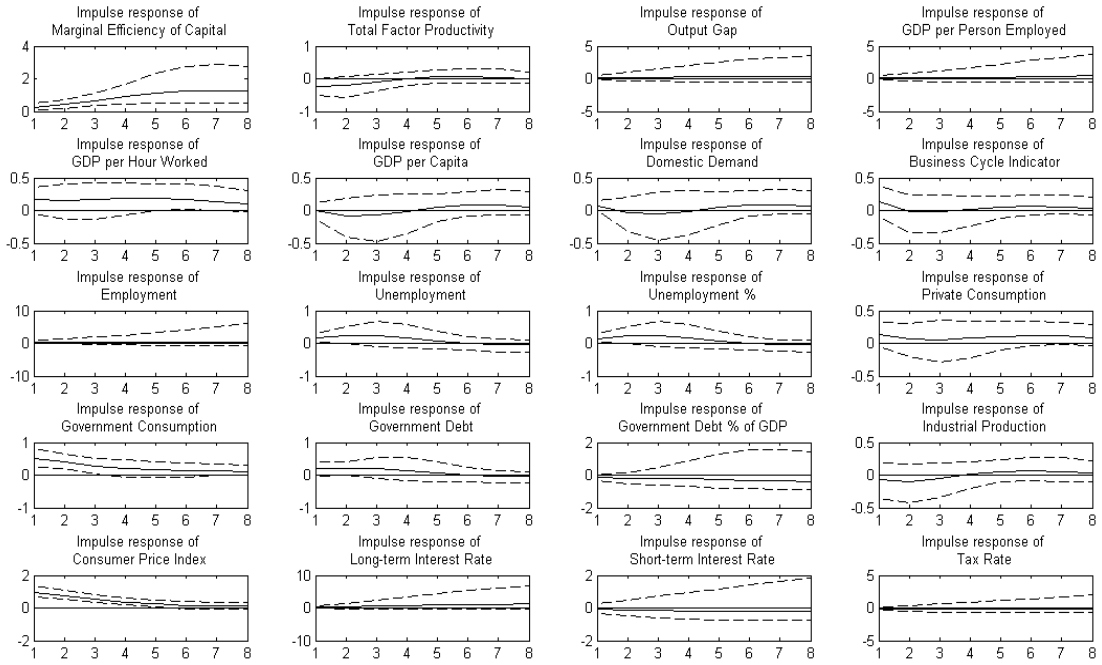

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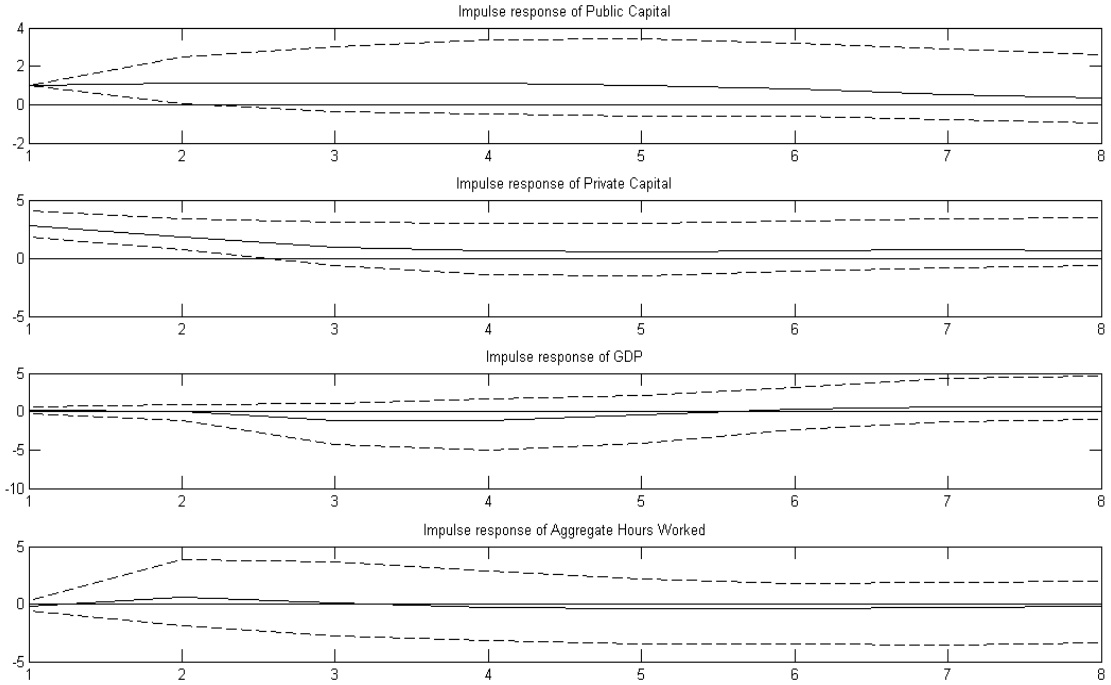

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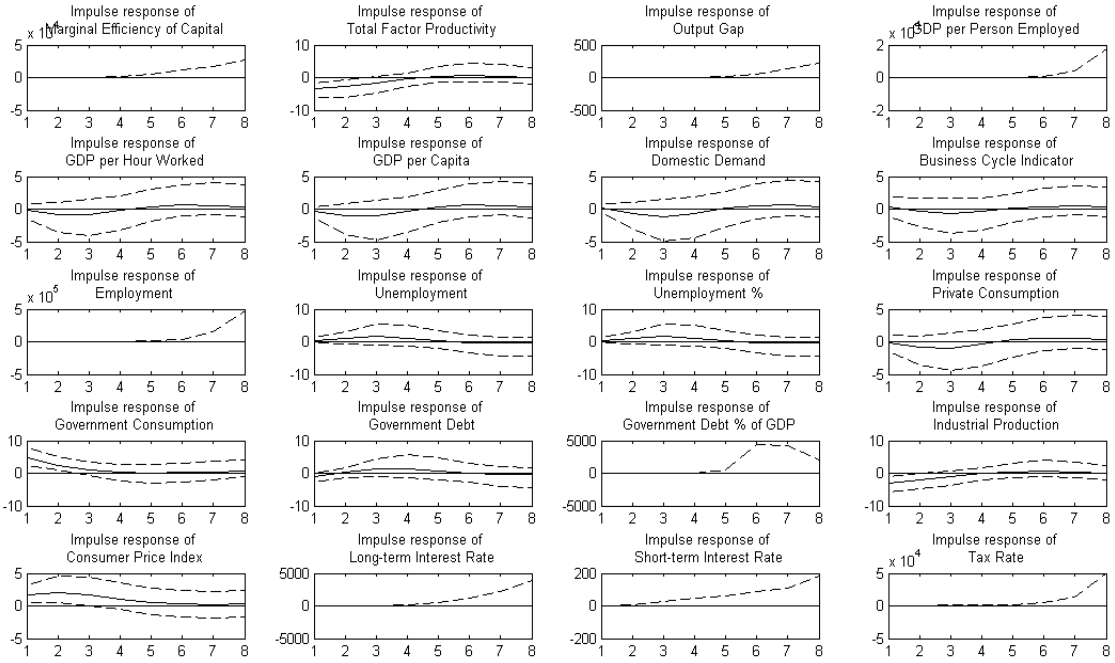

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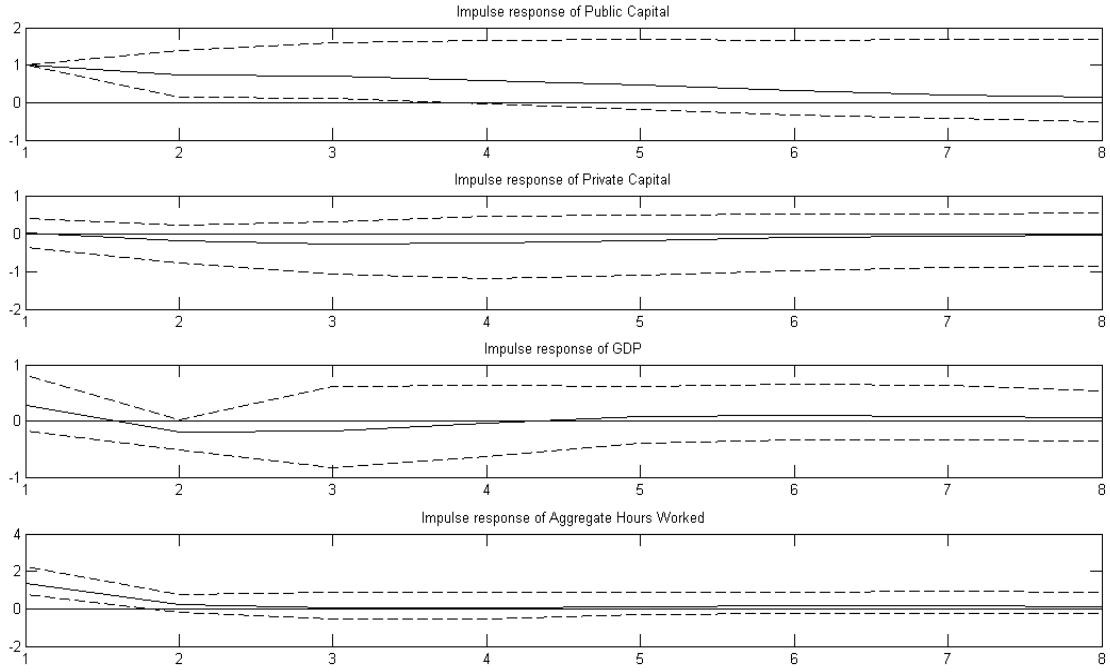
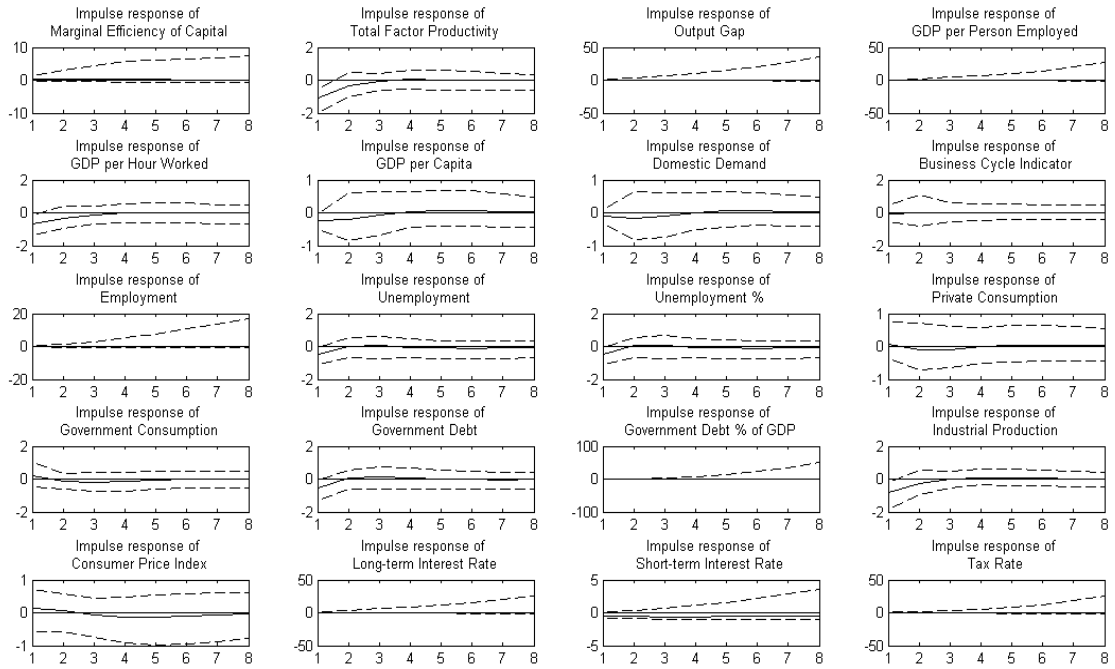


