RESEARCH AND POLICY NOTES 2

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Incorporating Judgments and Dealing with Data Uncertainty in Forecasting at the Czech National Bank

Jan Brůha, Tibor Hlédik, Tomáš Holub, Jiří Polanský, Jaromír Tonner *

Abstract

This paper focuses on the forecasting process at the Czech National Bank with an emphasis on incorporating expert judgments into forecasts and addressing data uncertainty. At the beginning, the core model and the forecasting process are described and it is presented how data and the underlying uncertainty are handled. The core of the paper contains five case studies, which reflect policy issues addressed during forecasting rounds since 2008. Each case study first describes a particular forecasting problem, then the way how the issue was addressed, and finally the effect of incorporating off-model information into the forecast is briefly summarized. The case studies demonstrate that a careful incorporation of expert information into a structural framework may be useful for generating economically intuitive forecasts even during very turbulent times, and we show that such judgements may have important monetary policy implications.

JEL Codes: C53, C54, E17.
Keywords: DSGE models, forecasting, Kalman filter, monetary policy.

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Nontechnical Summary

Model-based forecasts serve as important tools for the monetary policy decision making process. Although a core model usually stands at the heart of each forecasting process, the forecast is not a simple 'press the button' exercise, but it is done iteratively by the forecasting team. The close cooperation between forecasters and sectoral experts and analysts is necessary, as a forecast in real-time should contain all important information about the economy. This paper focuses on the forecasting process at the Czech National Bank with an emphasis on dealing with data uncertainty and the way of incorporating off-model information.

We use five case studies to illustrate practical examples of incorporating off-model information into the forecasting process. These case studies reflect 'real-life' issues addressed during forecasting rounds at the Czech National Bank using its core DSGE model.

The case studies include (i) the analysis of the import-price deflator during the period of sizeable exchange rate depreciation at the beginning of 2009, (ii) the impact of a structural change in employment on the average wage dynamics during the crisis, (iii) the effects on foreign demand due to car scrapping subsidies in European countries, (iv) the recent rise in money market premium and (v) incorporation of judgments related to the implementation of fiscal measures. Each case study first describes the rationale behind the particular issue and the way how the issue was addressed. We then examine the implications of expert judgments for the economic story and monetary policy decision-making process. Expert judgments often have an important direct impact on the monetary policy decision making. But even when the monetary policy implications are not direct, the judgments are important in terms of making the forecast more acceptable to its key users by manifesting the ability of the forecasting team to incorporate important phenomena.

These case studies reflect issues that had to be addressed at the time when the Great Recession hit the Czech economy most severely. The choice of the period is partly dictated by the introduction of the current core model in mid-2008, and partly is made deliberately to demonstrate that a careful incorporation of expert information into a structural framework may be useful for generating economically intuitive forecasts even during very turbulent times.

Our paper can be useful not only for general readers who are interested in how the CNB forecasts are actually made, but also for professional forecasters working with macroeconomic models, as the basic principles and lessons learned are applicable to forecasting based on structural macroeconomic models in general.

1. Introduction

Model-based forecasts serve as important tools for the monetary policy (MP) decision making process. Although a general equilibrium core model usually stands at the heart of each forecasting process, the forecast is not a simple 'press the button' exercise, but it is done iteratively by the forecasting team (FT). Since there is always a trade-off between the size of a model and its tractability, a structural model should capture the most important stylized facts of an economy and deliberately leave other data features outside its structure. During the forecasting process, the FT incorporates all relevant pieces of off-model information into a forecast to improve its reliability and acceptability for the Board and public. Thus, a model employed in (medium-term) forecasting should be a flexible tool for incorporating judgments that can potentially improve the forecast. Inserting expert judgments into the structural model-based forecast is a result of a close cooperation among many analysts in real-time; at the same time, this process should not 'destroy' the fundamental consistency provided by model equations.[1]

This paper describes the forecasting process at the Czech National Bank (CNB) with an emphasis on the way of incorporating off-model information into a forecast and addressing data uncertainty. The illustration of this process is provided by means of case studies, all of which deal with particular situations when an expert judgment was perceived as necessary for *improving* the forecast or generating its alternative scenario. Our motivation here is not to cover all expert judgments[2] which have been used, but rather to select a few of them which had *significant impact on forecasts* and the monetary policy decision-making, and also which are sufficiently distinct from each other to provide a broad insight into the forecasting process.

Each case study in this paper describes the motivation for implementing a judgment into a forecast, its incorporation into the core model and the implied change of the forecast for the most important variables (interest rate, inflation, GDP and exchange rate). We then examine the implications of expert judgments for the economic story and monetary policy decision-making process. Although some judgments (as will be seen later) need not have direct implications for the monetary policy (i.e., the model-implied trajectory of interest rates was only marginally changed), we show that a judgment can make the forecast more intuitive and acceptable for the Board and public, i.e. for its key users.

The regular model-based medium-term forecasting has a rich history at the Czech National Bank. In 2002, the CNB started using the Quarterly Projection Model (QPM), a structural macroeconomic model with an endogenous monetary policy rule and model-consistent expectations, for forecasting and policy analysis. As a consequence, the demand for careful data treatment and incorporation of additional off-model information into the forecast intensified soon after launching regular model-based forecasting rounds. In July 2008, the Czech National Bank switched to a full-fledged DSGE model, called g3, as its main forecasting and policy analysis tool. Since it fits Czech stylized facts in a more structural way than the QPM and contains a richer structure (most importantly balanced growth path, national accounts etc.), it allows a more precise use of expert judgments on the 'appropriate place' within the model structure.[3]

[1] Currently in the Czech National Bank, the FT presents incorporating of expert judgments to the Board and explain their application to the public in the Inflation Reports. The Inflation Reports also contain the decomposition of changes in the interest rate forecast between two subsequent forecast rounds where the impact of changes in expert judgments are explicitly presented and discussed. See Section 2.3.

[2] In fact, it would even not be possible to cover all expert judgments made as they are usually applied in each forecast round.

[3] It should be noted that we do not dispraise the QPM model and the period of its use for forecasting. Although we believe that the full-fledged DSGE model g3 is better in terms of its structure and possibilities of incorporating

Thus, the modification of a model forecast on the basis of off-model information collected and analysed by sectoral experts (near-term forecasting unit, experts on fiscal policy or on the external development) have become easier, and at the same time more transparent.[4] Insights obtained from discussions between the FT and sectoral analysts highlight the relevance of additional information which is iteratively incorporated into the forecast during each forecasting round.

All examples of incorporating off-model information into the forecast in this paper reflect 'real-life' issues addressed by the forecasting team when working on CNB's predictions. Many of these case studies relate to the period of the Great Recession which hit the Czech economy significantly. Partly, this is due to the fact that the g3 model was introduced into forecasting practice in mid-2008, i.e. just before the outbreak of the crisis, but partly we prefer this period to demonstrate that a careful incorporation of expert information into a structural model framework may help to generate economically intuitive forecasts even during very turbulent times.[5] Put differently, a crisis generates issues that need to be addressed, which we show in this paper. Ultimately, the incorporation of judgement into model-based forecasts serves two key purposes, i.e. improving the forecast accuracy and increasing its acceptability to the key users by reflecting important off-model phenomena observed in the economic reality.

Recently, the importance of incorporating off-model information into structural models has been appreciated by many authors. For example, Beneš et al. (2010) illustrate how to incorporate real-time data to the Small Quarterly Structural Model for the United States with real-financial linkages. The paper shows the benefit of being able to work with asynchronously released data compared with the usual situation when data are used up to the date for which all data observations are available.[6] Although the main concern of the paper is to efficiently use all information available (and not to wait until all data is released), the methodology can be easily generalized when one wants to impose any additional piece of information. Besides, many other central banks incorporate external judgments or address real-time issues when forecasting with their structural models. For example, González-Gómez et al. (2009) show on an example of a DSGE model of the Central Bank of Colombia how to incorporate into the forecast additional variables not directly included in the model.

The approach in our paper is in many aspects similar to Beneš et al. (2008). These authors describe the effects of incorporation of off-model information into a DSGE-based forecast on two illustrative examples and suggest a construction of the implausibility index to assess the magnitude of the effect. The present paper, however, differs in that our examples are practical in the sense that they were actually used during the real-time forecasting process. Therefore, we are primarily interested in the intuition behind the effect of judgments on the four most policy-relevant variables and their potential influence on the actual policy decisions rather than in reporting summary statistical measures.

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expert judgments, we should say that the QPM did a great service to the Bank and allowed to obtain necessary skills for the staff. Thus, we perceive the 2008 model switch as a part of evolution, rather than as a revolution.

[4] Sectoral experts rely on all available analytical tools, including single-equation statistical models, data decompositions, satellite simultaneous models, and any available off-model information. Thus, the experts' knowledge of micro data, methodological changes or some non-standard features, such as one-time effects of tax changes, is an integral part of the forecasting and policy analysis system at the CNB.

[5] Some economists claim that models do not 'work' during the times of a strong economic crisis. We do not want to question this view from the academic point of view, rather we try to show a way how to produce forecasts useful for policymakers as an input into their decision-making process even during such times.

[6] Many financial data (such as interest or exchange rates) are usually available in real time, while national accounts are available with about 2-quarter lags.

The paper is organized as follows. In the next section, we briefly describe the structure of the core model, the taxonomy of dealing with raw data during the forecasting process, and the approaches to using off-model information. Then, Section 3 provides a set of case studies, which describe particular forecasting problems, the way how the problems were addressed, and the effects of the imposed judgments on the forecasts and monetary policy decision-making. Section 4 concludes. Appendices contain additional materials. Appendix A illustrates data uncertainty and revisions which were faced by the FT. Appendix B describes a particular example of assessing the effect of the wage distribution on the forecast.

2. The g3 Model and Forecasting Process

The CNB's current forecasting model, called g3, was put into practice in July 2008 when it replaced the QPM.[7] The g3 model is a dynamic stochastic general equilibrium model. It reflects recent academic advances in the field and is extended by features that allow fitting country-specific characteristics that are usually not addressed by prototype monetary-policy models.[8] Long-run real appreciation of the exchange rate, improving quality of production during the economic transition or the existence of administered prices are good examples of such specific issues relevant for a converging transition economy.

Since the g3 model is currently used as the core forecasting model, all practical case studies discussed in this paper are illustrated on this model. Nevertheless, the paper can be useful not only for the general readers who are interested in how the CNB's forecasts are actually made, but also for experts in practical forecasting with macroeconomic models, as the examples included in this paper can serve as inspiration for other forecasters who are regularly involved in forecasting with their own DSGE models or structural macroeconomic models in general.

For the sake of readers' convenience, the rest of this section is devoted to the brief description of the g3 model and to the introduction to the CNB's forecasting process, including the terminology used.

2.1 The g3 Model

The g3 model is a small open economy model aiming at fitting stylized facts of the Czech economy. The construction of the g3 model in years 2004-2007 reflected (i) an appreciation of the achievements in academic literature on abilities of DSGE models to fit the observed economic fluctuations (see e.g. Christiano et al., 2005; Smets and Wouters, 2007), (ii) a need for careful treatment of the long-term trends observed in the data, and (iii) a need to incorporate other special features of the Czech economy (such as regulated prices). To reflect the observed trends, the g3 model contains a balanced growth path with trends in relative prices (including the long-run real exchange rate appreciation) as well as non-stationarity in the real economic data (e.g. the increasing openness of the Czech economy). In order to obtain plausible business cycle properties, most DSGE models – including the g3 – incorporate a set of real rigidities, various sector-specific technologies for fitting sector-specific stylized facts, and a rich production structure with a cascade of nominal rigidities, which *inter alia* leads to imperfect and gradual exchange rate pass-through.

[7] The QPM was introduced in 2002 as a key tool for regular quarterly-based forecasting. Its initial version is described in Coats et al. (2003).
[8] See e.g. Tonner et al. (2011) and Tovar (2008).

Between January 2007 and July 2008, the g3 model was extensively tested by means of regular shadow forecasts, historical recursive filtration, carrying a set of shocks decompositions, and analysing its properties. The model also started being communicated inside and outside of the CNB to make the switch of the forecasting framework as smooth as possible.

The g3 forecasts are – like the previous QPM forecasts – based on an endogenous monetary policy rule (reaction function), i.e. the future (forecasted) path of interest rates is derived endogenously by the model. This is a distinction from some central banks (such as the Bank of England), who condition the forecast on an exogenous path of interest rates. Moreover, the trajectory of the interest rate (and the endogenously determined exchange rate of the CZK/EUR - see below) is published and communicated. In particular, a forward-looking central bank implements inflation targeting regime using interest rate policy in the g3 model: the interest rates respond to the deviation of y/y monetary policy-relevant (MP) inflation from its target four periods (quarters) ahead. It is assumed that monetary policy is fully credible in the model.

Since the structure of the g3 model is described in Andrle et al. (2009)[9], we avoid repeating the technical details in our paper. Instead, we stress only each particular part of the g3 model relevant for the selected case studies. For example, before discussing a fiscal policy judgment, we briefly describe the fiscal policy treatment in the model, and thus highlight the relevance for the judgment. For reading consistency and convenience, we put these descriptions at the top of each case study section.

2.2 Forecasting Process and Data

The FT devotes a considerable effort to analysing data for the forecasting purposes. Seasonal adjustment and measurement errors are applied to the employed time-series at the beginning of each forecasting process.