A.2.6 FAVAR (I) Factor Variables. Time Period: 1992-2011



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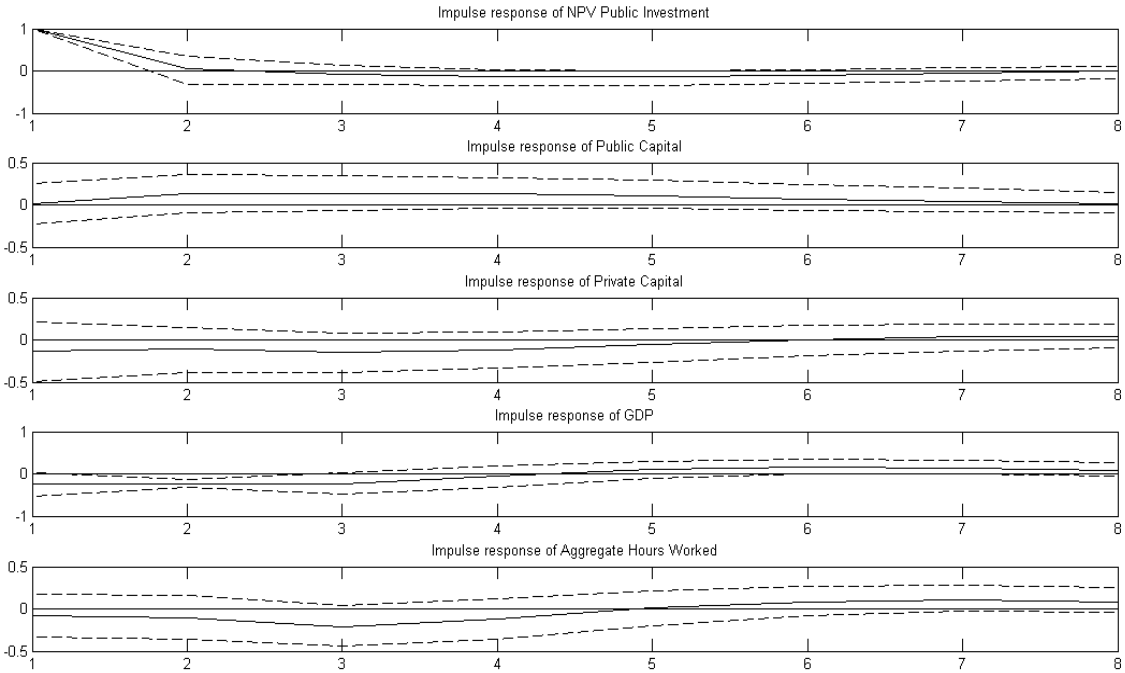

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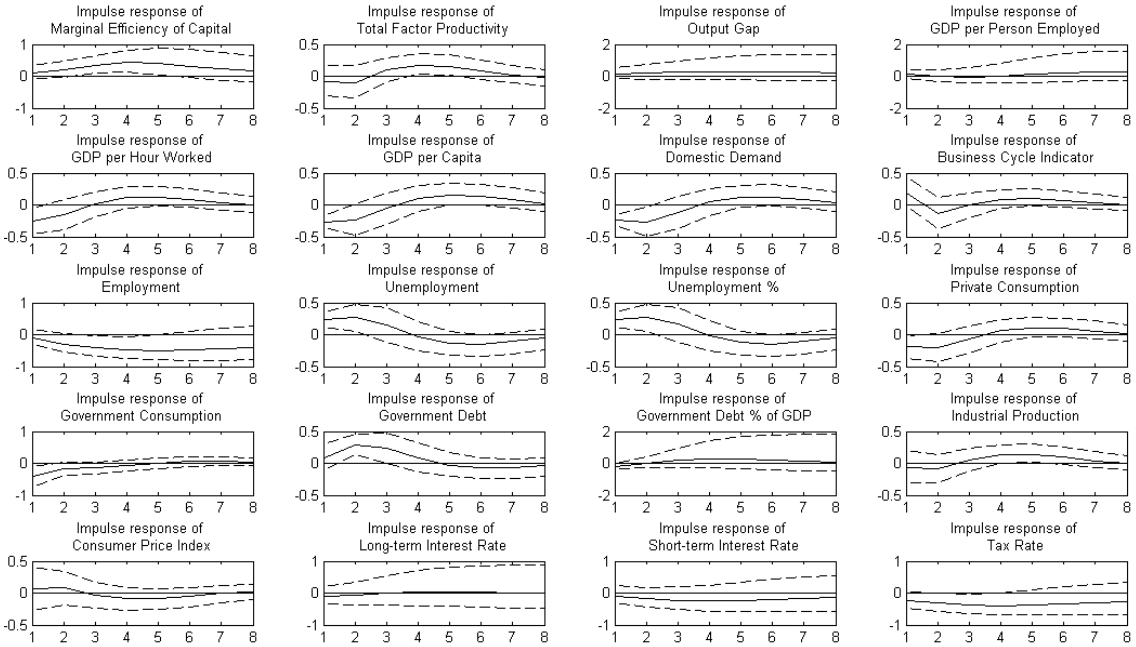

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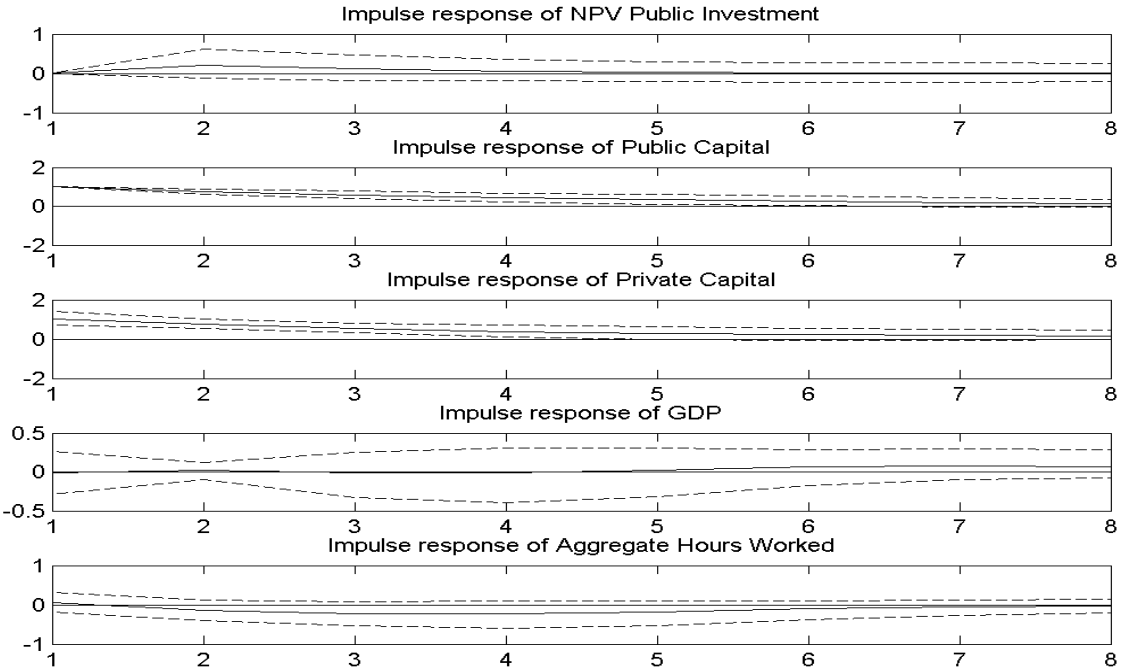

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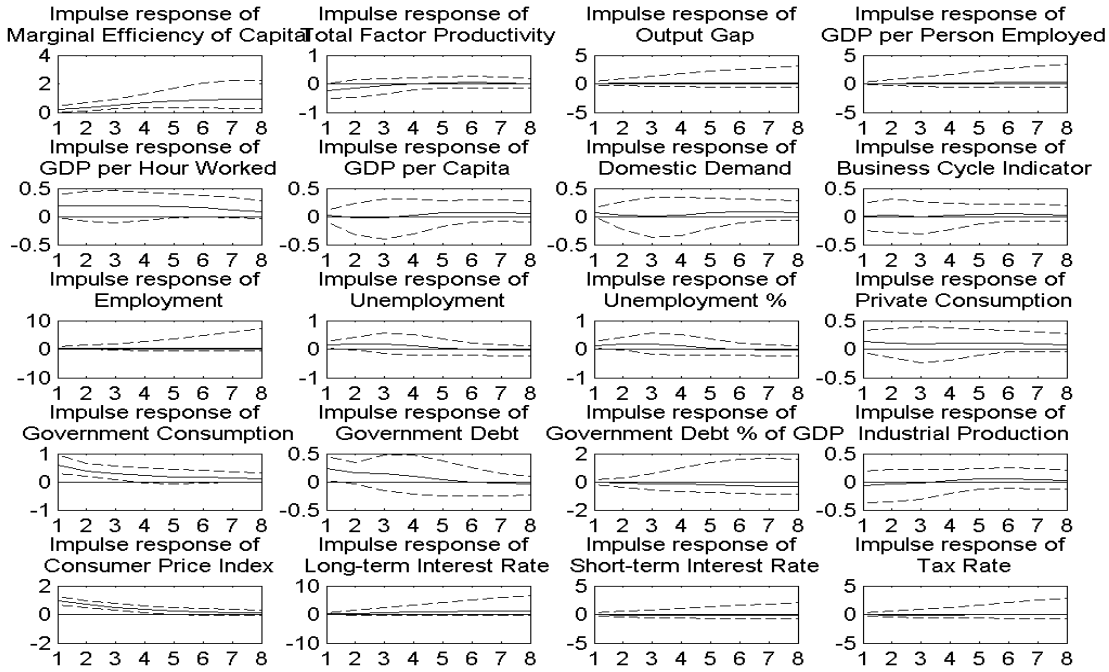
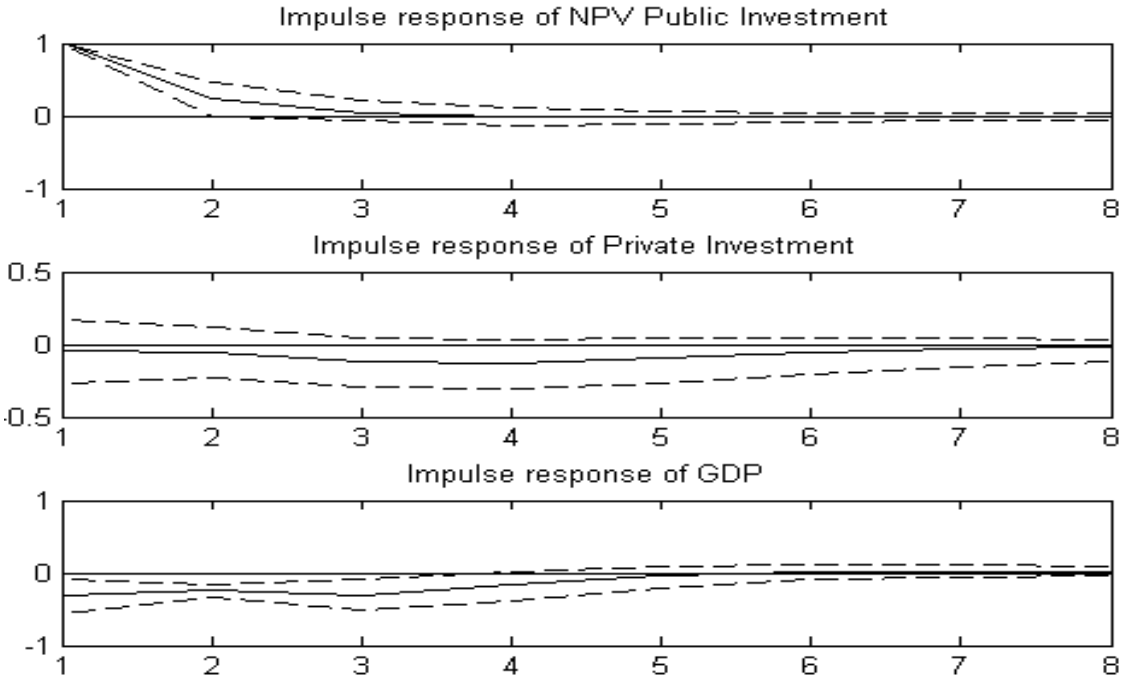


A.4.1. IRF FAVAR (III) Main Variables. Time Period: 1972-2011.