The forecasts based on the g3 model are made on seasonally adjusted time series containing trend and cyclical components. In majority cases, the officially released seasonally adjusted data are used for the forecasting purposes. When they are not available, the x12 seasonal adjustment method within the IRIS Toolbox (Beneš, 2011) is applied.[10] The main reason for the choice of the seasonal adjustment from official sources is its clear communication as two different seasonally adjusted time series for macroeconomic aggregates used at and outside of the CNB would be confusing.[11]

Moreover, since some time series (such as quarter-on-quarter changes in some components of the national accounts data) exhibit high-frequency noise either due to one-off idiosyncratic factors or due to data issues (as manifested e.g. in frequent data revisions or methodology changes),

[9] The first version of the model is described in Beneš et al. (2005). Recently a paper on the g3 extension with a rich fiscal block has been published, see Ambriško et al. (2012a).
[10] The Matlab-based IRIS Toolbox is being used for the whole forecasting process (filtration, forecasting, carrying out scenario analyses etc.).
[11] The CNB staff has also experimented with their own approach to seasonal adjustment with the vision of integrating the seasonal filter to the model state space. As a first step, a state-space representation of the multivariate seasonal filter was designed and applied on quarterly growth rates of national accounts. The multivariate nature of the designed filter restricts the sum of seasonal components of individual series to be exactly equal to the seasonal component of their sum. Moreover, for the sake of communication, an additional restriction was imposed: the year-on-year growth rates of the filtered series should be equal to the official figures. There were designed several formulations of seasonal adjustment. Nevertheless, the results of such filters were almost undistinguishable from the seasonal series published by the Czech Statistical Office.

the application of measurement errors is useful to put emphasis of the discussion on medium-term economic fundamentals. Specifically, such noise embedded in some data is removed with model-consistent filtering. This is done by adding measurement errors to the observable equations of the state space representation of the model. Standard deviations of these measurement shocks differ among observed time series depending on the magnitude of unexplained high frequency noise in the data. There are variables, such as interest rates and the exchange rates, which are assumed to be perfectly observed and therefore the standard deviations of their measurement errors are zero. The second set of variables contains inflation rates and nominal wages. These time series have low measurement errors. Finally, the measurement errors of national accounts data have the highest standard deviations since there is a lot of short-term volatility and are subject to significant revisions.[12]

To demonstrate the magnitude of some measurement errors, Figure 2.1 presents a comparison between observed and filtered (de-noised) series for some relatively volatile variables. First, due to a presence of high-frequency noise in quarter-on-quarter terms, the application of measurement errors is useful for extracting the model-consistent fundamental information from data to assess current (and past) state of the economy. Second, the use of measurement errors does not automatically mean that series are smoothed.[13] Take as an example the export growth rates during the crisis from mid-2008 till 2009. A mechanical application of a univariate statistical filter (such as HP filter with a low value of λ or Christiano-Fitzgerald band-pass filter) would end up with a smoothing the export drop in the mid of the crisis. However, as this drop was consistent with the dynamics of other variables, it was cut off by the model-consistent filter only marginally. This highlights the usefulness of the multivariate model-consistent filter.

Although de-noised time series are acquired 'automatically' via model-consistent filtering, their profiles are verified. As sectoral experts are well-informed about latest data releases, filtering results are discussed with them to reach agreement on the 'fundamental' part of the time series. If the need arises based on these discussions, a judgment can be placed within the Kalman filter setting to modify the outcomes of the de-noising process. This kind of judgment can be considered as a part of filter judgments, which are described in the next section.

2.3 Forecasting Process and Judgments

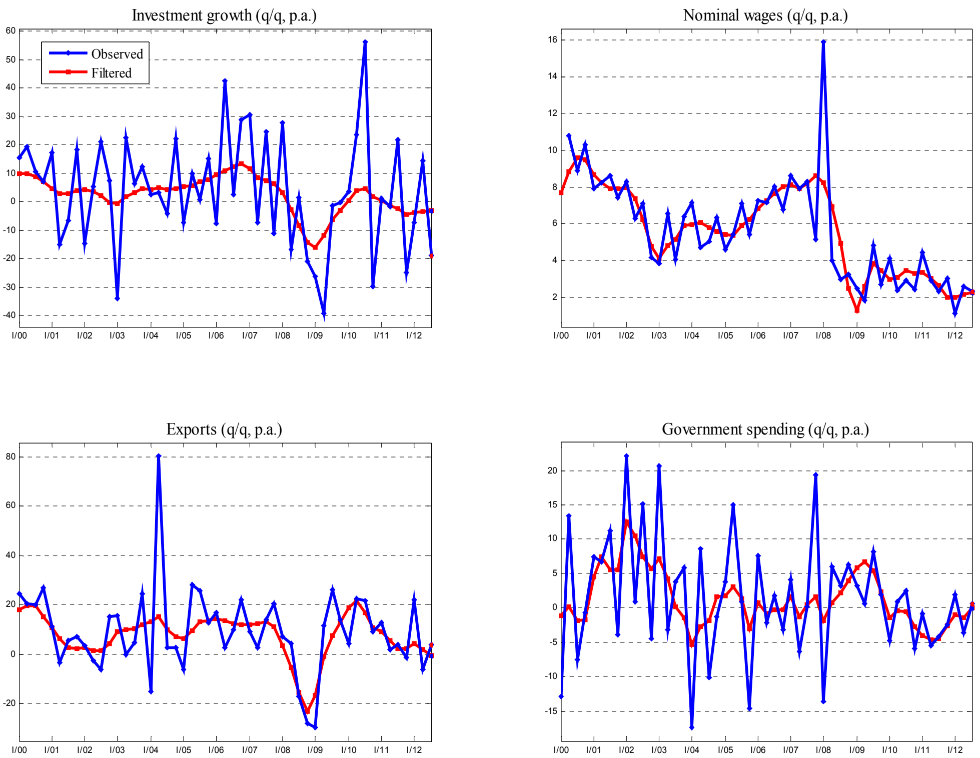
The g3 model is used for regular forecasting, sensitivity analysis, simulating alternative policy scenarios, monetary policy experiments etc. Forecasting rounds consist of two – not strictly separated – steps. First, initial conditions are identified. The initial conditions analysis is used to assess the current state of the economy via the Kalman filtration. As the outcome, the FT identifies the position of the Czech economy within the business cycle and thus evaluates inflationary pressures. During filtration rounds, the staff discusses the magnitude of identified structural shocks and measurement errors, especially at the end of data sample.[14] Second, based on initial

[12] In Appendix A.1, we show a magnitude of revisions for national accounts data. For each time series, we present the latest data release at the time of writing the paper and a range which is constituted by maximal and minimal values of other data releases from 2008 to the present.

[13] The measurement errors on national accounts may seem to be large. However, the model measures *levels* of national accounts, which implies that for example, exports and imports cannot diverge from each other. This provides a consistency guard and shows an additional benefit of the multivariate filtering.

[14] Some data are released with a delay with respect to forecasting rounds. For example, last-quarter national accounts data are not available and have to be imputed. This imputation is referred as a nowcast. E.g. during January forecasts, actual released data contain national accounts series up to the third quarter of the previous year. Data for the fourth quarter are released after finishing the January forecast. After releasing data for the last quarter of the year (in March), the FT updates the January forecast with actually released data and more recent outlook of

Figure 2.1: Measurement Errors



conditions, an outlook of exogenous variables and any off-model information available on the forecast horizon, the forecasts are produced.[15]

In cases, when the FT identifies that the off-model expert information would capture initial conditions more realistically, **judgment on the filtering horizon** is applied in order to identify structural shocks plausibly. This takes the form of imposing a particular value on observed or unobserved (set of) variable(s). An example, where the application of a filter judgment is useful, could be an idiosyncratic wage increase due to factors such as a tax optimization or a change in statistical methodology. If such a judgment is not used, the model may falsely identify labour productivity or wage-push shocks, which would propagate to the forecast. Alternatively, one can impose judgments on unobserved variables such as shocks (i.e., the observed movement is explained by a particular structural shock, which may differ from a mechanical application of the model consistent filter). These two alternatives are in fact formally similar: to impose a

exogenous variables. Since 2012, this update is communicated to public using the *Graph of risks to the inflation projection* (GRIP). The GRIP is a visual aid capturing the risks to the latest macroeconomic forecast by means of an assessment of the effect of new information on the outlook for headline inflation and interest rates.

[15] After completing the forecast of all variables that are included in the core model, the FT also produces forecasts for those variables of interest that are not directly part of the g3. Those include monetary aggregates, sub-indices within the consumer price index, selected labour market or fiscal variables, and the balance of payments. The forecasts of these off model variables are based on a set of satellite models. Those were built to either decompose the endogenous aggregate forecast of the core model into more detailed structures or bridge the development of important off-model variables with that of the aggregate forecast.

particular value of a variable from officially published data is the same as to impose a particular value to a measurement error in a given period.

The majority of expert judgments on filter deal with initial conditions of the forecast (last quarter of the history). The most often discussed variables are quarterly national accounts and nominal wage growth as their end-point values are forecasted/nowcasted by the near-term forecast (NTF) team.[16]

Judgments on forecast set the values of some future variables differently from the model's outcome. Expert judgments on forecasts are usually associated with setting technologies in the first quarter of the forecast, however they can also be used for exogenizing a particular endogenous model variable, for example the policy rate in the case of monetary policy experiments. These forecast judgments can be in principle done in various ways. When a specific variable is exogenized, then the model consistent filter can be used to determine structural shocks that will achieve the prescribed path of the exogenized variable – such an approach is popular in academic literature and in state space models and is equivalent to the popular technique by Waggoner and Zha (1999). Another, and usually more useful, approach is to determine which structural shocks will be used to replicate the exogenized variable as a part of the judgment itself, which – given the knowledge of the model structure – is equivalent to imposing judgments on future values of structural shocks. The advantage of the later approach is that the choice of the particular shock that would exogenize a given variable is a result of discussions within the FT and such discussions help to shape the underlying 'economic story'. The economic intuition is important in explaining the choice of the particular shock to policymakers and the public.[17]

We highlight the importance of having possibility of putting judgments directly on structural shocks (or unobserved variables) for practical forecasting on the following example. Consider the situation of assessing consequences of potentially high future wage growth. The implications of such wage growth for monetary policy differ depending on the underlying reasons. If the wage growth is explained by productivity, approximated in most DSGE models by the labour-augmenting technology[18], then the impact on interest rates is negative, while if nominal wage growth is caused by wage-push shocks, the effects are opposite. Thus, recognizing the source of nominal wage growth is necessary for deriving an appropriate, stabilizing monetary policy reaction. This is illustrated in Figure 2.2 where the horizontal axis displays the deviation of inflation from inflation target at time $t + 5$ and the vertical axis displays the mean deviation of interest rates between times $t + 2$ and $t + 7$. The figure compares implications of three different shocks: a labour productivity shock, a foreign demand shock, and a wage-push shock, on interest rates and inflation. Shocks are normalized so that the mean annualized increase in the wage growth is 1% over the subsequent four quarters. First, a labour productivity shock decreases both inflation and interest rates, despite the increase in the wage growth. An increased productivity (technology) is a positive supply-side shock, which affects an economy with anti-inflationary pressures as the same volume of production can be made with lower costs. Second, a wage-push shock works in the opposite direction. It captures an increase of (wage)

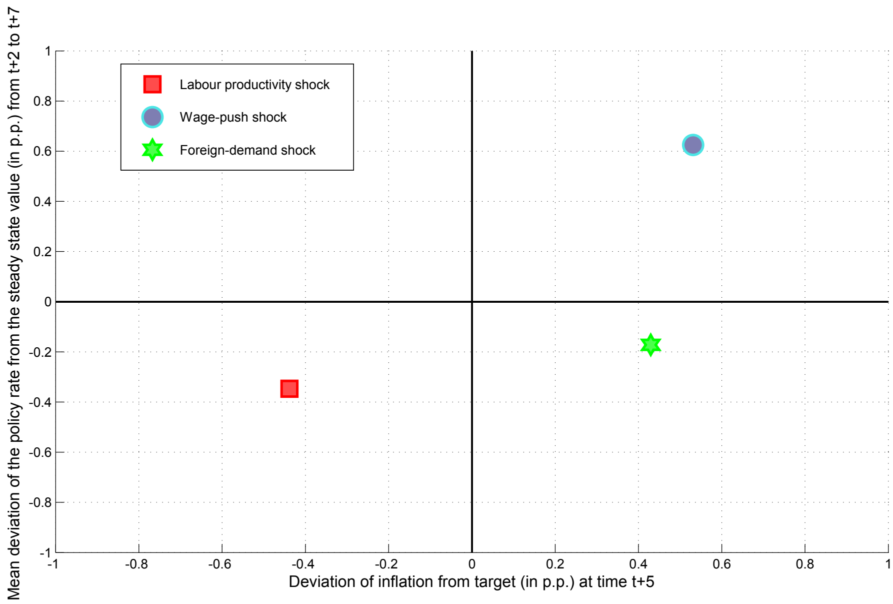
[16] For simulation purposes, these nowcast values are inserted into input databases as 'observed' historical values. For communication purposes, these values are presented as forecasts in the graphs.

[17] There is also a technical difference. If the model-consistent filter is used to find shocks (similarly to Waggoner and Zha, 1999), the Kalman smoother of the original system is needed. While judgments are introduced in the model by augmenting the measurement equation: in a given period the shock used to exogenise the variable is 'observed', i.e., the set of observation equations is temporally enlarged. This approach was initiated long ago by Clarida and Coyle (1984), and now is used by many modellers, who use state-space representations (see., e.g. Section 6.3 in Andrle et al. (2009) or Beneš et al. (2010)).

[18] The labour-augmenting technology is the main source of long-run growth in the g3 model.

costs which is not supported by an increase in productivity. And third, a foreign demand shock increases inflation and slightly decreases interest rates. A higher inflation reflects boosted aggregate demand whereas lower interest rates are caused by an exchange rate appreciation due to foreign trade surplus and better net foreign assets position.

Figure 2.2: Effects of Various Shocks Implying Wage Increase

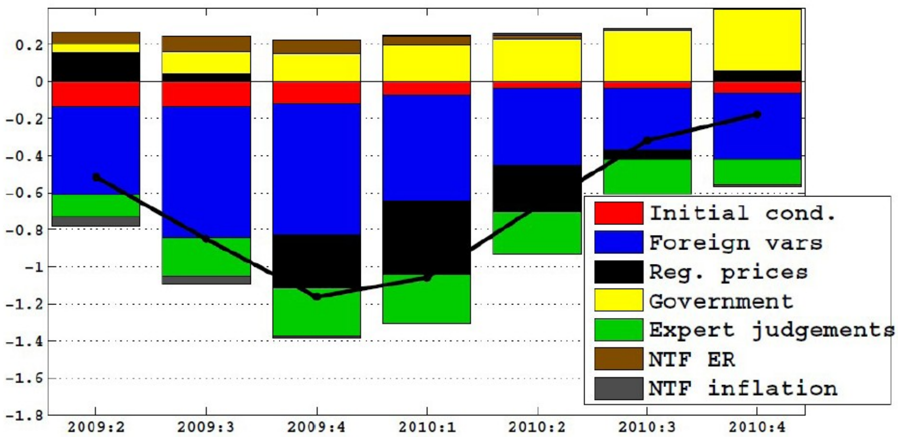


Without structural interpretation of shocks, the possibility of describing a particular economic story is difficult. Given the poor identification of structural shocks to wage inflation in DSGE models (Chari et al., 2009) and their utmost importance for policy, it would not be wise to rely on mechanical results of Kalman filtering. It is worth noting that the approach of imposing external judgments on the forecast in the state space framework that in fact corresponds to the least-square approach to hard conditioning à la Waggoner and Zha (1999), can be applied even to non-structural models, such as VARs or BVARs.[19] Hence, expert judgments are not specific to forecasting with DSGE models. They can be (and actually have been) used in semi-structural (such as QPM-style) or in non-structural models as well.[20] However, the virtue of working with structural models for practical forecasting is magnified by the fact that one can be more confident about the underlying economic intuition when imposing the external information. The more solid foundations are laid down in the structural interpretation of shocks, the more flexible is the process of judgment incorporation; and the economic story behind the forecast can be more credibly communicated to its users (such as policymakers or the general public). The DSGE models are specific in that there is a more solid consensus about the interpretation of their shocks relative to semi-structural or traditional macroeconomic models.

[19] See Franta et al. (2011) for such an application of forecasting with external judgments applied to the Czech economy.
[20] In fact, many types of judgments used under the g3 model had been applied in the forecasting process with the QPM, too.

The implementation of expert judgments into forecasts of CNB is regularly communicated in Inflation Reports (IR). The IR presents and explains a decomposition of changes of two subsequent forecasts where all factors are aggregated to usually seven groups which stand behind the change of the interest rate path. In Figure 2.3, the y-axis shows the difference between two subsequent interest rate forecasts in percentage points per annum which are decomposed into these factors. The 'initial conditions' group captures the effect of a change of the initial position of the economy in the business cycle. The estimated (by Kalman filtration) position is affected by new data releases as well as historical data revisions. The 'foreign variables' group depicts changes of future outlook of foreign variables, namely foreign interest rate, demand and PPI inflation. The 'regulated prices' and 'government' groups represent changes between two subsequent future outlooks for regulated prices and government consumption (or more generally fiscal policy if there are some discretionary measures in public finances), respectively. The 'NTF ER' and 'NTF inflation' groups correspond to the effects of fixing the 1Q-ahead forecast values for nominal exchange rate and inflation. And finally, the 'expert judgments' group captures the effects of incorporation of any expert judgments. For example, if the FT had decided to implement off-model information on a forecast variable affecting domestic interest rate and changed them in the next quarter forecast, the resulting effect would be depicted in the figure as expert judgments. Thus, as each factor having a significant impact on the forecast should be (and it is) explained, the forecasting team is required to present strong arguments for the judgments applied. This presumably gives the forecast's users more confidence in the final output.

Figure 2.3: Decomposition of Changes in the Interest Rate Forecast



3. Case Studies

This section presents some examples of expert judgments that were used within several forecasting rounds since the breakout of the Great Recession. We select five examples which to our opinion were important for improving the forecasts and made them more acceptable to policymakers and the general public. Also, these examples are sufficiently different to each other to demonstrate the width of options for imposing judgements.[21]

In this section, each case study constitutes a self-standing part of the text with no direct link to any other case study. Each part is structured as follows: We first describe the economic situation (story) and the problem. Then, we outline our motivation for incorporating the judgment and the way how the issue was addressed. If necessary, we present brief information about the g3 model at the beginning of each part. Also note that we depict vintages of time series *from* a particular period, not their current values. In other words, we do not consider data revisions (or changes in seasonal adjustment) of e.g. national accounts.

Except for the case study with the money market risk premium (the fourth case), we present results in a subplot where each panel shows a difference between the forecast with and without a particular expert judgment.[22] In these panels, red lines depict the baseline forecast; blue lines depict the same forecast with the judgment switched off. The differences between both scenarios are presented with the black bar graphs whose magnitude is shown in the right-hand scale in percentage points. In the case study with the money market premium, we do not use this type of presentation since the differences are negligible except for the interest rate.

3.1 2008Q4 – 2009Q1 Exchange Rate Depreciation

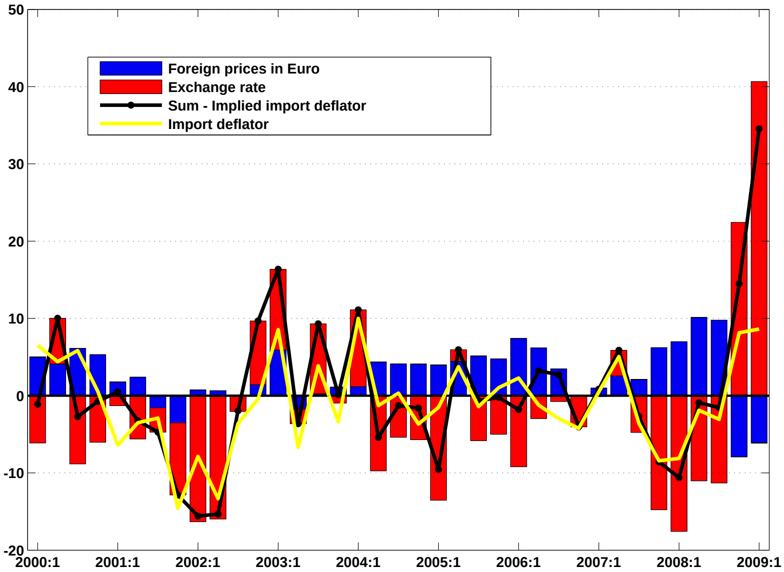
One of the most discussed issues associated with the identification of initial conditions is the link between exchange rate and import prices, or more generally an identification of inflationary pressures stemming from import prices. In particular, significant depreciation or appreciation periods are of the highest interest. Since the g3 model embeds gradual exchange rate pass-through (implied by monopolistic competition of importers and the local currency pricing), the magnitude of pass-through to import prices has usually a different size compared with the change of the exchange rate.

During the Great Recession, the CZK/EUR exchange rate significantly depreciated in two quarters after the Lehman Brothers collapse (2008Q4-2009Q1). In Figure 3.1, the black line depicts foreign prices in CZK decomposed into their two key factors - the exchange rate development and foreign PPI prices in foreign currency (i.e. euro). The yellow line is the deflator of Czech import prices where the value in 2008Q4 is observed and the value in 2009Q1 is a nowcast. Differences between these lines reflect changes of the mark-up as the monopolistically competitive importers in the g3 model ‘produce’ imports from foreign goods as the sole production input and set import prices in the domestic currency. Each factor, i.e. exchange rate, import price deflator and foreign PPI, is observed (except for the above mentioned nowcast). The exchange rate is observed perfectly and the foreign PPI almost perfectly with low measurement errors. Thus in essence, the costs of importers are nearly given. The main discussion thus relates to import prices.

[21] We acknowledge the support of the rest of our colleagues in the Monetary and Statistics Department of the Czech National Bank. The deep and intensive discussions during forecasting rounds helped to establish the final chosen approach.

[22] Such type of figures is used in Inflation Reports of the CNB.

Figure 3.1: Decomposition of Foreign Prices Growth in CZK (%, q-o-q, ann.)

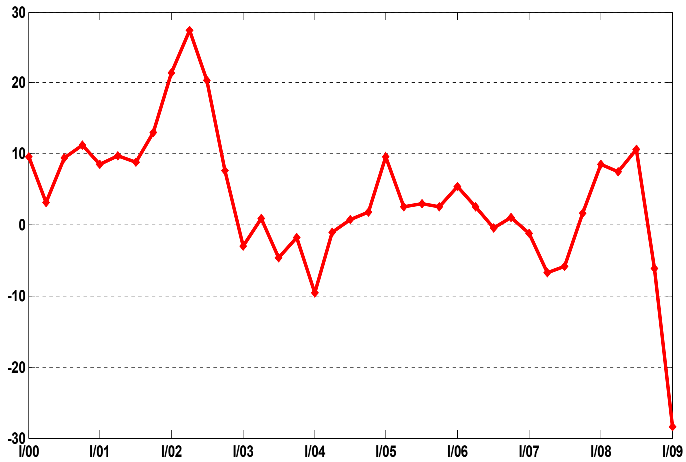


The main task associated with import prices during the April 2009 forecast was to assess the strength of inflationary pressures stemming from the imported goods sector. At the beginning of the crisis in 2008Q4, the observable for the import price deflator almost corresponded to costs indicating that importers lowered their mark-ups relatively moderately. In 2009Q1, however, the crisis fully hit the economy, which got reflected in even stronger currency depreciation, larger slump of domestic GDP and negative sentiment in the economy. In such a situation, importers could hardly propagate increased costs into prices of their production and they rather temporarily lowered their mark-ups. Although the 2008Q4-2009Q1 depreciation was unprecedented, the historical experience (e.g. in 2003) had indicated that significant depreciations had not been fully transmitted into import prices (Figure 3.2).

Thus, since a high value of the nowcast of the import price deflator in 2009Q1 would imply strong inflation pressure during the Great Recession, the FT decided to 'insert' an expert judgment on filter implying lower inflationary pressures stemming from the import price deflator. This was achieved by imposing a cost-push shock to import prices during the filtration process which was equivalent to lowering the filtered value of the import price deflator.

From the ex post point of view, the incorporation of the judgment was correct, as the forecast would otherwise imply a contra-intuitive reaction of the implied trajectory of interest rates. Figure 3.3 shows a comparison of the baseline (with inserted judgment) forecast with a scenario without the judgment in which profit mark-up growth in the imported-goods-production sector is around zero (i.e. not strongly negative). In this hypothetical scenario, inflationary pressures lead to higher future inflation, and thus monetary policy must immediately react by increasing nominal interest rates to keep inflation near the target. Higher interest rates appreciate the exchange rate, which reduces GDP growth at the beginning of the forecasting period via lower net exports. In reality the actual developments turned out to be even more anti-inflationary on

Figure 3.2: Model-Based Profit in the Imported-Goods-Production Sector (%, q-o-q, ann.)

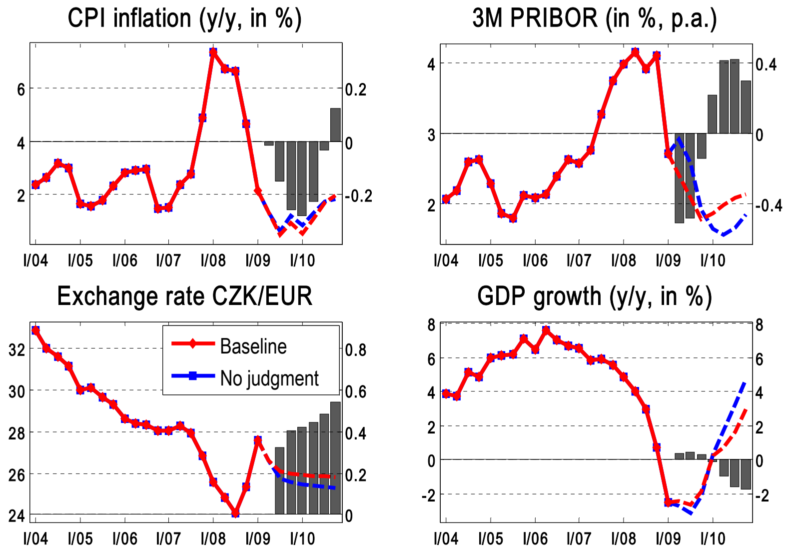


the monetary policy horizon[23] than in the baseline with inserted judgment, let alone the no-judgment scenario. The real economy in reality fell much faster into recession compared with the forecast scenario, leading to a dramatic fall in demand-led inflationary pressures. The ex-post evaluation suggests that the judgment incorporated into the forecast correctly captured the less pronounced transmission of the exchange rate into import prices.

The immediate policy implications of the applied judgment are straightforward. The baseline forecast implied further cuts in short term interest rates to mitigate falling inflationary pressures on the monetary policy horizon, as opposed to the judgment-free simulation. The simulation without judgment was consistent with a more significant transmission of the weakened exchange rate into import prices and subsequently to CPI inflation. The higher inflationary pressures were the main reason behind the delayed fall in interest rates by two quarters compared with the baseline. The quantitative effect of the judgement in terms of short terms interest rate setting was quite significant. During the second and third quarters of 2009 the short term interest rates are about 0.5 p.p. lower in the baseline compared with the no judgment scenario. The CNB's Board decided to lower the policy rates by 0.25 p.p. at its meeting in May 2009, i.e. in line with the baseline forecast, and in contrast with what the judgment-free scenario would imply. With the benefit of the hindsight short-term interest rates could have fallen during 2009 even more than in the baseline, given the fall of MP inflation below 0 % at the beginning of 2010.

[23] The deviation of inflation from the inflation target on the monetary policy horizon is crucial for the interest rate setting in 1Q 2009, given the forward-looking nature of the CNB's policy reaction function.