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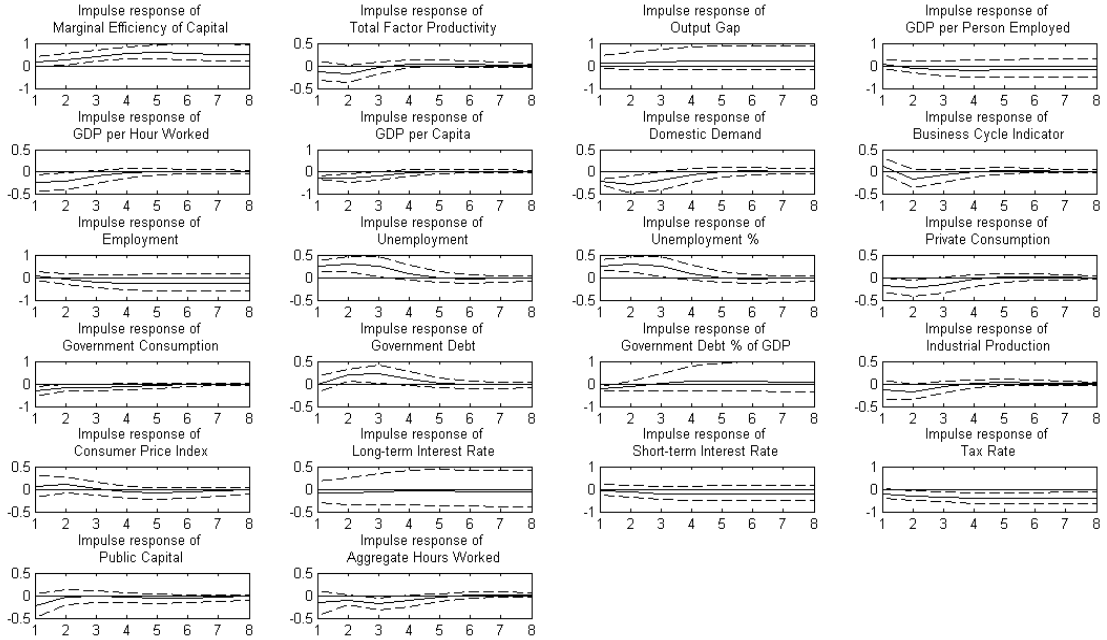

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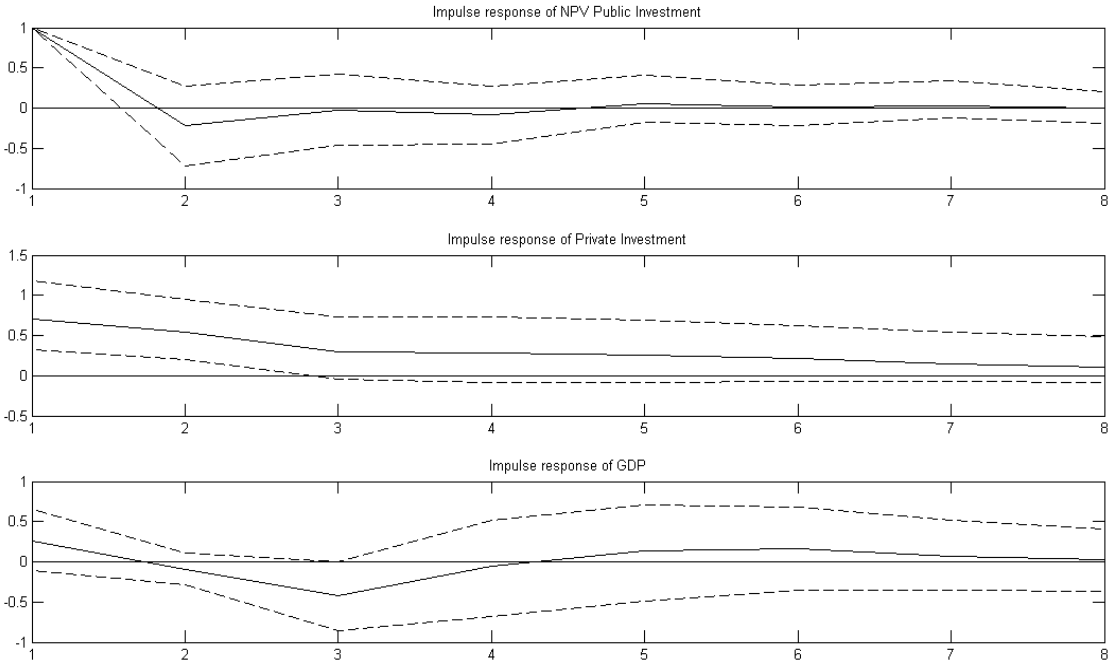

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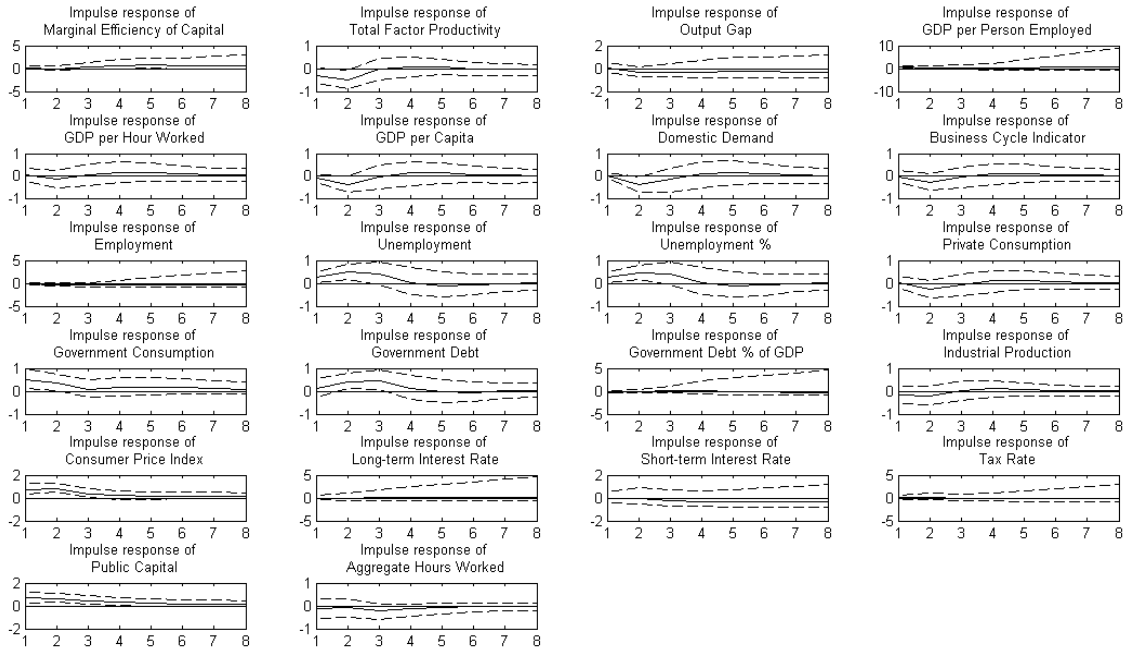

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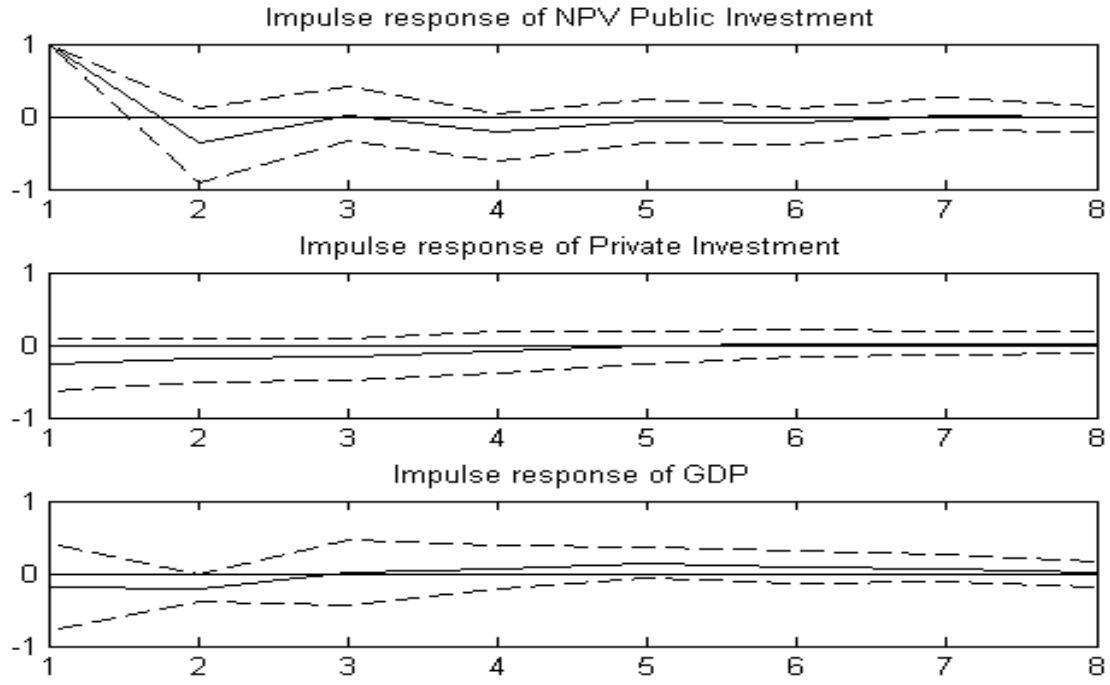

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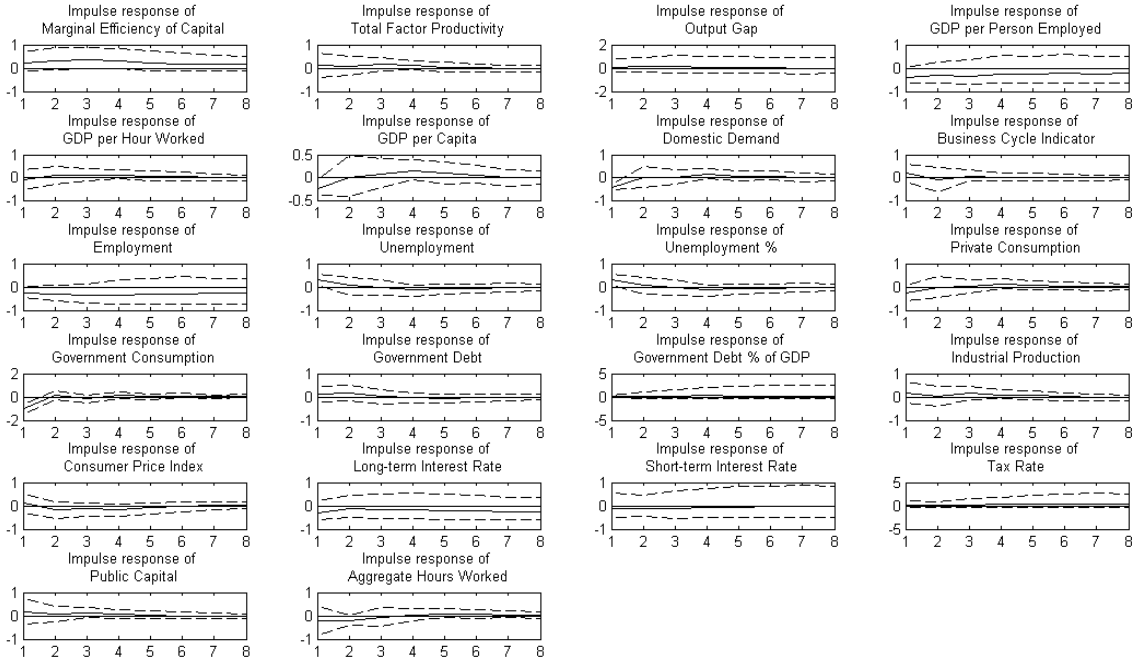
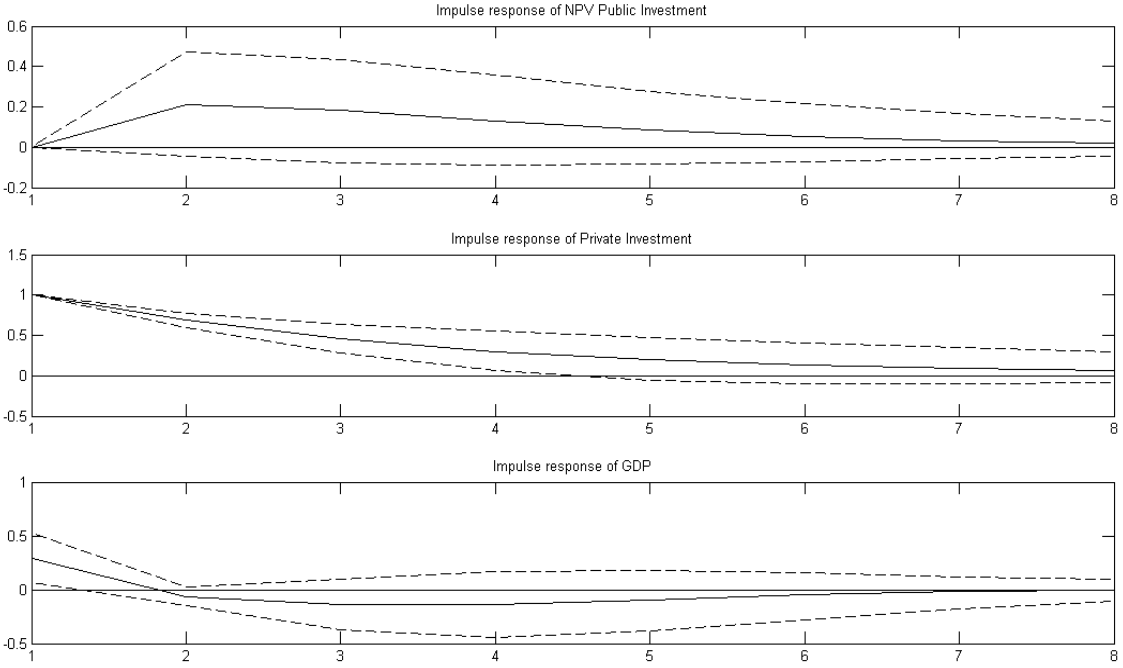