Figure 3.3: Judgmental Forecast



3.2 The Change in the Wage Distribution During the Crisis

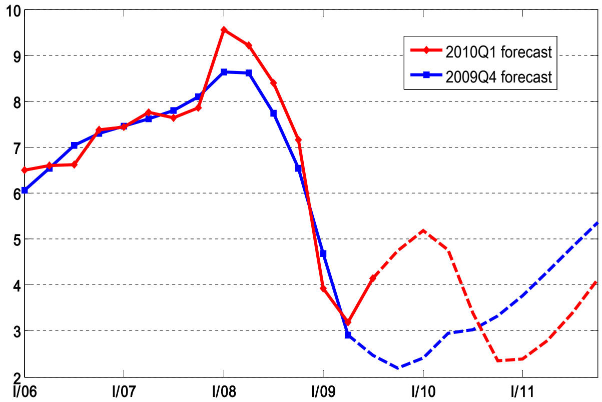
Proper treatment of wage dynamics is one of the most important tasks during the forecasting process, as the wage costs are a key and often quite persistent determinant of nominal marginal costs, and thus of inflation developments. At the same time, the analysis of these wage pressures on inflation is not easy for several reasons. First, different fundamentals explaining observed wage growth have completely different implications for inflation and monetary policy; recall the illustration given in Section 2.3. Second, there are important issues, not explicitly accounted for by the model, which affect the observed wage dynamics in a number of ways. These include tax optimization and the often countercyclical change in workers' sickness rate (see below). Third, the wage distribution across workers' types is important, too, as will be demonstrated in this section below.[24] Finally, there may be a significant degree of uncertainty about how to correctly measure wage dynamics.[25]

The following case study captures a dilemma faced by the forecasting team during the January 2010 forecast. The underlying economic and analytical background was as follows. The Czech economy in the 3Q of 2009 was already in a deep recession, the y-o-y economic growth having reached -4.1 %. The rapid decline of foreign demand resulted in a deep fall of Czech investments as well as exports, the y-o-y growth of nominal wages and real household consumption had been gradually slowing down. Employment fell by 2.8 %. The October 2009 forecast, based on the cyclical position of the economy, assumed a further deceleration of nominal wage

[24] The distribution of wage growth across production sectors could also be of interest. Appendix B illustrates one of the particular instances of a detailed analysis of this issue during the October 2009 forecast.
[25] The g3 works with the average monthly wage in the business sector to approximate wage developments in the economy. See Appendix A.2 for a discussion of alternative wage indicators.

dynamics from 2.9 % to 2.5 %. The new data, however, indicated a sudden and relatively significant y-o-y increase in the average nominal wage in the business sector at 4.2 %, i.e. 1.7 p.p. above of the forecasted value, despite falling employment and economic activity. Since wages are the most inertial determinants of nominal marginal costs in the CNB core model, the forecasting team had to decide on the magnitude of the fundamental, noise-free wage growth, this decision having a significant impact on nominal marginal costs on the forecast horizon. See Figure 3.4 for the illustration of the surprise in the 2010Q1 forecast round versus 2009Q4 forecast.

Figure 3.4: Nominal Wage Growth in the Business Sector (y-o-y in %, s.a.)



In order to understand the main causes of the surprisingly high average wage growth in an environment of falling internal and external demand, sectoral specialists responsible for the analysis of the labour market provided the FT with a detailed, disaggregated analysis of latest labour market trends. They identified two main factors that were behind the high average wage growth: an above-average fall in the sickness rate, and the wage distributional effect arising from the high share of low-pay workers among those who were being laid off.

The breakdown of available data indicated that the sickness rate fell in y-o-y terms significantly due to two key factors. First, the sharply deepening economic crisis and higher risk of lay-offs made employees more cautious in terms of being on sickness leave in those cases when such absence was not absolutely necessary. Second, employment – as we will discuss in more detail below – fell more significantly in those professions where the sickness rate is above the average. The economic crisis-related fall in the sickness rate had an estimated 0.8-1.1 percentage point positive contribution to the average wage growth compared with 'normal' times.

The shift in employment and wage distribution during the deepening crisis in 2009 was identified as the second reason behind the surprisingly strong average wage growth. The information obtained from Czech Statistical Office (CZSO) and survey data indicated that most workers among the laid-off were those in low-pay positions. This numerically shifted the average wage up. The unofficial estimate of this distributional effect was quantified to contribute approximately 1 percentage point to the average wage growth.

In order to verify this estimate, the sectoral specialists examined the wage distribution based on the Czech Statistical Office's data (ISCO 88 compatible), providing the average wage and employment data according to professions classified into nine main groups. Unfortunately these data are available only with yearly frequency; therefore the estimate below was carried out on 2008 data.

Table 3.1: Average Wage and Employment According to CZSO Classification KZAM

Classification	**Code**	**Av. wage**	**No. of employed**
Legislative bodies, middle- and top management	1000	54 847	107 599
White-collar workers, scientists	2000	35 395	285 880
Technical, pedagogic and healthcare workers	3000	28 592	413 067
Lower-administrative workers	4000	21 099	122 083
Operating officers in services and commerce	5000	16 245	134 127
Qualified workers in agricult., forestry and fishing	6000	17 756	7 877
Craftsman, qualified producers and manufacturers	7000	21 896	243 390
Operators of machines and equipment	8000	21 219	284 634
Low-skilled workers	9000	14 448	113 154

Wage distribution data for 2008, captured in Table 3.1 above, were used for estimating the effect of the loss of employment predominantly in below-the-average wage groups. Obviously, classification groups 9000, 5000 and 6000 were the professions representing the lowest average wage according to the CZSO's classification. The estimation simply assumed that the 2.8 % fall of employment in the 3Q 2009 was concentrated in these three groups.[26] The assumption implied an increase in the average wage between 1.1 and 1.3 percentage points.[27] Despite the crude and approximate nature of this simple estimation, the FT came to the conclusion that the analysts' estimate of the wage distribution effect is not questioned by the simple calculation carried out above. The initial conditions of average nominal wage growth were, therefore, lowered by 1.5 p.p., i.e. 0.9 p.p. due to lower sickness rate and rather conservatively by only 0.6 p.p. due to the distributional effects.

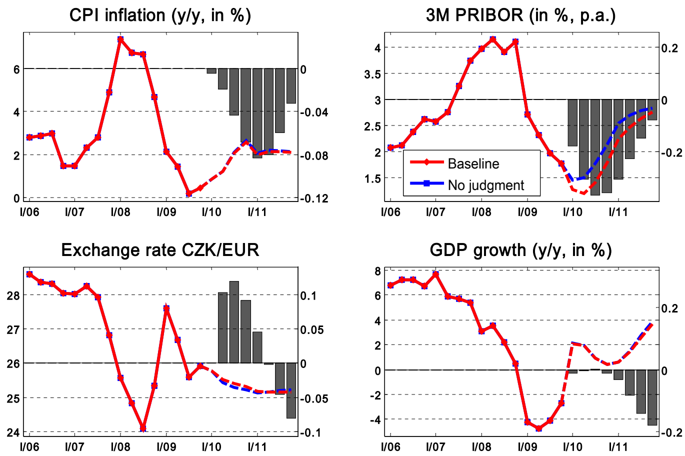
Figure 3.5 illustrates the quantitative effect of this judgment on the forecast, most importantly on the implied interest rate path. Lower initial conditions of nominal wages generate lower marginal costs of firms and subsequently lower inflationary pressures than the unadjusted wages would imply. The lower interest rates are consistent with a slightly more depreciated exchange rate. The effect of lower nominal wage growth on the firm cost side dominates the higher y-o-y growth of import prices; therefore, overall inflation is slightly lower in the baseline scenario containing the expert adjustment of high wage growth. From the ex-post view, the analysis of the main sources of wage growth proved to be correct in two aspects. First, y-o-y growth of nominal wages in the business sector were fluctuating around 3 % during the 2010-11 period,

[26] Of course, in reality the fall of employment could have happened in other profession groups as well. Neither could the FT rule out the option that employment in some higher wage groups went up and in low-skilled wage groups fell by even more than 2.8 %.

[27] Even if we assumed that the total fall in employment was concentrated in the next group 4000 with higher average wages, we would still observe a 0.6 percentage point increase in the average wage.

very close to forecasted values. Second, the high wage dynamics observed in the data at the beginning of 2010 did not become a source of any additional inflationary pressure compared with the forecast in the baseline scenario. In fact, CPI inflation was slightly below the baseline forecast depicted in Figure 3.5 on the whole forecast horizon.

Figure 3.5: Effects of the Judgment on Nominal Wage Growth



The monetary policy implications of the applied judgment are even more pronounced than in the case of previously discussed import prices. Lower wage growth in the baseline scenario implies lower inflationary pressures, as the lower domestic inflation stemming from suppressed wages is dominating the effect of the slightly depreciated exchange rate.[28] Given high wage rigidity and its sustained transmission to domestic costs of firms, the effect of lower wage growth in the baseline forecast is rather significant and sustained in terms of the implied interest rate trajectory. Compared with the simulation without judgment, the implied interest rates in the baseline scenario were lower for a period of more than 6 quarters, with a maximum difference reaching almost 0.5 p.p. in the 3rd and 4th quarter of 2010. For the immediate interest rate decision for the 1Q 2010 the difference between the two scenarios was somewhat less than 0.2 %, nevertheless the whole interest rate trajectory consistent with the baseline forecast implied an ample room for further monetary easing. At the November 2009 meeting, the CNB's Board decided by a slim majority not to change the interest rates due to the prevailing high degree of uncertainty; but as during the subsequent forecasts anti-inflationary risks were more and more materialising, the interest rates were actually cut by the CNB Board even faster than the path captured by Figure 3.5 would imply. Thus the applied judgment appears to be correct from the monetary policy perspective in the ex-post view.

[28] The weakening of the koruna was due to the lower domestic interest rate trajectory, compared with unchanged Euribor rates.

Sensitivity Analysis Related to the Source of Wage Growth

After presenting the above judgment to the CNB Board, the forecasting team was asked to analyse the implications of alternative sources of wage growth in more detail. Such a sensitivity analysis is presented here to further describe the importance of micro-based wage adjustments applied on both historic sample and/or the forecast horizon.[29]

The sensitivity analysis[30] focuses on the implications of fundamental as opposed to non-fundamental sources of wage growth for the forecast outcome. By fundamental wage growth we understand wage growth induced by an increase in productivity, while non-fundamental wage increases are not accompanied by an increase in productivity and are simulated by wage cost-push shocks. The simulation results, as will be seen later, are economically intuitive in the sense that wage growth induced by higher productivity is consistent with lower inflationary pressures compared with the case when a non-fundamental shock (resulting e.g. from labour-union demand and collective agreements not reflecting the economic performance) is the source of wage increases.

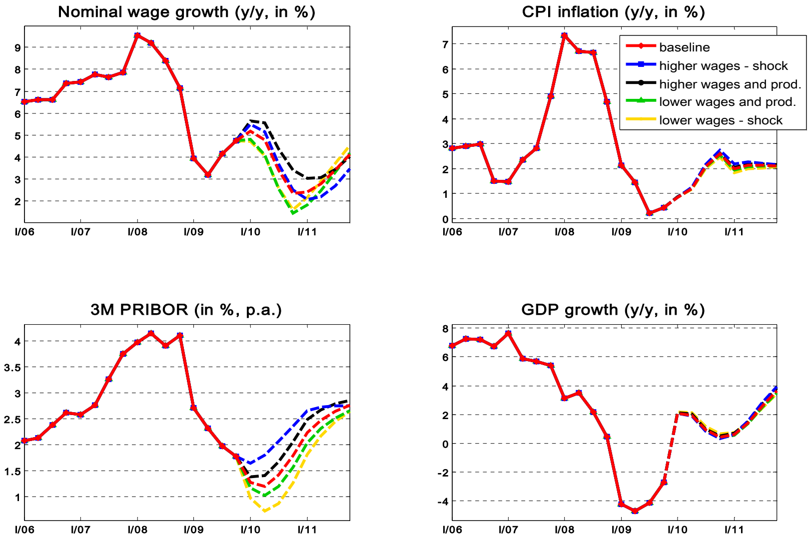
The simulations, captured by Figure 3.6, were constructed as follows. In the first scenario (blue line) the judgment-based downward wage adjustment during the second half of 2009 used in the baseline scenario of the January 2010 is almost absent, and the observed high wage growth is taken at its face value, and is assumed to be caused solely by a wage-push shock. The interest rates set by the central bank in this case are naturally higher than in the baseline scenario, since the wage-push shock would propagate also into future wage increases, which – without changes in productivity – would create upward pressures on inflation. In the second scenario (black line) it is assumed that a part of the wage increase is given by productivity growth and the rest is caused by wage-push shocks. The short-term interest rates determined by the central bank lie between the first scenario and the baseline. This result is given by the cushioning effect on unit wage cost induced by higher productivity growth that in turn generates lower inflationary pressures on the forecast horizon. This experiment clearly shows that wage growth does not necessarily result in higher short term interest rates when it is backed by productivity increases.

In the last two scenarios it is assumed that wage growth in the first quarter of 2010 might be lower than in all the scenarios discussed above, potentially due to a strengthened bargaining position of firms reflecting the weak labour market conditions. Again, the simulations quantify two potential interpretations of the low wage increase at the beginning of 2010. Either the low wage dynamics is explained as a combination of a lower productivity increase with higher bargaining power of firms (grey line) or as a pure result of firms' domination on the labour market (yellow line). The combined effect of lower productivity and negative wage-push shock is consistent with lower inflation and interest rate path, but to a lesser extent than in the case of a pure shock-determined wage growth. The reason is clear and analogical to the reasoning above: the lower productivity increase in the third simulation compared with unchanged productivity in the last scenario generates, ceteris-paribus, higher inflationary pressures and consequently higher interest rates compared with the low wage growth caused by wage-push factors. All these simulations demonstrate the utmost importance of a correct identification of the key sources of nominal wage growth for monetary policy decisions. Specifically, when wage increases are backed by fundamentals in terms of corresponding productivity increases, monetary policy

[29] This sensitivity analysis was presented to the CNB Board prior to the completion of the January 2010 forecast as well as at the CNB's regular meeting with analysts. For more detail see the presentation on the CNB web page: http://www.cnb.cz/en/monetary_ policy/forecast/analysts_ meetings/download/analysts_ 2010 _ I.pdf.

[30] The design of this sensitivity analysis was proposed by our colleague Michal Andrle at that time. We gratefully acknowledge his contribution.

Figure 3.6: Uncertainty About the Wage Growth in 2010Q1



Source: Meeting with analysts (Inflation Report I/2010)

can stay ‘neutral’ without jeopardising the inflation being off the target. Should the observed wage growth be a result of unexpectedly high/low demand, labour union negotiations or other non-fundamental sources causing a deviation of wages from the level that would be justified according to productivity, the central bank must correct the corresponding price pressures to keep inflation close to the inflation target. Of course, in practical policy making recognizing the fundamentals from noise is one of the most challenging tasks, requiring a detailed analysis of the micro data and proper knowledge of the labour market at hand.

At November 2009 monetary policy meeting, the CNB’s Board discussed the wage sensitivity scenarios, and in particular those with even lower wage growth than in the baseline forecast.[31] Possibly lower future growth in nominal wages was listed as the main downside risk to the forecast; to a large extend offsetting the inflationary impact of observed weaker exchange rate. This sensitivity scenario thus had an important influence on the monetary policy decision making.

[31] ”The conclusions of a nominal wage sensitivity scenario quantifying the impacts of potential lower nominal wage growth at the forecast horizon were identified as an argument for a further easing of the interest rate conditions. In support of the conclusions of this scenario, it was repeatedly said that many non-financial corporations would have to cut costs through zero or negative wage growth in 2010 because of the need to keep their margins positive.”

3.3 Car Scrapping Subsidies

Since the export sector, especially manufacturing, generates a substantial share of Czech GDP, the cyclical position of Czech export markets is crucial for our economic developments. Moreover, increased uncertainty in the global financial markets often strongly influences exchange rate movements. For these reasons, dealing with the outlook of foreign variables is one of the most crucial and discussed issues within the forecasting process. The outlook of foreign interest rates, effective foreign demand and effective foreign PPI price growth are inserted into the forecasting process as exogenous time series.[32] Expected trajectories of these variables are modelled as fully anticipated in model simulations as they are based on public information (Consensus Forecasts survey and market outlooks).[33] Beyond the forecast horizon given by the Consensus Forecasts, the foreign variables are assumed to be returning to the steady-state levels or growth rates. Besides, other important foreign variables that are directly not used in g3 (USD/EUR exchange rate, price of Brent oil, foreign CPI etc.) can exert an effect on the forecast, potentially requiring inserting expert judgment. For example, the effects of an increase of the oil price can be implemented as a cost-push shock into import prices, via the NTF nowcast and also into the outlook of regulated prices.

During the Great Recession, some European countries important as Czech export markets introduced subsidies for purchasing a new car with a simultaneous scrapping of the old and presumably less ecological one.[34] Since there was a limit on the maximum amount of subsidies obtainable, the car scrapping subsidies had a major impact on the segment of small-to-medium sized cars. In April 2009, the estimated subvention amounted to 6.6 bn. EUR from all programs introduced in Europe of which 5 bn. was released by Germany. These subsidies were paid out for the purchase of 3.7 million cars (more than a half of overall purchases in this segment).

As the small and medium size car production is one of most important industries for the Czech economy, an expert judgment to the foreign demand outlook was necessary to make an *(ex ante) unbiased* forecast of the real domestic economic activity. This was due to a fact that although the Consensus Forecast had already incorporated the car scrapping subsidies, the included impact on the Eurozone would not have been proportional to the Czech economy. Thus, the estimation of additional effects on Czech production was based on Adda and Cooper (2000a,b).[35] Adda and Cooper (2000b) estimated that the subsidy program boosts the demand by 10% in the very short run (in our case the first year of the car scrapping subsidy introduction, i.e. 2009), which is then followed by a lower demand compared with what would have been realized in the case of no policy change scenario. Adda and Cooper (2000b) estimated the reverse effect to last for 15 years. The FT came to the conclusion that this reversed effect in the Czech economy would be significant within 3 years. Since the foreign demand is represented by effective euro zone GDP, we did not introduce the percentage changes directly to the GDP since the effect would be overestimated. Hence, the expert judgement changed the effective foreign demand via the

[32] The weights used in the calculation of the effective variables are the shares of the individual euro area economies in the foreign trade turnover of the Czech Republic.

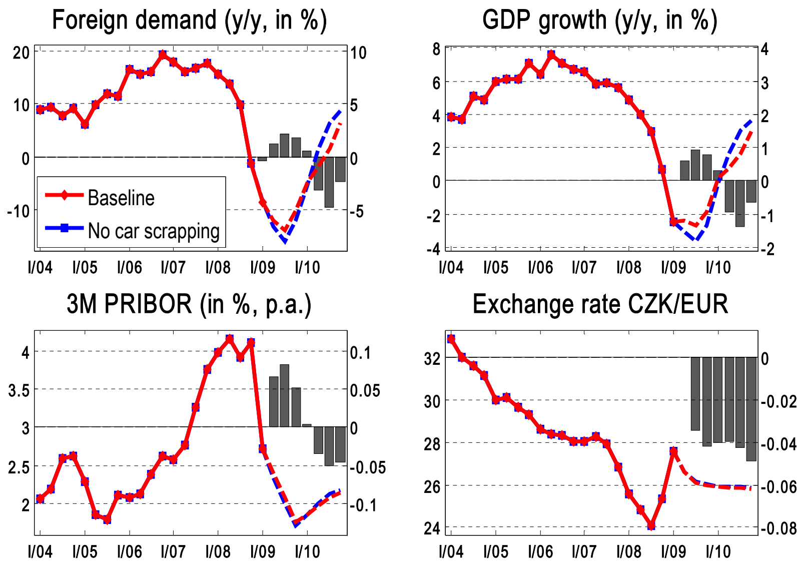
[33] Projections of some other exogenous variables, such as government spending and regulated prices, are inserted as unanticipated. Inserting e.g. regulated prices as anticipated would imply an immediate model reaction to the expected future shocks. In reality, Czech households do not strongly react in advance to regulated prices shocks that are expected to occur in a year time or later. Thus, the unanticipated nature of regulated prices and government spending outlook is more in line with reality. In general, judgments on the forecast horizon can be inserted as a mix of expected and unexpected shocks.

[34] These incentives are known as 'car scrapping subsidies' or 'cash-for-clunkers programs'. We use the former term here to be consistent with the CNB's Inflation Reports.

[35] We are grateful to David Kocourek for providing us with the empirical evidence. Recently, Kocourek (2012) analyses in more detailed this issue and exhaustively describes the European programs.

modification of the industrial production of euro zone. The year-on-year growth in 2009 was increased by 10% and lowered by 3% in the following 3 years. Having estimated the effect of euro zone industrial production on the euro zone GDP, the expert judgement was translated into the model.

Figure 3.7: Car Scrapping Subsidies



The estimations were based on calculations of additional demand stimulated by the programs for newly produced cars which would not be realized otherwise.[36] The scale of the expert judgment is shown in Figure 3.7, which presents the real-time expectations of car scrapping subsidies effects. The blue line depicts foreign effective demand outlook based on the GDP predictions from Consensus Forecast. The red line depicts the demand after the incorporation of car scrapping subsidies, which was used for the forecast. Thus, the subsidies raised the effective demand for Czech exports in 2009. At the same time, the foreign demand for 2010 was decreased, based on the assumption that people who aim to purchase a new car would prefer to employ the subsidy before its termination. In other words, the demand was frontloaded into 2009 and dropped later compared with the hypothetical no-subsidy situation. The overall effects on annual Czech GDP dynamics in 2009 and 2010 were at that time estimated at 0.6 p.p. and -0.7 p.p., respectively.

Figure 3.7 presents the effects of the expert judgment incorporation for the main variables of the forecast. The change of the profile of domestic GDP corresponds to the foreign demand through contributions of net exports. It is worth noting that this judgment significantly changed the forecast of the Czech economic growth profile, by adding about 1 p.p. to y-o-y economic

[36] The alternative calculations based on an estimation of price elasticity (McCarthy, 1996) implied a lower size of the adjustment to foreign demand. However, since the car scrapping has additional effects on subcontractors, whose additional demand is in fact hard to estimate, the higher estimate was applied.

growth in the last three quarters of 2009 and subtracting a little bit more than that on average in the last 3 quarters of 2010. The differences in other variables are negligible as the higher demand in 2009 is compensated by the lower demand in 2010 and foreign demand is modelled as fully anticipated. Nonetheless, despite the fact that the direct policy implications of the incorporation of this judgment in terms of short-term interest rate setting were negligible, it still played an important role for the forecast as a whole. In particular, taking into account the demand side effect of foreign car scrapping subsidies on the GDP forecast profile contributed to the overall credibility of the forecast. The quantification of the demand effect was supported by the detailed presentation of the underlying analysis to the CNB Board, thus demonstrating to the policymakers the ability of the forecasting team to cope with specific economic events emerging during the crisis. The effects of the car scrapping subsidies were then explicitly debated by the Board members in a discussion on the durability of the observed foreign demand recovery.[37]

With the benefit of hindsight, the Czech economic recession was deeper in 2009 than predicted by the baseline scenario. But this was due to a deeper-than-assumed recession in the euro area, while at the sectoral level the positive effect of car-scrapping subsidies was clearly visible in that year. At the same time, the negative subsequent effect on the export demand in 2010-2012 has been harder to identify in the data, as some of the domestic car producers increased their non-price competitiveness and were to some extent successful in penetrating non-EU markets, thus offsetting the negative carry-over effects of car scrapping subsidies in the EU with sales in other regions.

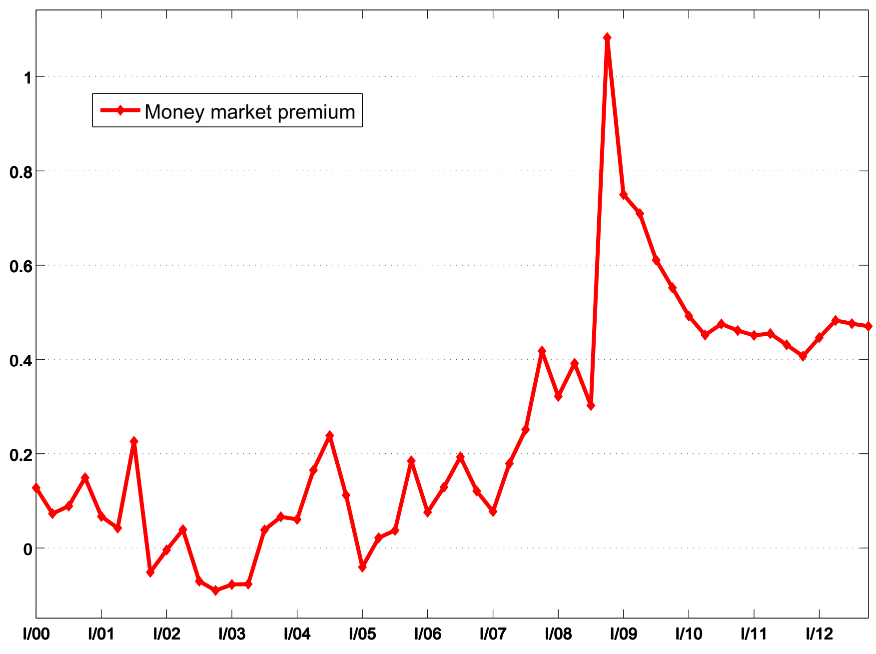
[37] "Attention was drawn in the debate to the effect measures such as car-scrapping incentives, i.e. to the fact that the signs of improvement were coming from areas in which one-off support measures were being implemented, measures whose effects would probably be only short-lived." See http://www.cnb.cz/en/monetary_policy/bank_board_minutes/2009/amom_090507.html.

3.4 Money Market Premium During the Crisis

The g3 model deliberately works with the interbank (3M PRIBOR) interest rate and does not contain the CNB's policy (2W REPO) rate in the monetary policy reaction function. The main reason for this decision was that the repo rate had always been very close to 3M PRIBOR and the resulting low historical spread between both interest rates had been relatively stable. Thus, a simple equation with an exogenous money market premium relating both rates was sufficient for the implication of each forecast for the 2W REPO. However, after the crisis started in 2008, we observed that the situation changed and the spread increased dramatically (some increase was in fact observed already from mid-2007, when the sub-prime mortgage crisis started in the US).

In the last quarter of 2008, the money market premium increased unprecedentedly (Figure 3.8), and very high uncertainty prevailed about its future evolution. Since the policy implications for 2W REPO depends on model-implied interbank (3M PRIBOR) interest rate forecast and a future development of the premium, the FT had to decide how to reflect the new situation. One possibility was to change the model to incorporate the 2W REPO rate into the central bank's reaction function, and to work with the money market premium in an 'endogenous' way. Another option was to maintain the 3M PRIBOR in the model as an indicator of the appropriate monetary policy stance, given its relevance as a reference rate mainly for corporate loans, and to use an exogenous path of the money market premium to derive the corresponding 2W REPO outlook. The implicit assumption here was that the monetary policy would fully offset the observed changes to the money market premium to achieve the desired level of 3M PRIBOR.

Figure 3.8: Money Market Premium



Given the above mentioned uncertainty, the FT decided to continue with the practice of working with the interbank interest rate in the g3 model and to make decisions about future development of the money market premium outside the core model. Such an approach was reinforced by the fact that there was at that time a relative close lagged connection between the Czech and euro area money market premia, which could indicate the near-term future Czech development. From the ex-post view, the money market premium led to higher-than-intended 3M PRIBOR level in late-2008, but once this was factored into the decision making and the premium started to follow a downward-sloping path broadly matching the forecast assumptions, the CNB was able to deliver the monetary easing consistent with the forecast. The exogenous way of reflecting the money market premium thus worked reasonably well.

On the other hand, a direct modelling of the 2W REPO in the g3 structure would bear several disadvantages which would complicate the forecasting and cause some additional uncertainty. In particular, the extended model would contain a mechanism which relates both interest rates by a persistent money market premium[38]

$$Pribor_t = Repo_t + Prem_t,$$

and

$$Prem_t = \rho Prem_{t-1} + (1-\rho)\overline{Prem} + \epsilon_t.$$

where the REPO rate is presented in the reaction function and other model equations (the Euler equation and the UIP equation) contain 3M PRIBOR rate which is crucial for the behaviour of economic agents. This approach requires an introduction of a new shock, which can alter historical filtration and decompositions and more importantly allows incorporating future expert judgments about the premium into the forecast. The main problem is that although these shocks are not directly a part of the central bank's reaction function, they in fact have a character of monetary policy shocks. For the forecast, inserting future MP shocks is questionable, because it would imply an ex ante too strict or too loose policy, and thus a temporary departure from the inflation targeting regime.[39]

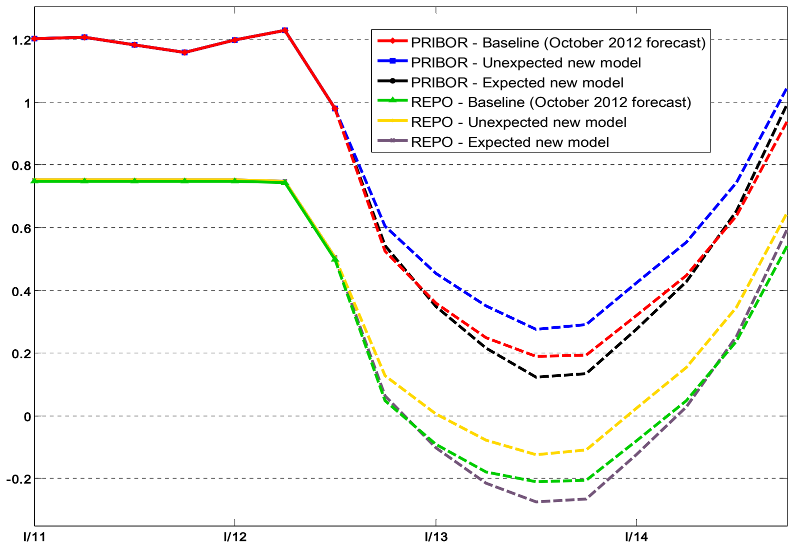
At the same time, the outcomes and monetary policy implications of this approach would not be unique, but would instead depend on the way of imposing the expert judgments on the premium. This is illustrated in Figure 3.9, which compares the baseline (from October 2012 forecast) scenario with two forecasts based on the extended version of the g3 model that contains the above mentioned two additional equations. The future values of the money market premium in the forecasting horizon are decreasing to 0.4. The steady-state of the premium (which is an object of extra uncertainty by itself) is calibrated to 0.2. In the baseline simulation, the REPO forecast is the difference between the 3M PRIBOR implied by the model and the exogenous premium. In the two remaining simulations, we use an extended model with endogenous mechanisms for 3M PRIBOR and REPO and assume the same size of the credit premium, which is modelled either as fully anticipated or as fully unanticipated. In the first case, where the future development of the premium is unanticipated, agents in the model assume its return to the steady-state (0.2) by the autoregressive mechanism. As this is less adverse than the assumption of the baseline scenario, the monetary authority cuts the REPO rates less aggressively. On the other hand, in

[38] We do not distinguish between time and risk components of the premium.