A.4.7 IRF FAVAR (III) Main Variables. Private Capital Shock. Time Period: 1972-2011



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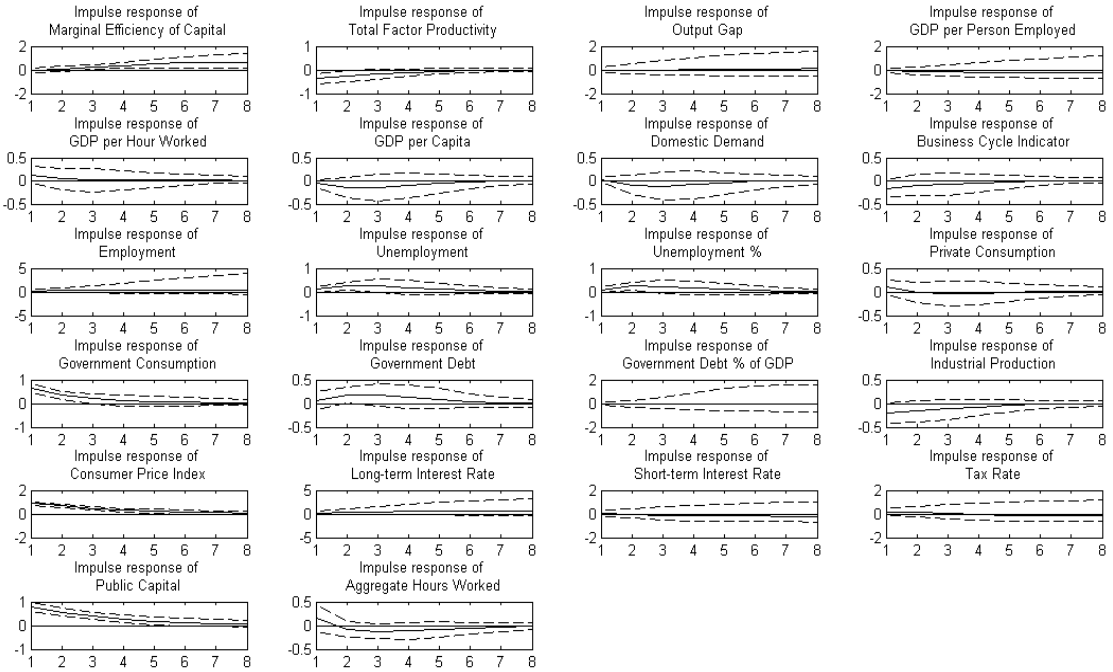
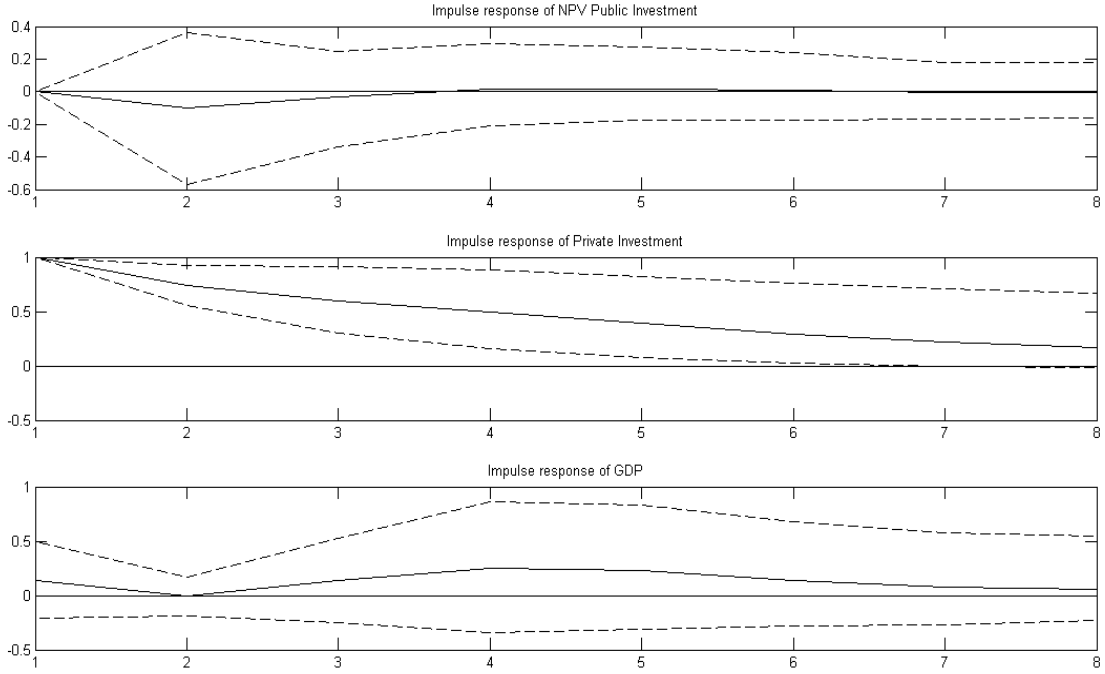
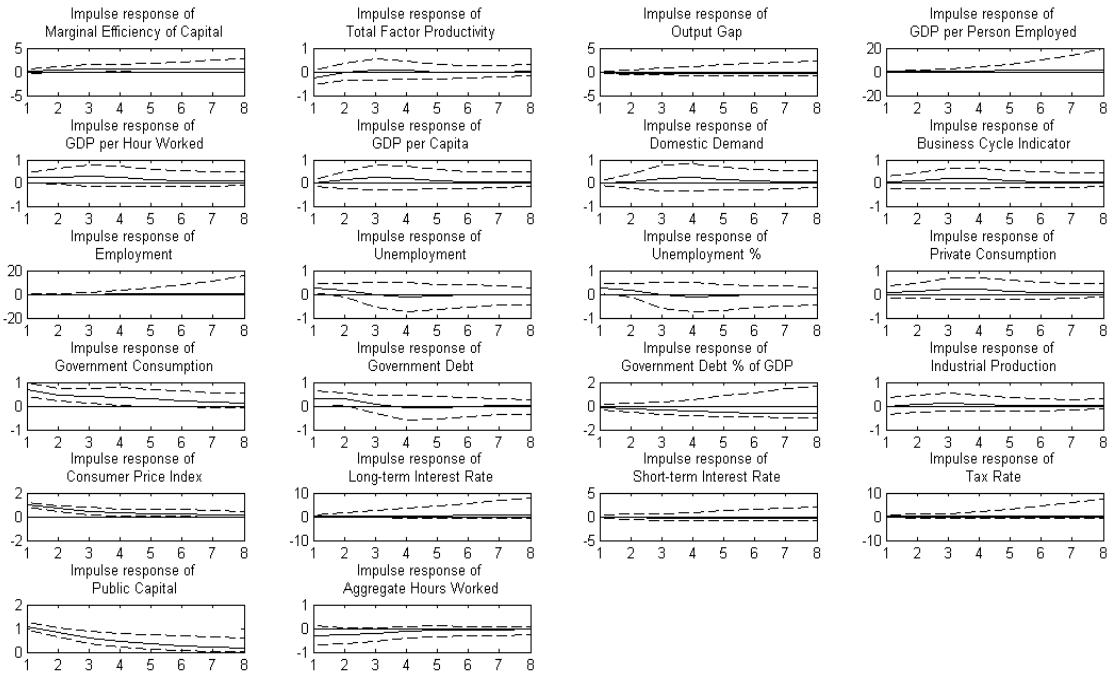


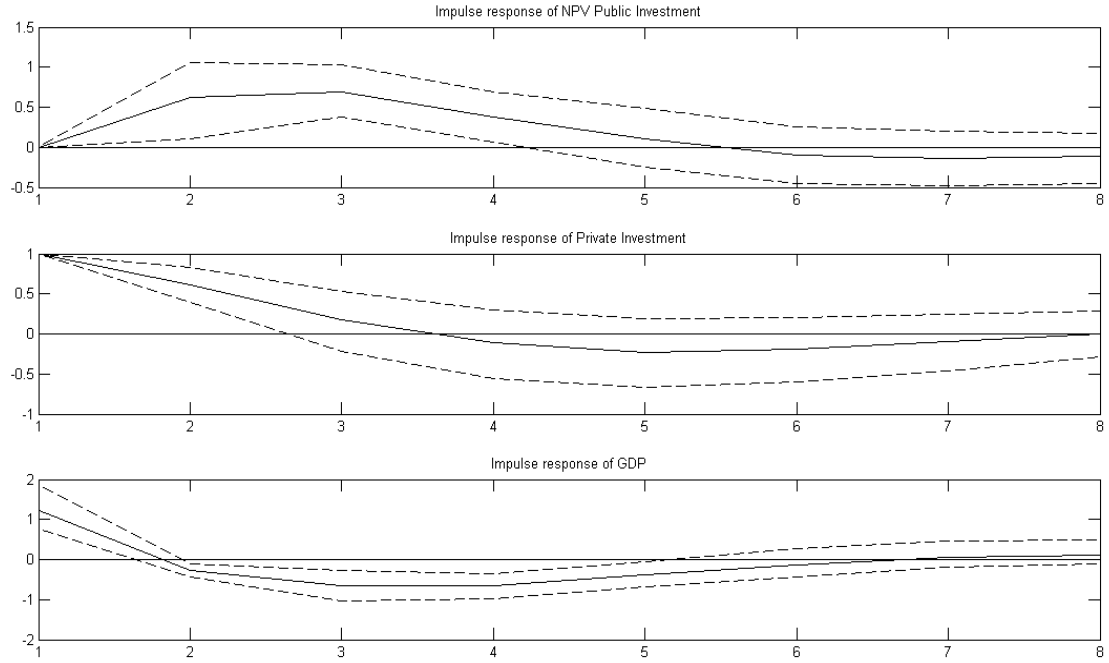
A.4.9 IRF FAVAR (III) Main Variables. Private Capital Shock. Time Period: 1972-1991



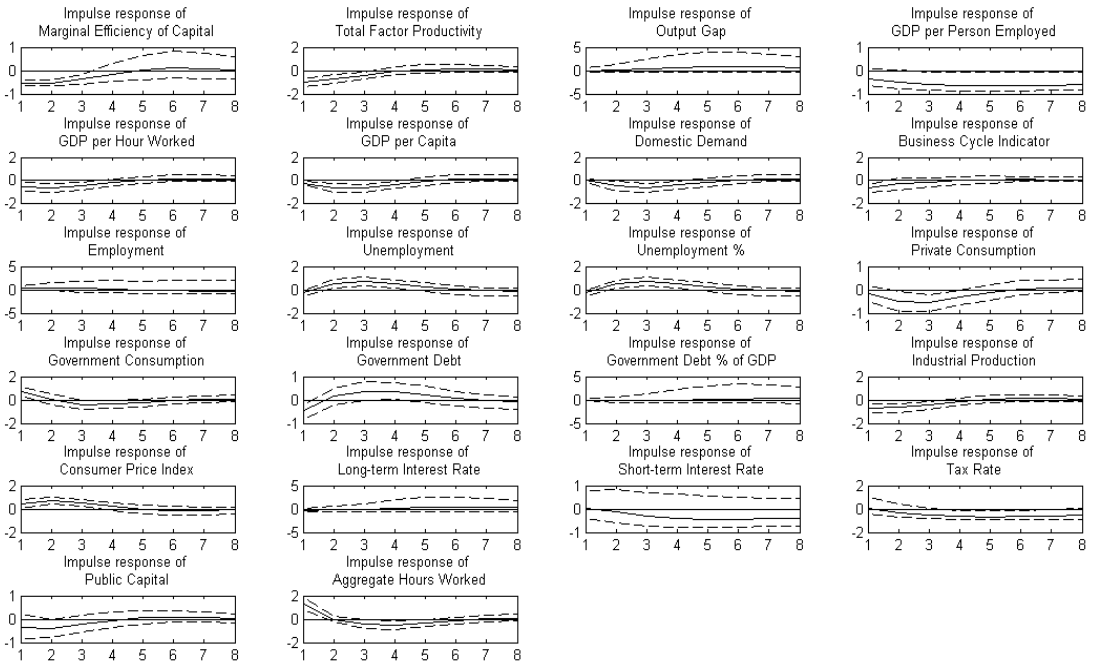
A.4.10 IRF FAVAR (III) Factor Variables. Private Capital Shock. Time Period: 1972-1991