[39] Therefore, the FT uses MP shocks only for various additional scenario analyses (usually called "monetary policy experiments") and not in the baseline forecasts.

the anticipated case, as agents in the model are aware of more restrictive conditions in the economy, the monetary authority cuts the REPO rate even more than in the baseline as it reflects the future negative shocks (expected shocks which increase PRIBOR rate).

Figure 3.9: The Effects of Expectations of Shocks to the Credit Premium on the Implied Trajectory of PRIBOR and REPO Rates



The implications of the model extension and of the way expectations about the premium are formed for other variables are negligible. The reason is that the baseline scenario lies between both simulations and the magnitude of the differences in the expected premium (0.2 p.p.) is relatively minor. Thus, the main disadvantage of extending the model is that it generates additional uncertainty about the implied PRIBOR and REPO trajectories due to the uncertain nature of expectations. This means that, in real time, the forecast and its implications for the interest rate setting would be influenced by the assumption concerning expectations (full expected, full unexpected or some part expected and some part unexpected, potentially depending on the time horizon). Moreover, as the future size of the credit premium (in a longer horizon, say 5 quarters or more) can be very hard to predict, the forecast and the implications for the REPO rate would be affected by these – quite arbitrary – assumptions. Thus, instead of communicating the future credit premium whose profile is highly ambiguous, we decided to work with the 3M PRIBOR in the model and the implied REPO is calculated with an additional ‘satellite’ equation.

To sum up, the approach taken by the FT allowed the money market risk premium to be quite directly taken into account, once the problem was recognised, in the monetary-policy decision making process. The autonomous increase in the premium was broadly offset by more aggressive cuts in the main policy rate in late-2008 and in 2009. At the same time, the off-model handling of the money market premium proved to be a pragmatic approach, which avoided some complications of incorporating the premium endogenously into the core forecasting model.

3.5 Fiscal Policy Expert Judgments

The analysis of fiscal policy effects is one of the most challenging issues of current macroeconomics. There is not only a huge uncertainty about the magnitudes of responses of macroeconomic variables to fiscal policy interventions, but the uncertainty is much more general.[40] Fiscal policy uses a wide variety of tools, e.g. complex tax systems with distortionary rates, which often non-trivially interact with the social security system (see Gordon and Tchilinguirian, 1998), various incentives, a set of expenditures, some of them with utility and productive enhancing effects etc. To consistently capture these measures, it is required to make non-trivial assumptions for model development.[41] Moreover, the adoption of a systematic fiscal policy rule by the government (a reaction function) is not in reality frequent. Empirical time series techniques (such as SVARs) have a limited ability for estimating fiscal policy effects. The usual identification approaches to SVAR (such as the recursive identification) are problematic since they cannot distinguish (i) temporary and persistent shocks stemming from fiscal policy (ii) and expected and unexpected shocks. Although some SVAR studies use sophisticated approaches to identification by isolating unexpected and temporary fiscal shocks (such as military expenditures), the results of such studies are limited: the multipliers estimated in this way cannot be used to predict the effects of fiscal policy reforms, since such reforms are usually announced sufficiently in advance, and are intended to be permanent.

The g3 model contains a Ricardian fiscal policy treatment. Within the model structure, the government sector is one of the final goods producing sectors using domestic intermediate production as inputs. More concretely, the model contains nominal and real government expenditures. On the forecast horizon, these two variables are assumed to be exogenous and their awaited future trajectories are inserted into the forecasts as unanticipated judgments and simulated consistently during forecasts. Thus, the fiscal policy treatment is aggregated and stylized, but the g3 model is very flexible to incorporate appropriate judgments in a number of ways. Despite this 'simple' treatment of fiscal policy in the g3 model, we believe that such a setting is sufficient for analyzing the initial conditions and regular forecasting based on future government measures.[42]

Besides inserting government spending as exogenous trajectories, there is close cooperation between the forecasting team and the Fiscal Policy Analysis Unit. Future fiscal policy measures are evaluated in terms of their impacts on main macroeconomic variables (e.g. disposable income, consumption, investment) and inserted as expert judgments through habit shocks (which approximate demand shocks within the model) or investment-specific shocks. For example, higher future government investment can be captured by an expert judgment formalized by a shock to the investment-specific technology which increases investment expenditures and propagates through the model mechanisms into other variables.[43]

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[40] Perotti (2007) claims that *in contrast (to monetary policy), perfectly reasonable economists can and do disagree on the basic theoretical effects of fiscal policy, and on the interpretation of the existing empirical evidence*.

[41] For example, the IMF uses a separate fiscal policy model which departures from the Ricardian equivalence (OLG assumption, distortionary taxes, or a presence of liquidity-constrained households), Botman et al. (2007).

[42] For simulation purposes, Ambriško et al. (2012a) developed a version of the g3 model with non-Ricardian features and a fully-fledged fiscal block.

[43] With respect to indirect taxation, the g3 model works with monetary-policy relevant inflation. The MP relevant inflation is the headline CPI inflation (incl. regulated prices) less immediate effects of changes in indirect taxation. The expected second-round effects of indirect tax changes are components of the MP inflation. Second-round effects are based on their magnitudes in history and sectoral experts' assessment. By definition, second-round effects are a difference between the primary effects (the magnitude of indirect taxes changes) and their projection into prices implying changes in the mark-up.

Table 3.2: Alternative Scenario: Additional Budget Measures – Government-approved Measures (CZK Billions Unless Otherwise Indicated)

7% additional solidarity personal income tax	1,8
Abolition of basic allowance for working pensioners	2,0
Reduction of flat-expense deductions for self-employed	3,5
Increase of withholding tax against tax havens to 35%	0,6
1 pp increase in VAT to 15% and 21%	19,6
Abolition of "green diesel" for agricultural producers	1,6
Higher tax on tobacco	0,1
Abolition of health insurance ceiling	1,8
Increase in real estate tax	1,8
Profit transfer from Lesy CR state company	4,0
Sales of emission permits	2,9
REVENUE MEASURES	39,8

Lower indexation of pensions	9,5
Freezing of wages for state employees	5,5
Abolition of housing benefit subsidy	0,8
Lower subsidies on renewable energy resources	2,0
Lower subsidy to SFDI state fund	0,2
EXPENDITURE MEASURES	18,0
TOTAL REVENUE AND EXPENDITURE MEASURES	57,8
% of GDP	1,4
Fiscal impulse to GDP in percentage points	0,8

For the incorporation of any off-model fiscal information, it is crucial to quantify the demand-side fiscal impulse. The fiscal impulse is based on the expected government discretionary decisions regarding the revenue and expenditure side of the public budget. The impulse is derived from individual revenue and expenditure side budgetary measures, expressed as a share of nominal GDP, subsequently multiplied by the assumed value of fiscal multiplier.[44] The value of the multiplier was set in the past forecasts to 0.6.[45]

The final estimate of the fiscal impulse is incorporated into the forecast through adjusting the expenditure side components of the GDP. Obviously, government and household consumption are the most significant items that are most strongly influenced by the government's discretion. Investments and the exchange rate are also sometimes used for capturing the effect of government's expenditure or revenue side decisions. Hence the fiscal unit provides the FT with its outlook for social benefits, public sector wage bill as well as government investment expenditures. These figures are used in the next stages of the forecasting process when preparing final, elaborated story containing details beyond what the core model structure provides.

The private consumption is influenced by several variables and indicators that are not (deliberately) present in the g3 model. The model-based consumption forecast is then compared with the sectoral experts' forecast of disposable income and saving rates.

3.5.1 The Effect of the 2013 Fiscal Consolidation Program

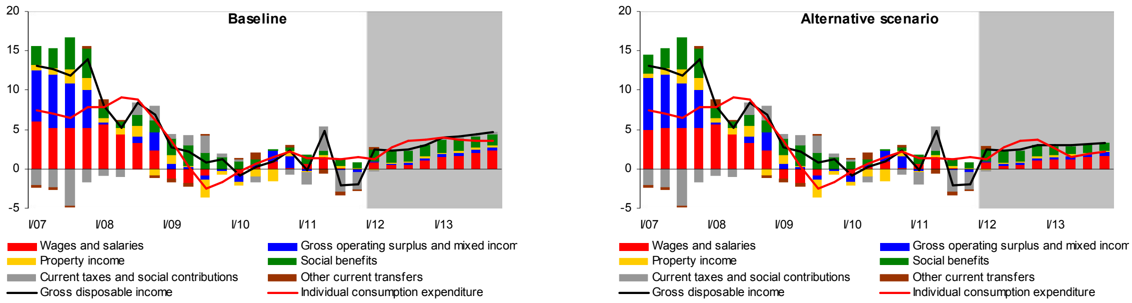
As an example, we show here the case of consolidation budgetary measures in the Czech Republic that were proposed by the government in 2Q 2012. Since the baseline forecasts are based on well-specified (future) fiscal policy measures that are already approved by the Parliament (or at least close to approval), planned or intended measures are usually treated by alternative forecasts or sensitivity scenarios and are communicated to the public as an evaluation of the possible risk to the baseline scenario. As most of the time the formal approval of budgetary measures is somewhat lagging behind their public announcement and the final shape may differ from the initial intensions, they become fully incorporated into baseline scenarios only after their formal approval. In line with this general approach, the FT prepared an alternative scenario in 2Q 2012, reflecting the planned fiscal consolidation package for 2013. The fiscal specialists calculated the budgetary effects of the proposed government measures, which are presented in Table 3.2.

[44] For detailed description of the derivation of the fiscal impulse; see Ambriško et al. (2012b) or Tomšík (2012).
[45] The Inflation Report IV/2012 contained a sensitivity analysis with the fiscal multiplier set to 1.

In the alternative scenario, the planned fiscal policy measures were assumed to reduce the structural government deficit by almost CZK 58 billion (i.e. 1.4% of GDP) in 2013. From this amount, more than two-thirds were on the revenue side and less than one-third concerned the spending cuts. According to the FT's estimates, the fiscal consolidation plan would slow down the economic growth by about 0.8 percentage points in 2013. In particular, this impact was expected to materialize through the price effect stemming from an increase in both VAT rates[46], through lower nominal disposable income of households, as well as via slightly lower government consumption.

In Figure 3.10, the most significant differences between the baseline and alternative scenario concerning the household nominal disposable income relate to wages and salaries and to social benefits. The fiscal measures are inducing a fall in the y-o-y growth of nominal disposable income in 2013 by approximately 1 percentage point in the alternative scenario. Similarly, consumption expenditure growth is lower for this period, although the difference between the two scenarios in the case of consumption is somewhat less pronounced in 2013[47] than for disposable income. The effects of these measures on the Czech economy are shown in Figure 3.11 as differences from the baseline forecast.

Figure 3.10: Disposable Income and Consumption (Annual Percentage Changes; Contributions in Percentage Points)

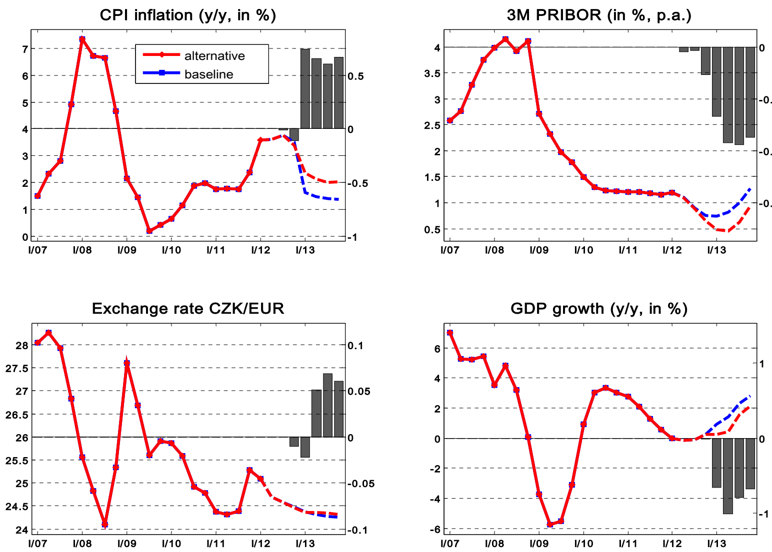


The increase in both VAT rates by one percentage point results in a jump in the headline inflation, which together with other revenue and expenditure effects implies a downward pressure on the real disposable income of households. Thus, compared with the baseline scenario, household consumption is lower by about 1.6 percentage points, leading to more subdued GDP developments. These effects are modelled via habit shocks to private consumption. The first-round effects of VAT changes are not included in the monetary-policy relevant inflation, so they do not have a direct impact on interest rates in the alternative scenario. Moreover, in line with past experience and the subdued economic activity, the alternative scenario does not assume any significant second-round effects of the VAT rate increase on inflation (e.g. due to rising inflation expectations or wages). Monetary policy is reacting by cutting short-term interest rates due to curb anti-inflationary pressures generated by the more subdued economic activity. The most significant difference between the interest rate trajectories of the two scenarios, almost 0.4 p.p., is achieved after 4-5 quarters. The exchange rate is almost the same as in the baseline scenario.