A.4.11 IRF FAVAR (III) Main Variables. Private Capital Shock. Time Period: 1992-2011



A.4.12 IRF FAVAR (III) Factor Variables. Private Capital Shock. Time Period: 1992-2011



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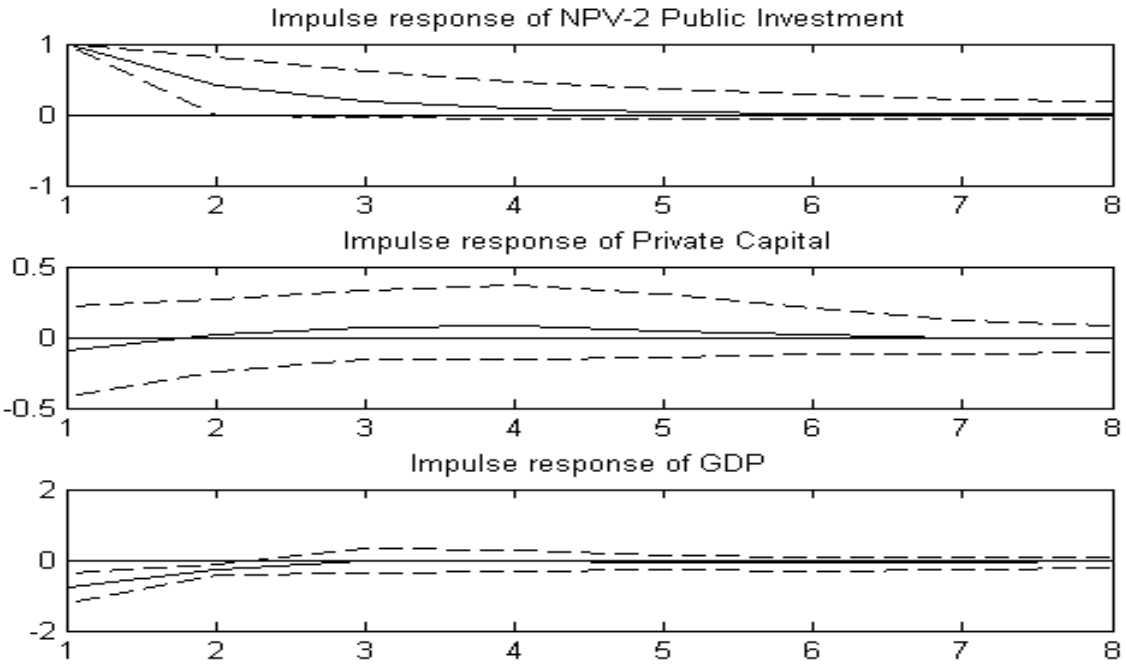

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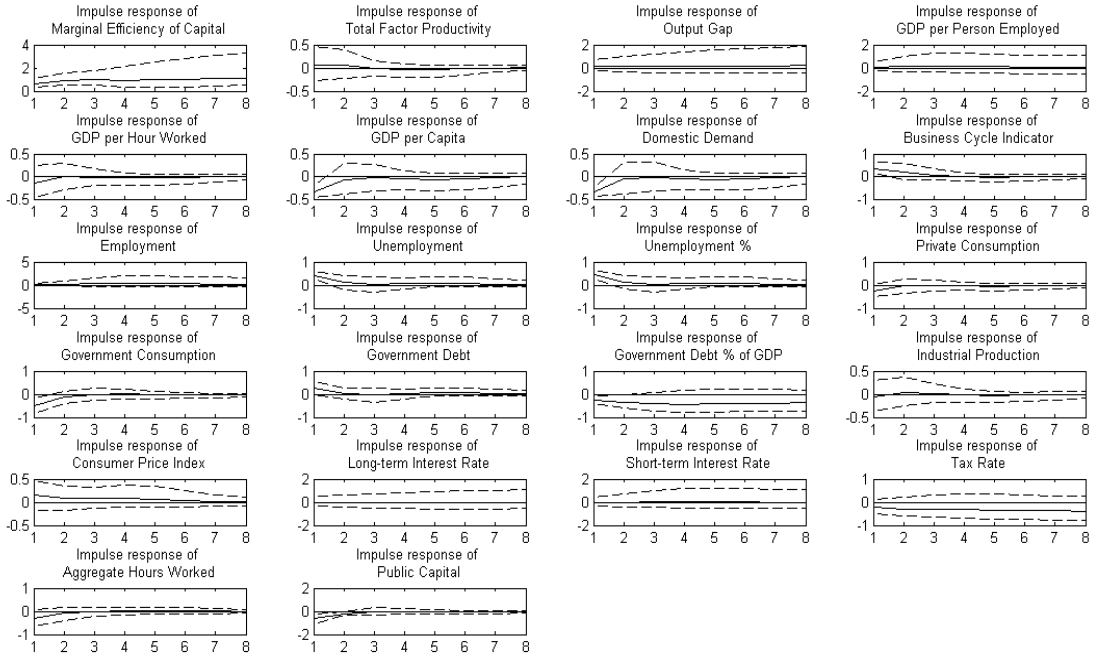
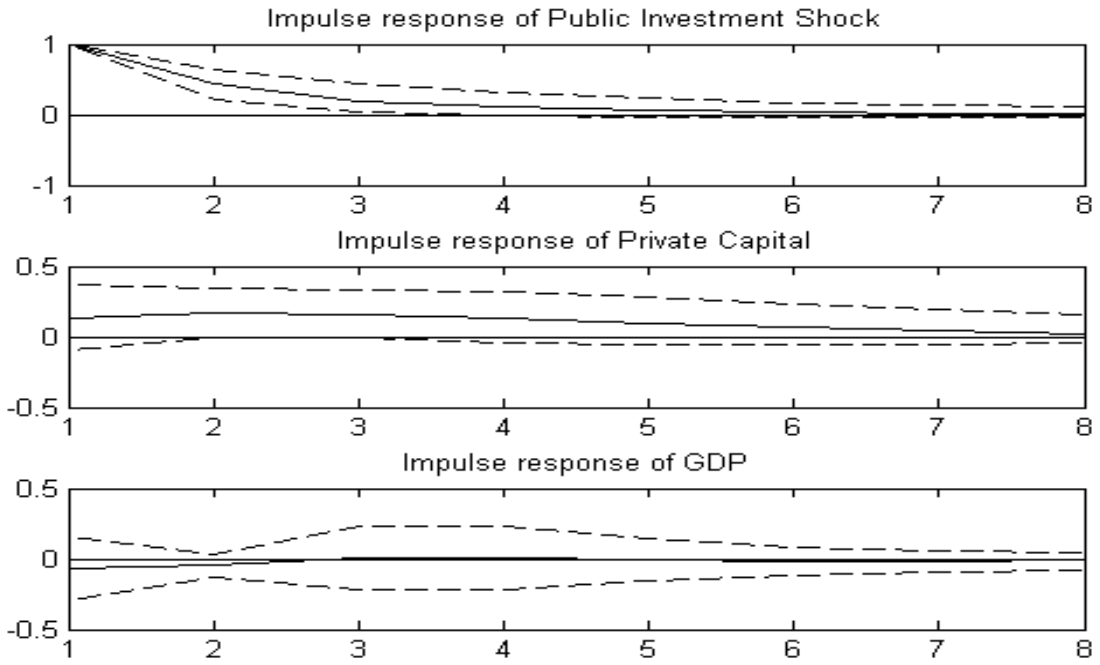


A.6.1 IRF FAVAR (V) Main Variables. Time Period: 1972-2011



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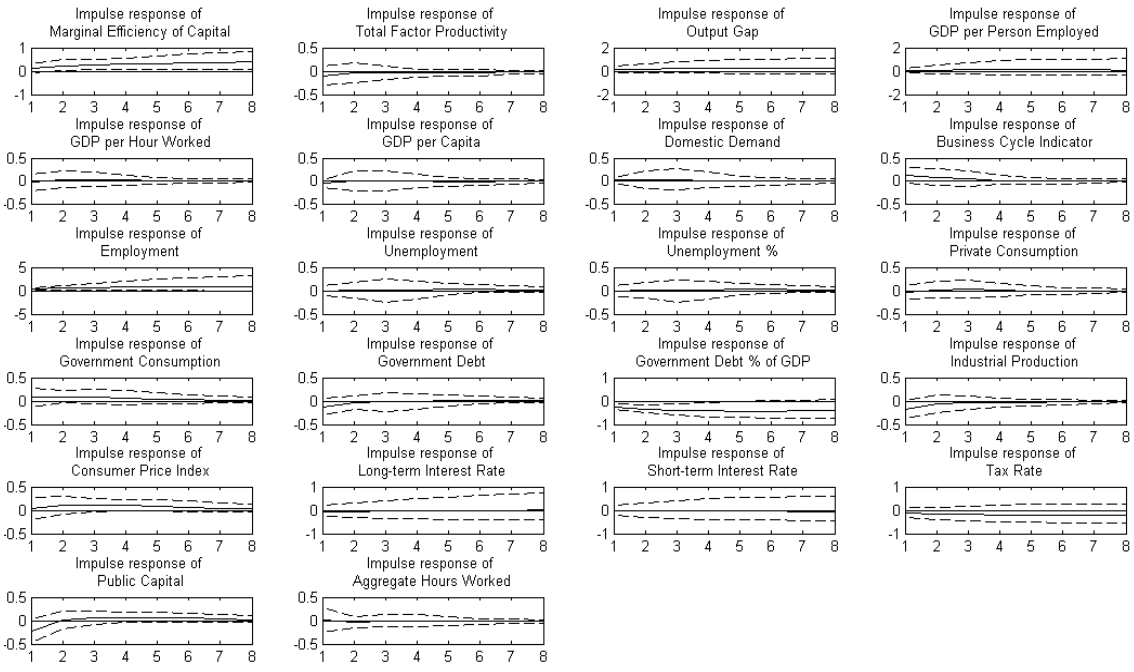

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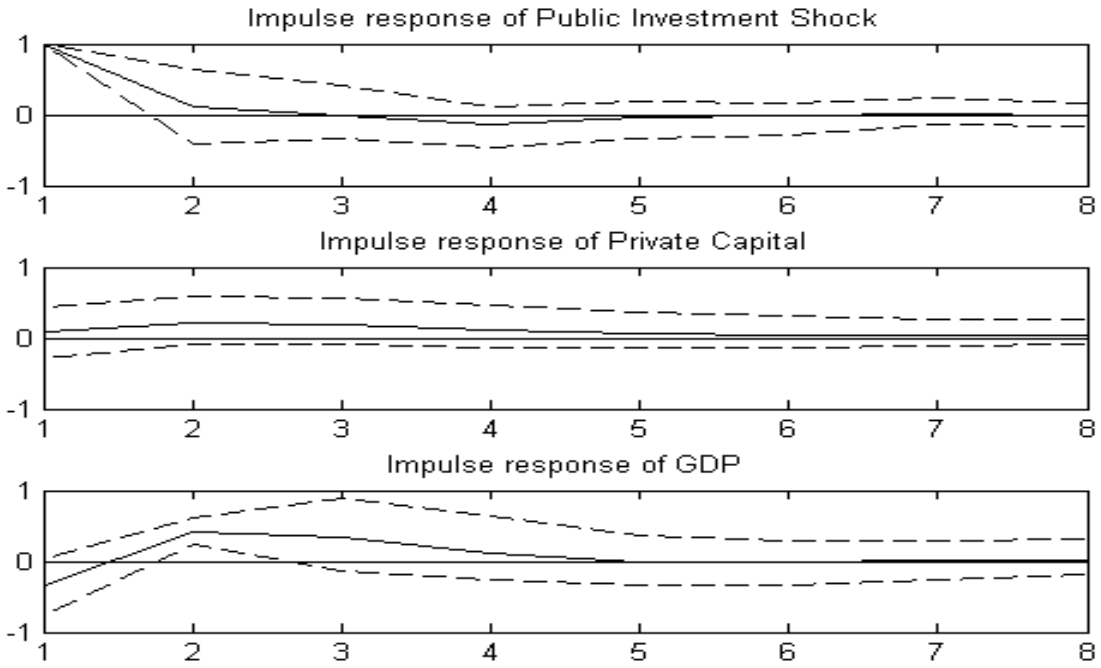

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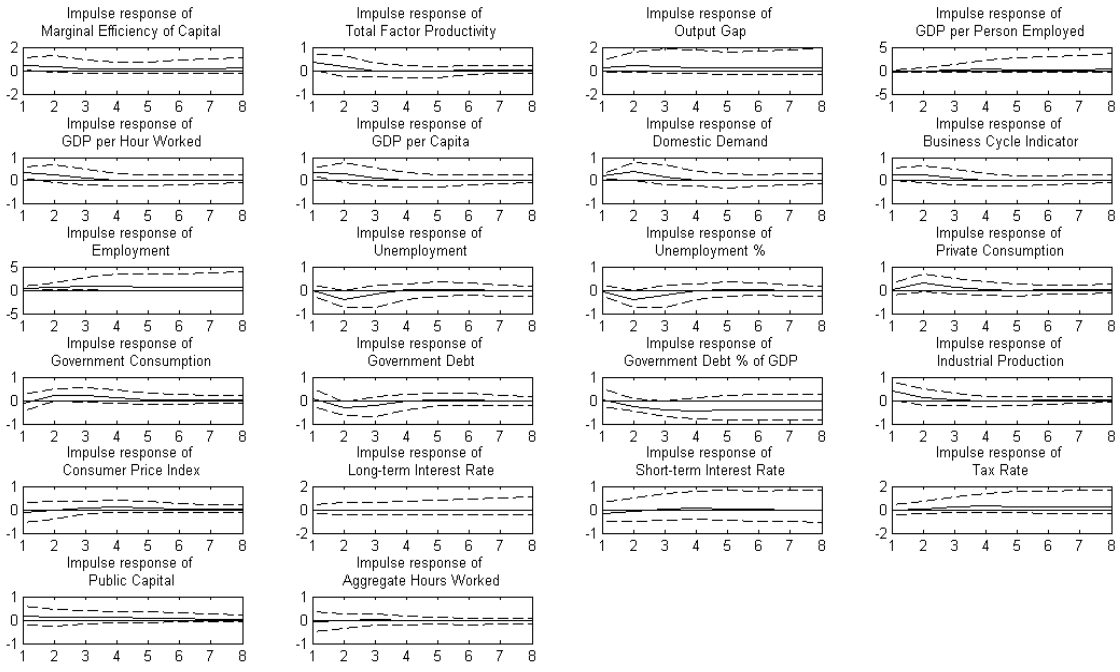
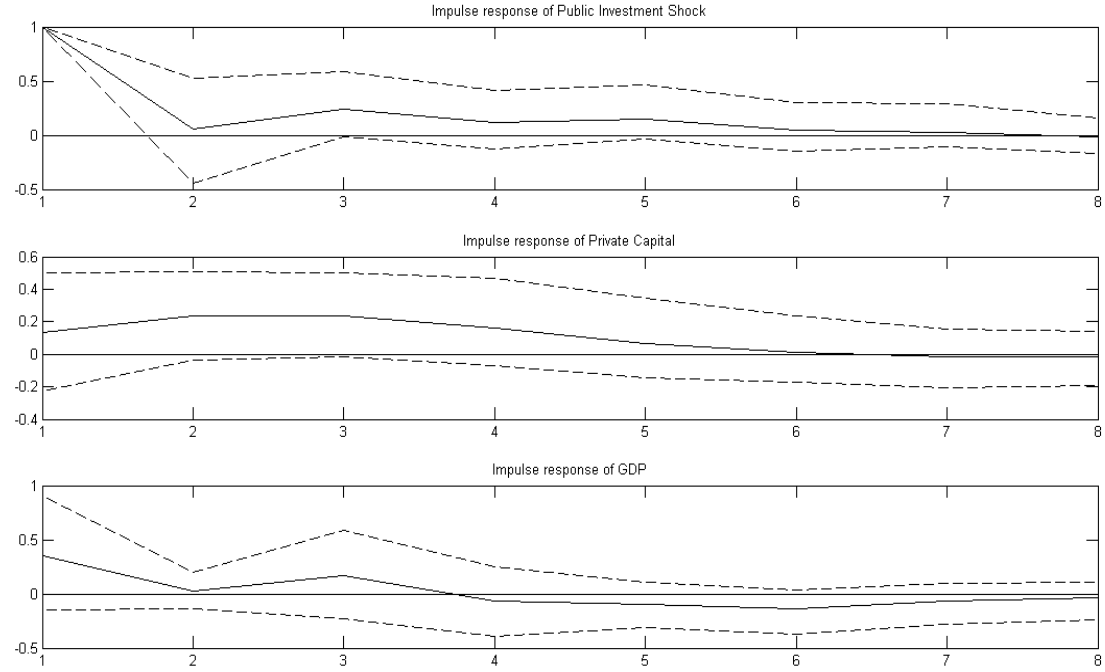


A.6.5 IRF FAVAR (V) Main Variables. Time Period: 1992-2011.



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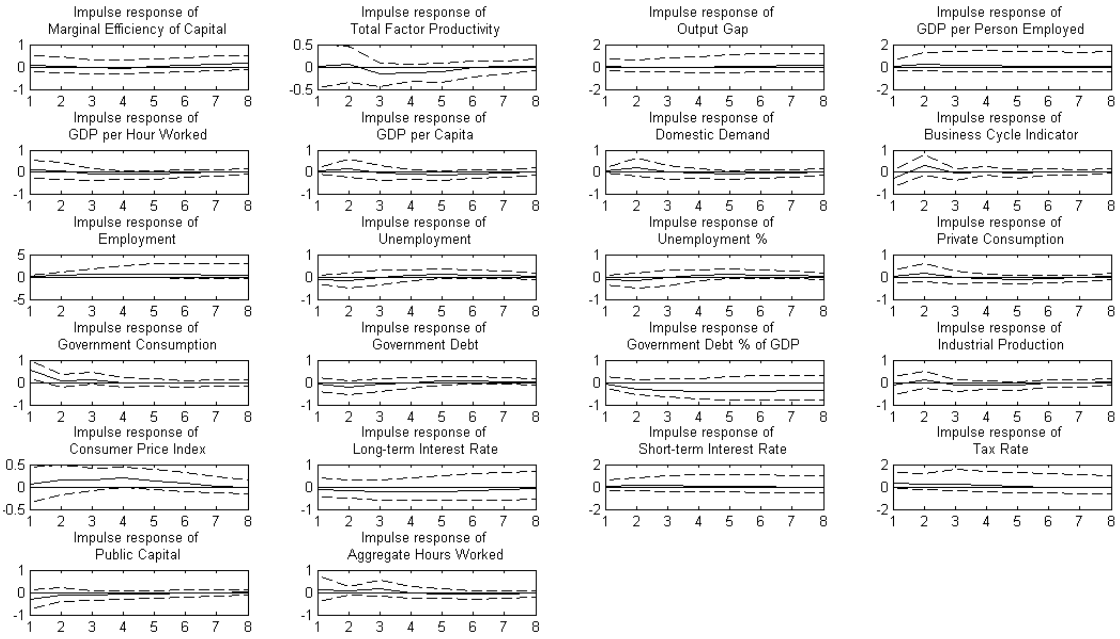


Appendix B – Diagnostic Testing

B. 1 Dickey – Fuller Test – Main Variables

Augmented Dickey-Fuller Unit Root Test						N=35
Variable	Lags	T-stat	5 % Critical Value	Transformation	T-stat	5 % Critical
Aggregate Hours Worked	3	-0.371	-2.268	HP-filter	-3.782	-2.275
Aggregate Hours Worked	2	-0.022	-2.305	HP-filter	-3.528	-2.312
Aggregate Hours Worked	1	-0.328	-2.337	HP-filter	-4.841	-2.346
GDP	3	0.385	2.268	HP-filter	-2.968	-2.275
GDP	2	1.374	2.305	HP-filter	-2.346	-2.312
GDP	1	1.34	2.337	HP-filter	-3.826	-2.346
Net Private Capital Formation	3	-0.229	-2.268	HP-filter	-3.986	-2.275
Net Private Capital Formation	2	0.238	2.305	HP-filter	-3.316	-2.312
Net Private Capital Formation	1	-0.022	-2.337	HP-filter	-4.772	-2.346
Net Public Capital Formation	3	-0.033	-2.268	HP-filter	-3.901	-2.275
Net Public Capital Formation	2	0.53	2.305	HP-filter	-3.258	-2.312
Net Public Capital Formation	1	0.315	2.337	HP-filter	-4.669	-2.346
NPV Public Investment*	3	-1.539	-2.268	Log-difference	-1.731	-2.275
NPV Public Investment*	2	-1.275	-2.305	Log difference	-2.065	-2.312
NPV Public Investment*	1	-1.077	-2.337	Log Difference	-2.830	-2.346
Public Investment Shock	3	-2.347	-2.268	None	N/A	N/A
Public Investment Shock	2	-1.700	-2.305	None	N/A	N/A
Public Investment Shock	1	-3.462	-2.337	None	N/A	N/A

*The same transformation is used to induce stationarity for NPV-2.

Notes: The null hypothesis in the Dickey-fuller test is that each variable has a unit root against the alternative that it does not. If a unit root is found, a transformation (log difference, first difference or trend removal by using the Hodrick Prescott (HP) filter) is used to make the time series stationary. A second dickey-fuller test is used to test whether the transformation succeeded in rendering the time series stationary.

B. 2 Dickey-Fuller Test - Factor Variables

Augmented Dickey-Fuller Unit Root Test					N=35		
	Unit Root Test				Unit Root Test		
	Lag 3	Lag 2	Lag 1	Transformation	Lag 3	Lag 2	Lag 1
Tax Rate	-1.049	-1.012	-1.149	Log-difference	-2.632	-2.75	-3.79
Marginal Efficiency of Capital	-1.564	-2.144	-3.137	Log-difference	-2.761	-3.724	-4.809
Output Gap	-1.41	-1.616	-2.486	Log-difference	-3.488	-4.036	-5.709
GDP per person employed	-1.171	-1.181	-1.639	Log-difference	-2.799	-3.515	-4.655
GDP per hour worked	0.215	0.777	0.996	HP-filter	-2.78	-1.977	-2.656
GDP per capita	0.178	1.003	0.909	HP-filter	-3.076	-2.391	-3.815
Long-term interest rate	-1.799	-1.676	-1.813	Log-difference	-2.088	-2.925	-5.244
Employment	-0.947	-0.21	-1.127	Log-difference	-2.701	-2.728	-4.558
Unemployment	-1.029	-0.856	-1.574	HP-filter	-3.181	-3.136	-4.924
Private consumption	0.669	1.043	1.282	HP-filter	-3.242	-2.398	-2.744
Government consumption	0.41	0.655	1.087	HP-filter	-2.556	-2.408	-2.348
Government Debt	-0.836	-0.857	-0.889	HP-filter	-3.378	-3.136	-3.553
Government Debt as percent of GDP	-1.452	-1.582	-1.861	Log-difference	-2.587	-2.679	-2.978
Domestic Demand	0.84	1.386	1.393	HP-filter	-3.22	-2.948	-3.666
Industrial Production	0.033	0.465	0.29	HP-filter	-2.94	-3.475	-4.867
CPI	-0.215	-0.006	0.22	HP-filter	-1.667	-1.731	-2.059
Unemployment percent	-1.297	-1.033	-1.808	HP-filter	-3.162	-3.128	-4.949
Total Factor Productivity	0.666	0.956	0.988	HP-filter	-3.589	-3.858	-4.289
Short-term Interest Rate	-0.756	-0.722	-0.942	Log-difference	-3.1	-4.504	-6.913
Business Cycle Indicator	-1.694	-2.41	-3.593	None	N/A	N/A	N/A
Critical Value 5 %	-2.262	-2.297	-2.329		-2.275	-2.312	-2.346

Notes: The null hypothesis in the Dickey-fuller test is that each variable has a unit root against the alternative that it does not. If a unit root is found, a transformation (log difference, first difference or trend removal by using the Hodrick-Prescott (HP) filter) is used to make the time series stationary. A second dickey-fuller test is used to test whether the transformation succeeded in rendering the time series stationary.