[46] There are two VAT rates in the Czech economy, which were raised from 14% to 15% and from 20% to 21% in 2013.

[47] The difference is diminishing from 0.9 percentage points in the 1Q to 0.2 in the 4Q.

Figure 3.11: Additional Budgetary Measures' Effects



Even though at the time of writing this paper it is too early to provide a definite ex-post assessment of the imposed fiscal policy judgments, the consolidation package has indeed been implemented in 2013, and the current CNB's (as well as consensus) projections are closer to the alternative scenario than to the baseline from 2Q 2012. As in earlier cases, the ability to incorporate fiscal measures via imposing expert judgments was also crucial in terms of increasing the forecasts' acceptability for the key users. The alternative scenario was discussed extensively at the Bank Board meeting, even though it was supported by some Board members only.[48] At the press conference following the meeting, the scenario was listed as the main downside risk to the forecast. In the subsequent forecast prepared during October 2012, the approved budgetary measures were incorporated into the new baseline forecast, and the CNB's Board decided based on that forecast to cut interest rates in November 2012 to what is regarded to 'technically zero' level (0.05% p.a. for the discount and 2W REPO rates). At the same time, the Board communicated that the rates would "remain at this level over a longer horizon until inflationary pressures increase significantly." It can thus be said that the forecast judgments related to fiscal policy measures have had a significant impact on the monetary policy decision-making process.

[48] "Several of the board members expressed the view that a scenario close to the alternative scenario was highly likely to materialise and that this represented a downside risk to inflation owing to more subdued domestic demand. However, it was also noted that the effects of fiscal consolidation on the domestic economy were possibly being overestimated." (see http://www.cnb.cz/en/monetary_policy/bank_board_minutes/2012/amom_120503.html).

4. Conclusion

More than five years of DSGE-model-based experience with forecasting and policy analysis enabled to the CNB's forecasting team to accumulate experience with incorporating off- model information and judgment into a model-based forecast. It can be said that the richer structure of the g3 model provides more degrees of freedom to incorporate judgment than the previous semi-structural QPM model in an intuitive and transparent way. Thanks to this, the forecasting performance has been relatively satisfactory even in the turbulent times of the Great Recession. The paper illustrates this by means of real-world case studies of using the DSGE g3 model for forecasting at the CNB.

The presented case studies describing the use of judgment in the CNB's forecasting process imply that a close cooperation of sectoral specialists with the modelling team can result in an 'integrated' forecast that reflects the available information from various sources in a balanced manner. From this point of view, applying expert judgments is a necessary part of each forecast to supplement the core model mechanisms. The applied expert judgments often had an important direct impact on the monetary policy decision making (such as the case of the wage growth during the crisis), mainly in the direction of delivering more monetary policy easing during the crisis times, which has proven to be correct from the ex-post point of view. But even in those cases where the monetary policy implication was not so direct (such as the case of car scrapping subsidies), the judgments were important in terms of making the forecast more acceptable to its key users by manifesting the ability of the forecasting team to incorporate important phenomena observed in the economic reality into model-based projections.

These selected case studies can be illustrative for general readers who are interested in how the CNB forecasts are actually made, but also inspiring for the experts who are interested in practical forecasting with macroeconomic models, as the basic principles are applicable to structural macroeconomic models in general.

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Appendix A: Data Revisions and Uncertainty

This appendix illustrates examples of data uncertainty due to data revisions and definitions.

A.1 Data Revisions

As was discussed in the main text, frequent data revisions are one of the reasons for the use of measurement errors. Measurement errors are highly useful, since without them the model would be pushed to explain the noise stemming from short-term volatility, data revisions and methodology changes by structural shocks with potentially fundamental impacts on the forecast. Figures A.1 – A.3 show the extent of data revisions of annualized quarter-on-quarter (q/q) p.a. and year-on-year (y/y) growth rates of consumption, investment, exports and imports. In each panel, we show the latest data release of national accounts data and the magnitude of data uncertainty which is demonstrated by maximal and minimal values from other data releases. More specifically, we select releases from mid of 2008 to the end of 2011. Since forecasts are based on quarter-on-quarter data, these figures indicate that some revisions are relatively significant, often enough to considerably change the economic story. Thus, the use of measurement errors and model-consistent filtering is a necessary prerequisite to take information from all time series in real time and also to maintain a consistency between subsequent forecasts in cases when there is no change in fundamentals in the economy, but a different noise would amend forecasts and with possible implications for the monetary policy.

Some central banks try to exploit the dynamics of revisions to improve the initial information: the evidence from advanced economies suggests that the initially realized estimate need not be an unbiased estimator of the final numbers, see e.g. Bermingham (2006) or Sleeman (2006). We do not follow this path as we believe that the careful examination of expert information is much more important than the mining of possible autocorrelation structure of forecast revisions. Recently, this line of research for Czech GDP has been opened by Rusnák (2013) who finds evidence for in-sample predictability for most of the variables, suggesting that the first releases of these variables are not efficient predictors of the actual values.

Figure A.1: National Accounts Revisions: Real Variables

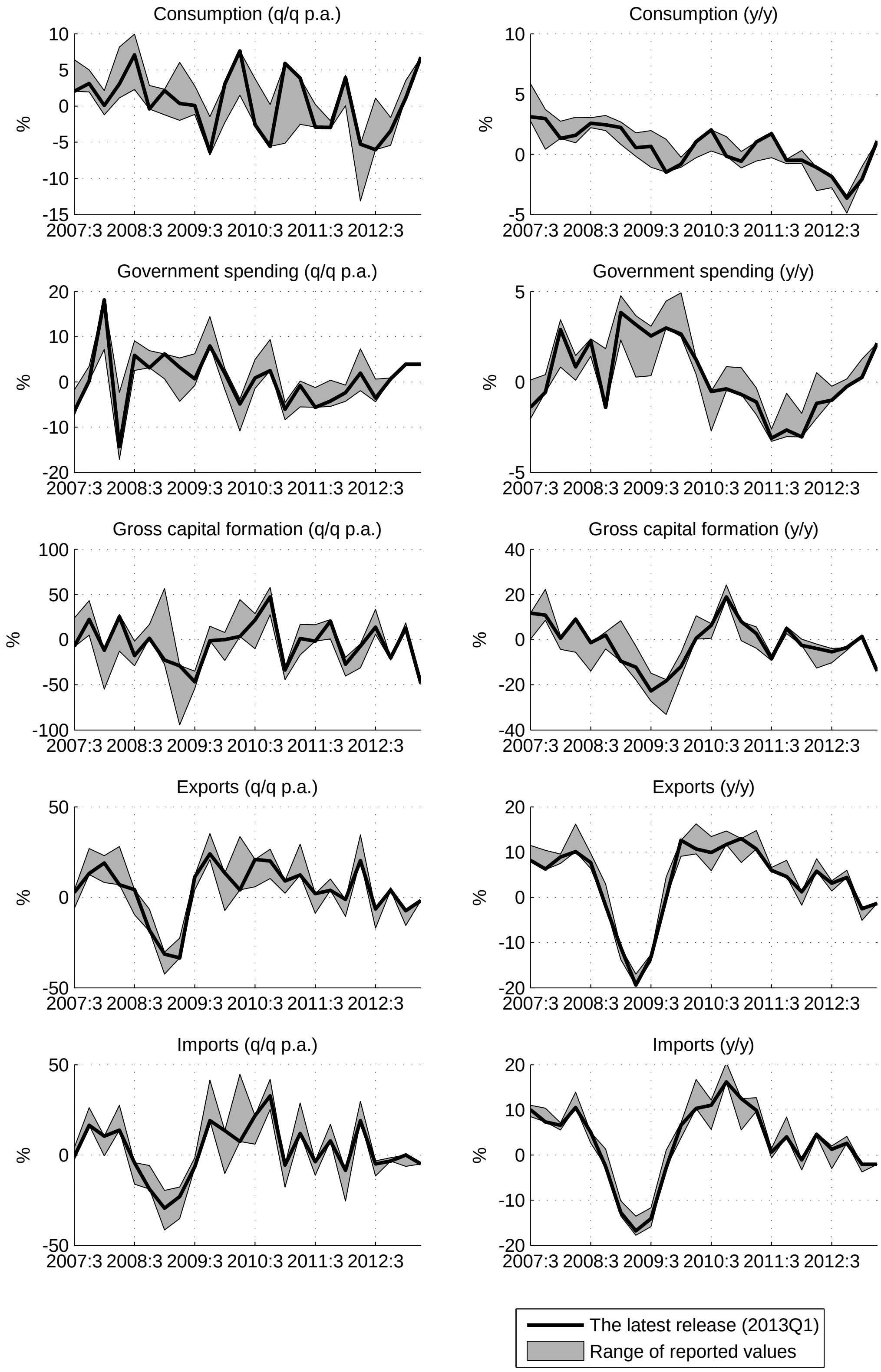


Figure A.2: National Accounts Revisions: Nominal Variables

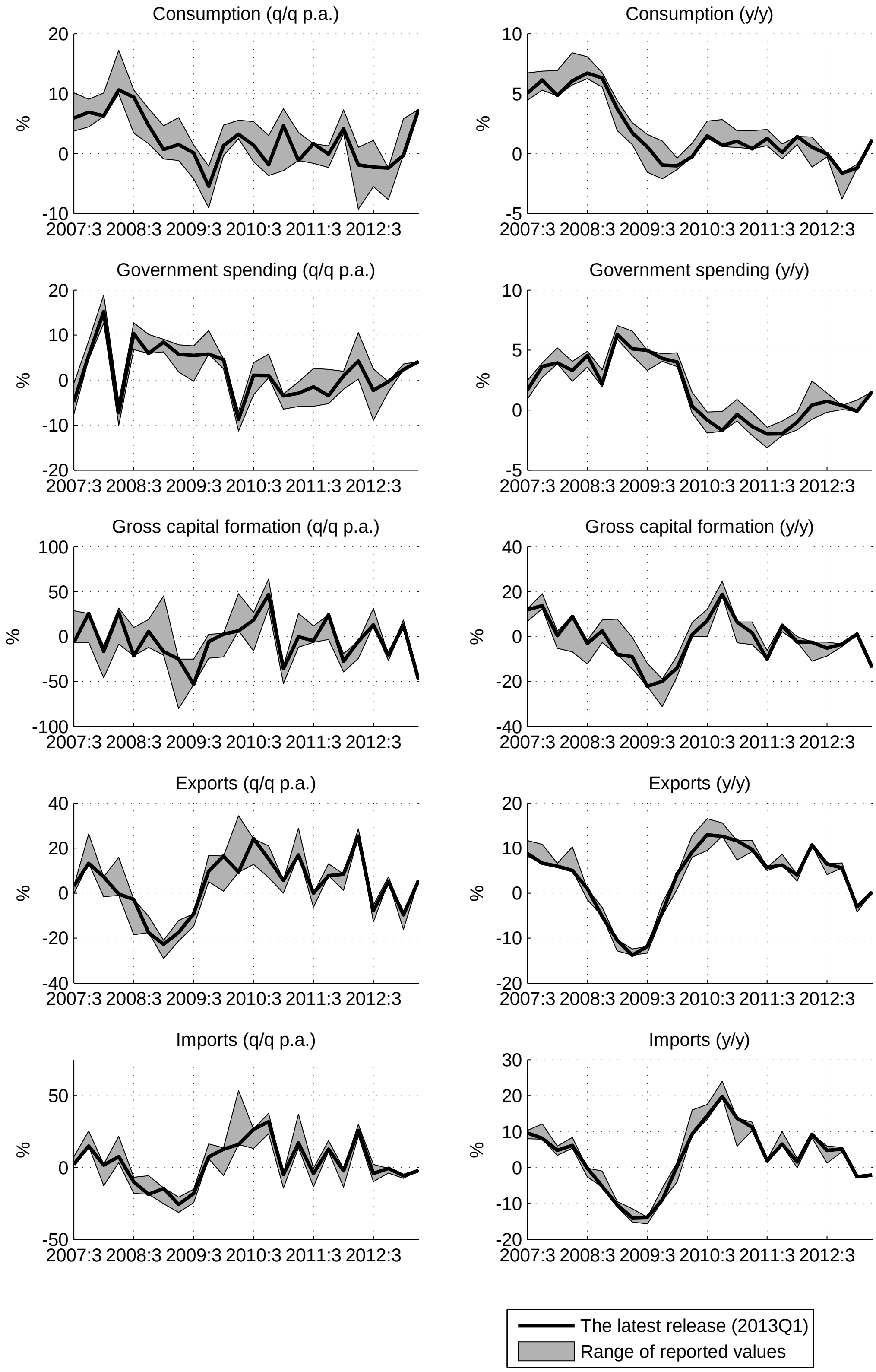
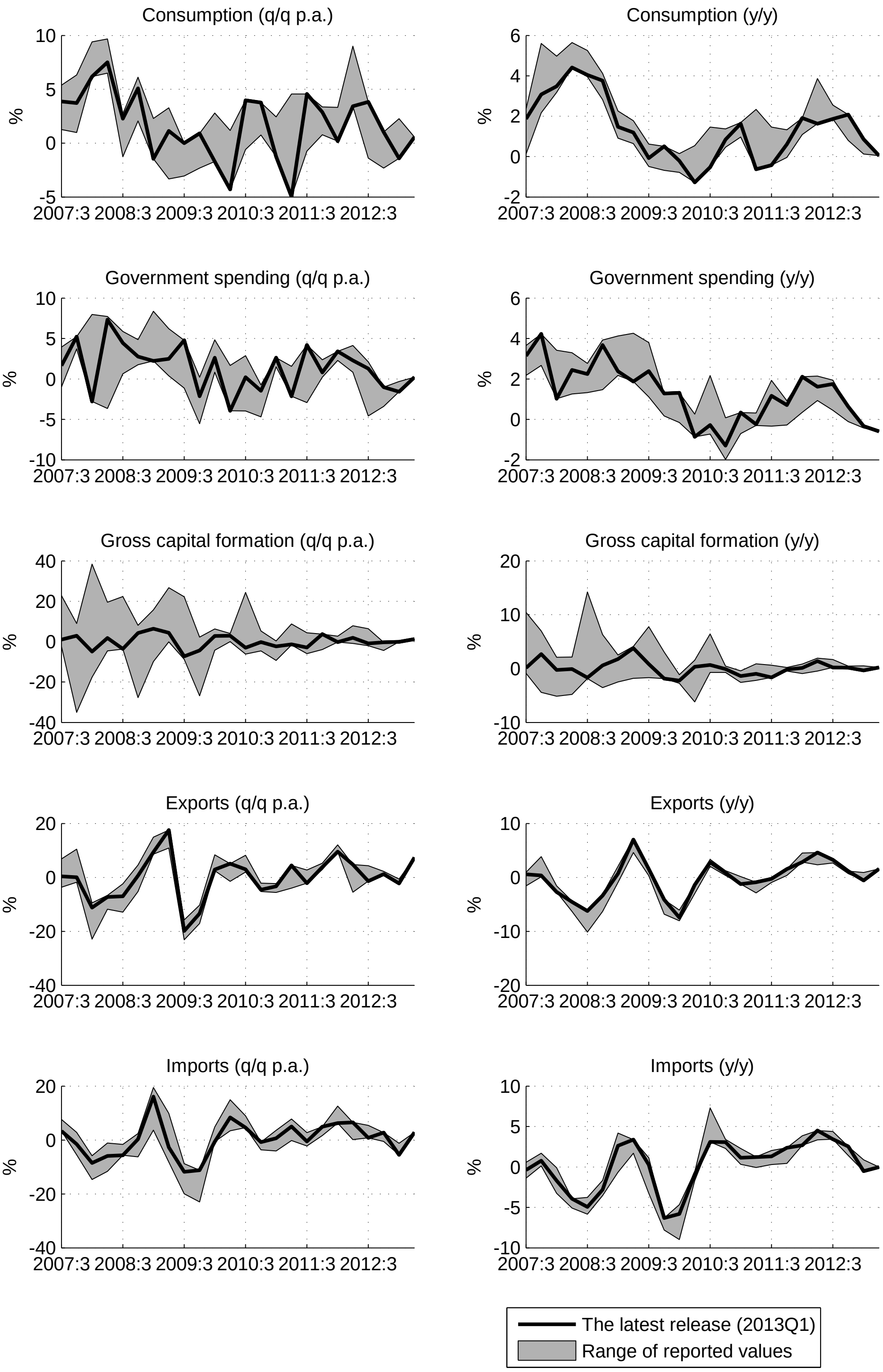