B. 3 Engle-Granger Test for Cointegration – Main Variables

Engle-Granger test for Cointegration			
Dependent Variable	Independent Variables	Test Statistic	5 % Critical Value
L	Y, K, P	-2.186	-4.7
L	Y, K, P, NPV	-2.471	-4.7
Y	L,K,P	-2.417	-4.7
Y	L,K,P,NPV	-2.787	-4.7
Y	K,NPV	-2.215	-4.7
Y	K,NPV2	-1.941	-4.7
Y	K, PS	-1.868	-4.7
K	L,Y,P	-2.183	-4.7
K	L,Y,P,NPV	-2.132	-4.7
K	Y,NPV	-2.878	-4.7
K	Y,NPV2	-1.951	-4.7
K	Y,PS	-1.706	-4.7
P	L,Y,K	-2.243	-4.7
P	L,Y,K,NPV	-1.966	-4.7
NPV	P,L,K,Y	-2.59	-4.7
NPV	K,Y	-2.361	-4.7
NPV2	K,Y	-2.542	-4.7
PS	K,Y	-2.613	-4.7

Source critical values: Enders (2008). L=Aggregate Hours Worked, Y=GDP, P=Net Public Capital Formation, K=Net Private Capital Formation, NPV=Net Present Value of Public Investment, Short-term Forecast NPV2=Net Present Value of Public Investment, Intermediate-term Forecast, PS=Public Investment Shock

Notes: The null hypothesis is that the residuals contain a unit root, against the alternative hypothesis that they do not. If the null hypothesis is not rejected there is a strong indication that the variables are not cointegrated.

B. 4 Lag Length Selection

VAR Lag Selection (* marks selected lag-length)							
Model	Lags	AIC	HQIC	SBIC	Normality	Autocorrelation	Stability
Baseline VAR/FAVAR(I)	0	-29	-29.2	-29			
Baseline VAR/FAVAR(I)	1*	-35	-34.2	-34	Yes	No	Yes
Baseline VAR/FAVAR(I)	2	-34	-33.8	-33			
Baseline VAR/FAVAR(I)	3	-34	-33.3	-32			
Baseline VAR/FAVAR(I)	4	-34	-33.2	-31			
FAVAR(II)	0	-32	-31.5	-31			
FAVAR(II)	1*	-37	-36.1	-35	Yes	No	Yes
FAVAR(II)	2	-36	-35.5	-34			
FAVAR(II)	3	-36	-34.6	-32			
FAVAR(II)	4	-36	-32.3	-32			
FAVAR(V)	0	-21	-21.3	-21			
FAVAR(V)	1*	-26	-25.9	-25	Yes	No	Yes
FAVAR(V)	2	-26	-25	-23			
FAVAR(V)	3	-26	-24.9	-23			
FAVAR(V)	4	-27	-25.3	-22			

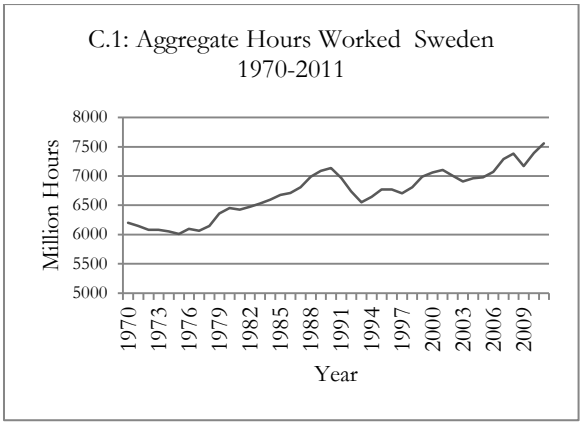
Notes: For *FAVAR(III)* and *FAVAR(IV),* selected lag-length is also 1. Exact values for the various criteria are available upon request.

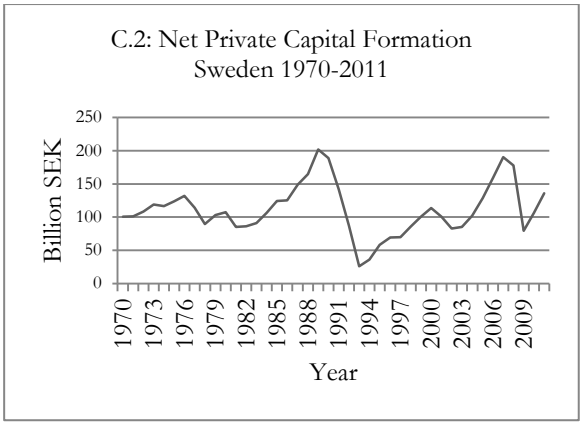
B. 5 Fast and Slow Moving Factor Variables

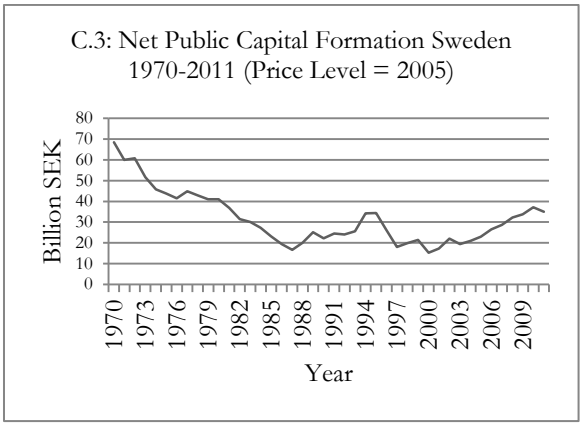
Variable	Specification 2-5	Specification 6
Marginal Efficiency of Capital	Slow	Slow
Total Factor Productivity	Slow	Slow
Output Gap	Slow	Slow
GDP per person employed	Slow	Slow
GDP per hour worked	Slow	Slow
GDP per capita	Slow	Slow
Domestic Demand	Slow	Slow
Business Cycle Indicator	Slow	Slow
Employment	Slow	Fast
Unemployment	Slow	Fast
Unemployment, % of Workforce	Slow	Fast
Private Consumption	Slow	Slow
Government Consumption	Fast	Fast
Government Debt	Fast	Fast
Government Debt, % of GDP	Fast	Fast
Industrial Production	Slow	Slow
Consumer Price Index	Slow	Slow
Long-term Interest Rate	Fast	Fast
Short-term Interest Rate	Fast	Fast
Tax Rate	Fast	Fast
Net Public Capital Formation	Slow	Fast
Aggregate Hours Worked	Slow	Fast

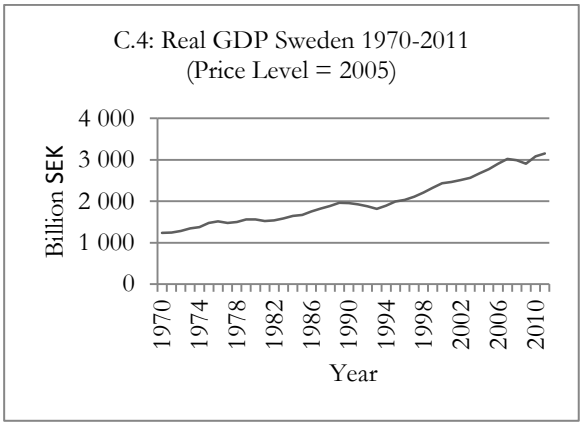
Appendix C – Time Series

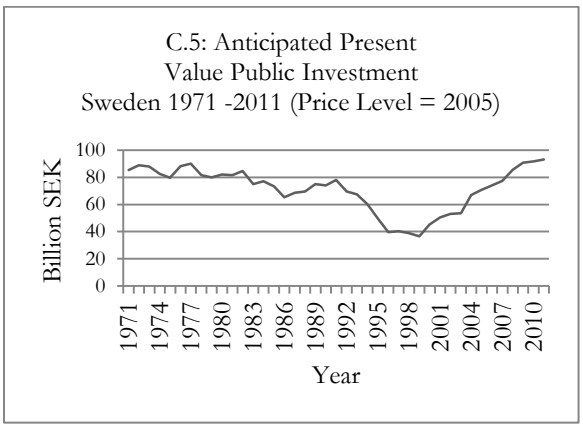
C. 1 – C.25 Graphs of Factor Extracting and Miscellaneous Variables

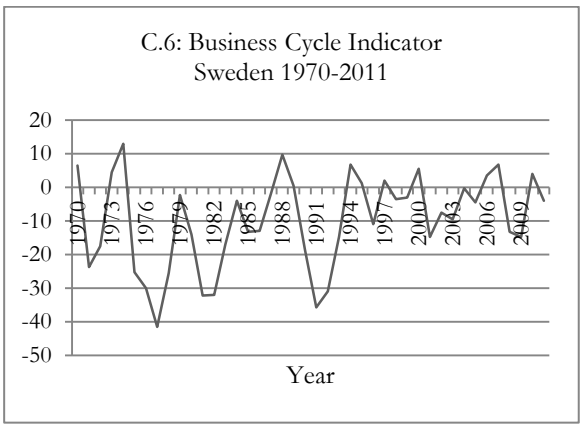






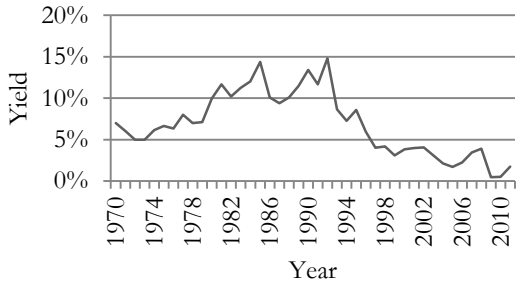




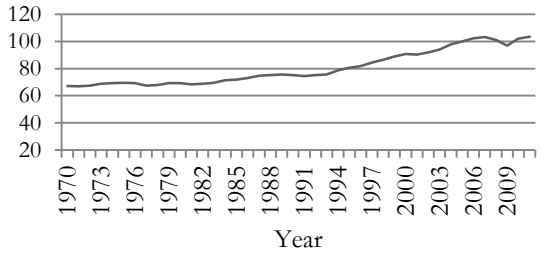


Notes: The business cycle indicator measures the private sector confidence in the future outlook of the economy. If the indicator is 10, the interpretation is that 10 percentage points more actors in the private sector actors deem the future to be positive rather than negative. That is, 55 % believe the future to be bright whereas 45 % believe in a down turn.

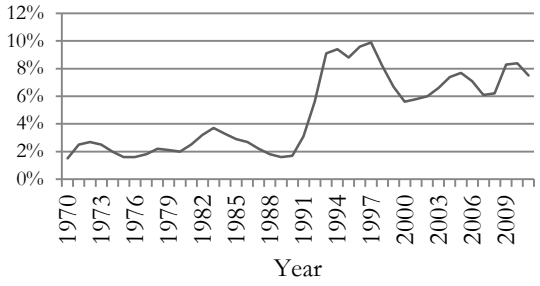
C.6: Yield Treasury Bills 30 Days Duration Sweden 1970-2011



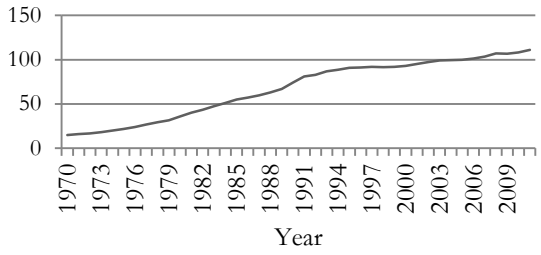
C.7: Total Factor Productivity Sweden 1970-2011 (Reference Year = 2005)



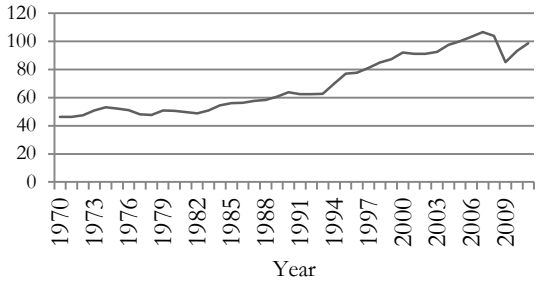
C.8: Unemployment, % Sweden 1970-2011



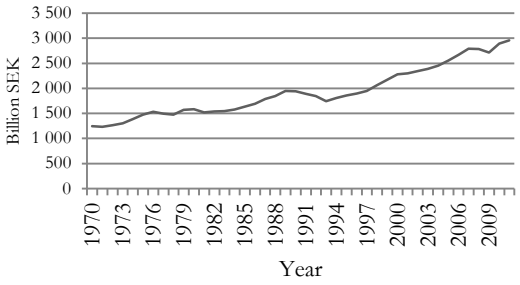
C.9: Consumer Price Index Sweden 1970-2011 (Reference Year = 2005)



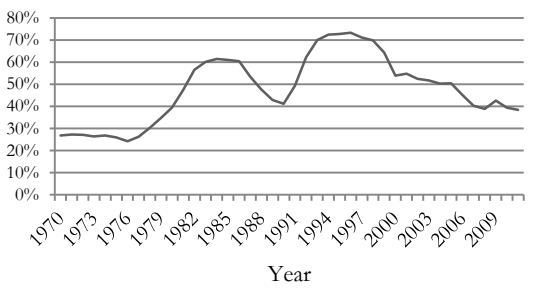
C.10: Industrial Production Index Sweden (Reference Year = 2005)



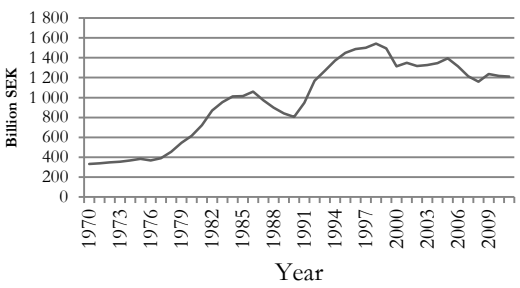
C.11: Domestic Demand Sweden 1970-2011 (Prive Level = 2005)

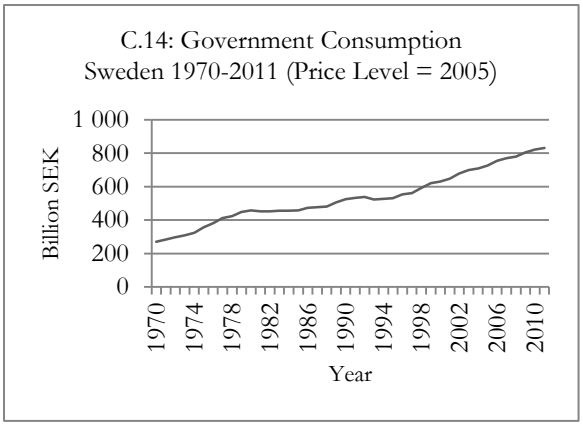


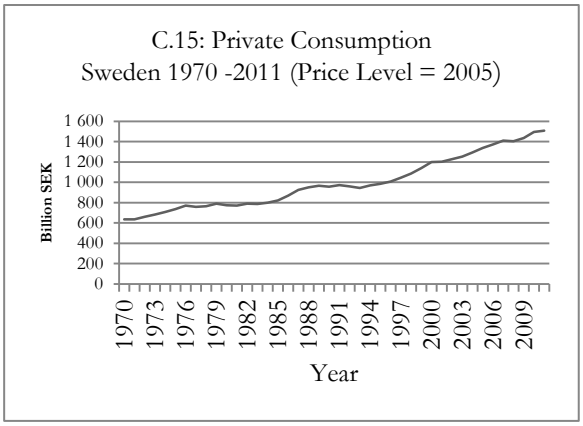
C.12: Government Debt, % of GDP Sweden 1970-2011

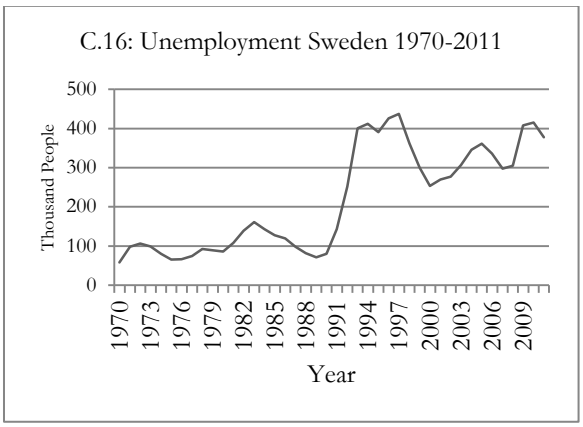


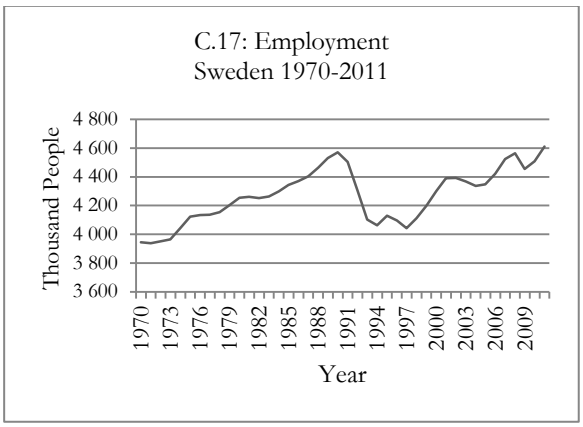
C.13: Government Debt Sweden 1970-2011 (Price Level = 2005)

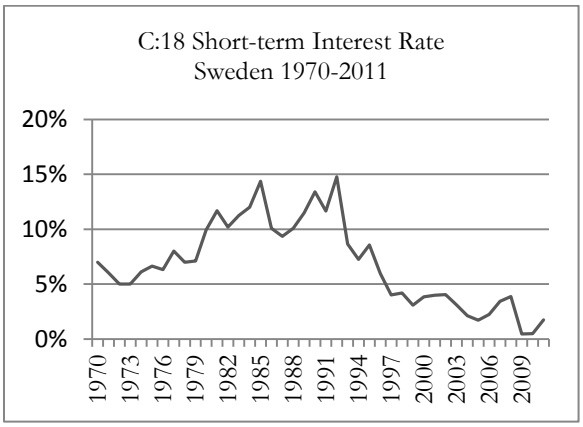


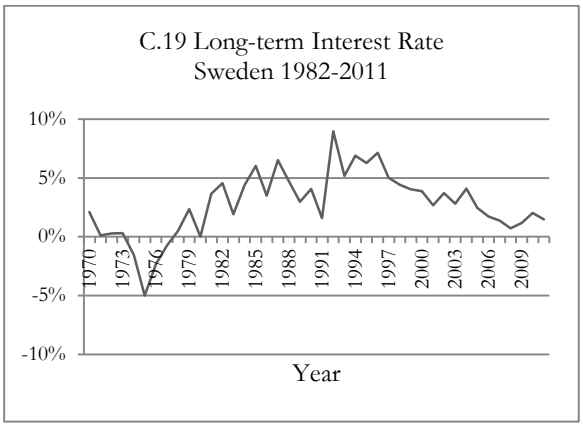

C.14: Government Consumption
Sweden 1970-2011 (Price Level = 2005)
Billion SEK
1 000
800
600
400
200
0
1970
1974
1978
1982
1986
1990
1994
1998
2002
2006
2010
Year

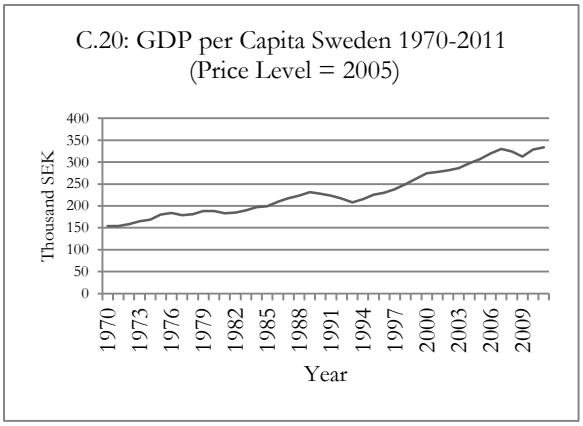

C.15: Private Consumption
Sweden 1970 -2011 (Price Level = 2005)
Billion SEK
1 600
1 400
1 200
1 000
800
600
400
200
0
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

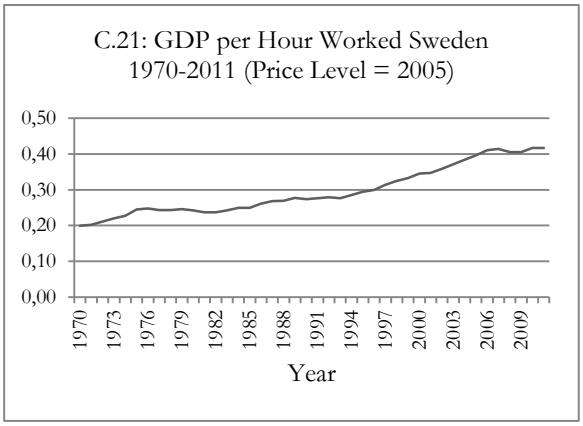

C.16: Unemployment Sweden 1970-2011
Thousand People
500
400
300
200
100
0
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

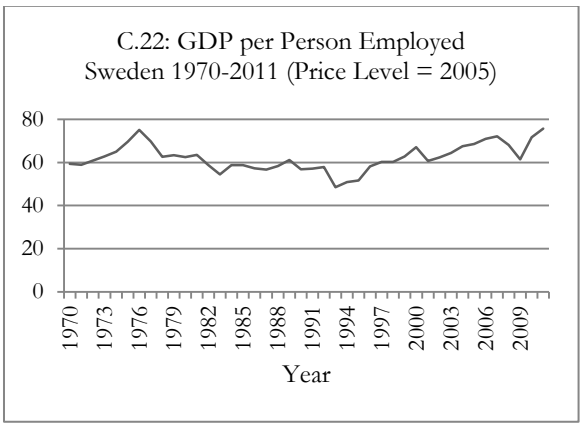

C.17: Employment
Sweden 1970-2011
Thousand People
4 800
4 600
4 400
4 200
4 000
3 800
3 600
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

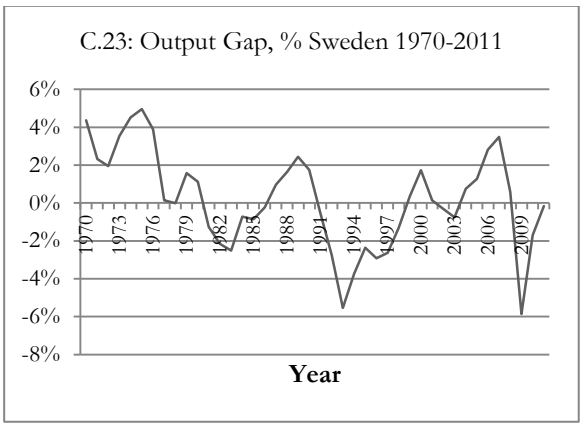

C:18 Short-term Interest Rate
Sweden 1970-2011
20%
15%
10%
5%
0%
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009

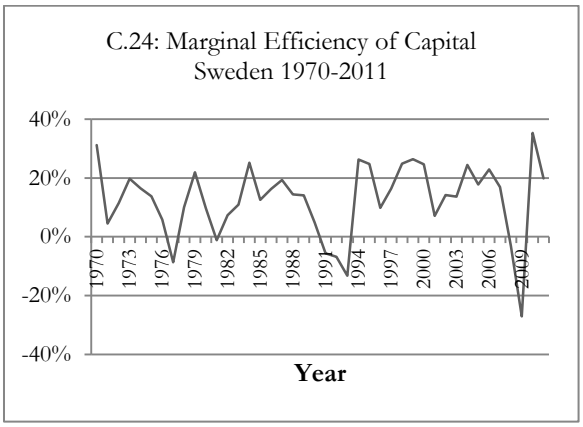

C.19 Long-term Interest Rate
Sweden 1982-2011
10%
5%
0%
-5%
-10%
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

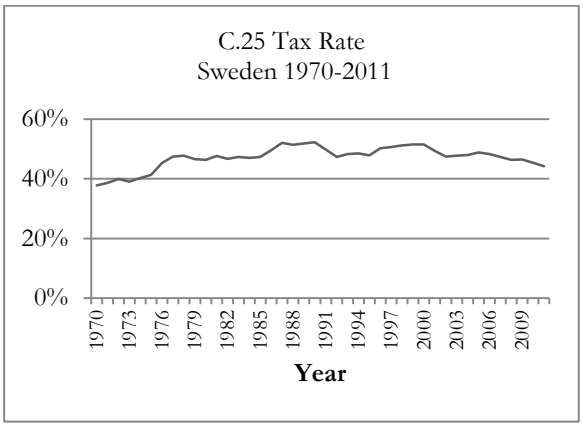












Notes: Output gap is the difference actual and potential GDP.