Figure A.3: National Accounts Revisions: Deflators

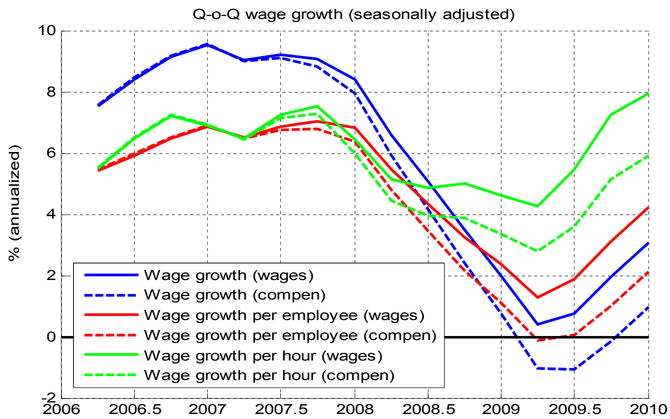


A.2 Sensitivity of Wage Dynamics to Alternative Measures

Not only data revisions, but also the choice of the proper indicator adds to data uncertainty. As an example, let us consider the case of nominal wages which can be used as observable for the model: there are various official estimates of the average wage and the total wage bill, and these estimates differ by the compilation technique, proneness to revisions, or real-time availability. Even the system of national accounts contains two time series, i.e. wages and compensation of employees, which can be used for modelling purposes. Usually, dynamics of these time series is almost the same (the level of the compensation of employees is higher than the level of wages), but till the beginning of the crisis the growth rates were almost identical). On the other hand, these indicators can differ during turbulent periods, which results in additional uncertainty the FT deals with.

The same comment applies also to average wages. Again, taking national accounts, one can compute the average wage by dividing the wage bill by the number of employees or by the total number of hours. Up to the beginning of the crisis, the differences in growth rates of the alternative measures were negligible due to the fact that the average hours per employee were almost constant. The increase in data uncertainty during the crisis manifested itself also in that the growth rates which were very similar before, started to diverge. This is illustrated in Figure A.4, which shows different growth rates of nominal wages.

Figure A.4: Wages Uncertainty



All series are from the National Accounts (CZSO). 'Wages' in parenthesis denote the national account series on wages and salaries, 'compen' denotes the series of compensations of employees.

Appendix B: The Wage Distribution Among Production Sectors

This appendix describes an application of the index decomposition analysis to the problem of decomposing of the observed growth in the labour share and the implications for forecast. This issue was discussed during the 2009Q3 forecast. The appendix has two parts; the first part briefly summarizes the index decomposition analysis (and can be skipped by readers familiar with this technique) and the second part describes the particular application.

B.1 Index Decomposition Analysis

The goal of the index decomposition analysis (henceforth IDA) is to understand historical changes in a socio-economic variable, and to gauge the driving forces or determinants that underlie these changes.

Let consider a variable Φ, which is given by

$$\Phi_t = Y_t \sum_i \phi_{1it} \ldots \phi_{Mit}, \tag{B.1}$$

where Y_t is the GDP, and the summation runs over sector shares, and over another interesting dimension. The goal is to decompose the change in the indicator into a number of determinants.

If observations were available in continuous time, the decomposition would be straightforward: the percentage change in the indicator $\dot{\Phi}_t/\Phi_t$ could be written as follows:

$$\frac{\dot{\Phi}_t}{\Phi_t} = \frac{\dot{Y}_t}{Y_t} + \frac{\sum_i \frac{\dot{\phi}_{1it}}{\phi_{1it}} \phi_{1it} \ldots \phi_{Mit}}{\sum_i \phi_{1it} \ldots \phi_{Mit}} + \ldots + \frac{\sum_i \frac{\dot{\phi}_{Mit}}{\phi_{Mit}} \phi_{1it} \ldots \phi_{Mit}}{\sum_i \phi_{1it} \ldots \phi_{Mit}},$$

where $\frac{\dot{Y}_t}{Y_t}$ is the GDP growth, and the expression $\frac{\sum_i \frac{\dot{\phi}_{mit}}{\phi_{mit}} \phi_{1it} \cdots \phi_{Mit}}{\sum_i \phi_{1it} \cdots \phi_{Mit}}$ could be interpreted as a weighted percentage change in factors ϕ_{mit}. The problem is that observations are not available in continuous time, and therefore discrete-time approximations should be used.

A discrete-time decomposition approximation can adopt an additive or a multiplicative mathematical form. The additive form decomposes the difference in the indicator Φ between times t_1 and t_2 into the sum of determinants D_i and a residual term R:

$$\Phi_{t_2} - \Phi_{t_1} = D_1 + D_2 + \ldots + D_N + R.$$

The multiplicative form decomposes the relative growth of the indicator into the product of determinant effects:

$$\frac{\Phi_{t_2}}{\Phi_{t_1}} = D_1 \times D_2 \times \ldots \times D_N \times R.$$

A number of mathematical forms for the additive, as well as, multiplicative decomposition forms have been proposed. Ang (1999) and Ang (2004) provide useful overviews of mathematical forms and their properties. The following four properties are particularly relevant for the index decomposition analysis:

Exactness: an exact decomposition has no residual; in the additive case this means that the residual equals 0, while it equals 1 in the multiplicative case.

Time reversal: the decomposition satisfies this property whenever the decomposition yields the reciprocal results after the reversal of the time periods.

Factor reversal: is about the invariance with respect to the permutation of determinants.

Robustness: a decomposition is robust if it does not fail when it meets with zero (or even negative) values in the dataset.

In the following part of the appendix, we use the log mean Divisia index (henceforth *LMDI*), suggested by Ang (2004) as the preferred method under a wide range of circumstances: the LMDI satisfies the four requirements mentioned above. The LMDI has both multiplicative and additive form. The multiplicative form is used for the analysis in Appendix B.2.

The multiplicative log mean Divisia index is defined as follows:

$$D_j^{t_2,t_1} \equiv \exp\left(\sum_i \frac{\mathcal{L}(\Phi_{it_2},\Phi_{it_1})}{\mathcal{L}(\Phi_{t_2},\Phi_{t_1})}\log\left(\frac{\phi_{jit_2}}{\phi_{jit_1}}\right)\right), \tag{B.2}$$

where $\Phi_{it} \equiv \prod_{j=1}^{m} \phi_{jit}$ and $\mathcal{L}$ is so called logarithmic average:

$$\mathcal{L}(x_1,x_2) \equiv \begin{cases} \frac{x_1-x_2}{\log x_1-\log x_2} & \text{if } x_1 \neq x_2 \\ x_1 & \text{otherwise.} \end{cases}$$

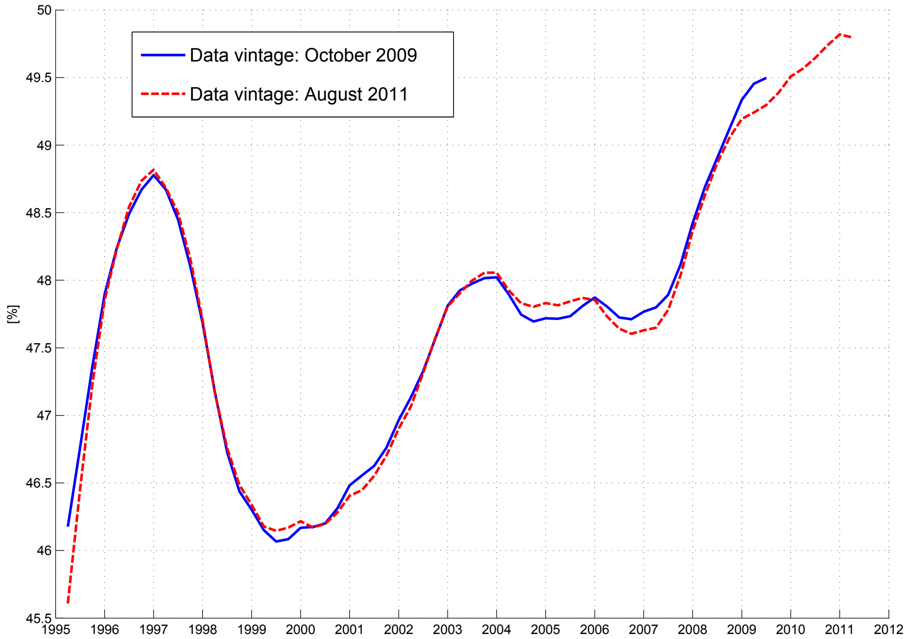
The residual term satisfies $R = 1$, and therefore the *LMDI* is the exact approach.

B.2 The Labour Share During the October 2009 Forecast

During the October 2009 forecast, the forecast team faced the following problem. Between 2007 and 2009, the share of nominal wages to GDP increased by 2 p.p. The evolution of the labour share is shown in Figure B.1. The figure compares two data vintages: the data available in October 2009 (in the solid blue line) and the data available in August 2011 (in the dashed red line). The then data suggested a continuation of the sharp increase even during the beginning of the crisis.

The forecast team discussed during October 2009 several explanations behind the then observed surge in the labour share and these explanations had different, indeed conflicting, implications for the forecast. The increase in the labour share could be a result of several factors: changes in the structure of the economy, productivity changes due to labour hoarding, fall in profits (mark-ups in the model world). For example, if mark-ups fell below their equilibrium levels, they were expected to increase back sometime in the future, which would imply an increase in prices, hence inflation. However, the productivity increase might be caused by a change in the structure of the national economy. This might be a plausible alternative for that period. Indeed, as the crisis hit the economy, the less productive sectors (and presumably low wage sectors) may have shut down and this might translate into the observed increase in productivity and the wage dynamics. Such a change would be neutral for inflation.

Figure B.1: Labour Share (as the ratio of compensation for employees on the gross value added)



Source: National accounts

Therefore, the forecast team applied the Index Decomposition Analysis and tried to decompose the observed changes in the labour share to easily interpretable factors.

The IDA has been applied to the following identity:

$$W_t/Y_t = \sum_i s_{it} l_{it} \varpi_{it}, \tag{B.3}$$

where $s_{it} = Y_{it}/Y_t$ are nominal shares, $l_{it} = L_{it}(1 + d_t)/Y_{it}$ is the labour intensity, and $\varpi_{it} = W_{it}/(1 + d_t)L_{it}$ is the average 'real' wage in the sector i (deflated using the **GDP deflator** d_t), and L_{it} is employment in the sector i. The IDA applied to (B.3) decomposes the labour share into:

Composition effect, which is related to changes in the structure of the current-year GDP, s_{it}. I.e., when labour-intensive sectors increase their shares, then *ceteris paribus* we may expect an increase in W_t/Y_t.

Labour intensity effect, which is related to changes in labour used to produce a unit of output in a given sector (note that the output is deflated not by sectoral deflators, but by the GDP deflator). This corresponds to the inverse of labour productivity.

Wage effect is the weighted average of the wage growth in individual sectors (the weighs are given by the output and labour intensity shares).

It would be also possible to consider a simpler case:

$$W_t/Y_t = \sum_i s_{it}\lambda_{it}, \tag{B.4}$$

where $\lambda_{it} = W_{it}/Y_{it}$ would be the ratio of wages to output in sector i.

The forecast team applied the above-mentioned log mean Divisia index (LMDI) to (B.3). Note that since the LMDI formula satisfies the factor reversal test, the decomposition results $D_{\varpi}^{t_2,t_1}$, $D_s^{t_2,t_1}$, and $D_l^{t_2,t_1}$ based on (B.3) immediately yield the decomposition in (B.4). In particular, $D_{\lambda}^{t_2,t_1} = D_l^{t_2,t_1} D_{\varpi}^{t_2,t_1}$. This is a nice property since it gives an exact correspondence between various forms of decompositions.[49]

The national accounts using 2-digit NACE sectors were used. For robustness, various measures of employment (hours versus employees) and various measures of output (gross value added versus product) were used. The results are quite robust. We report the results using hours and the gross value added indicators.

Figure B.2: Decomposition using 2009 October Data

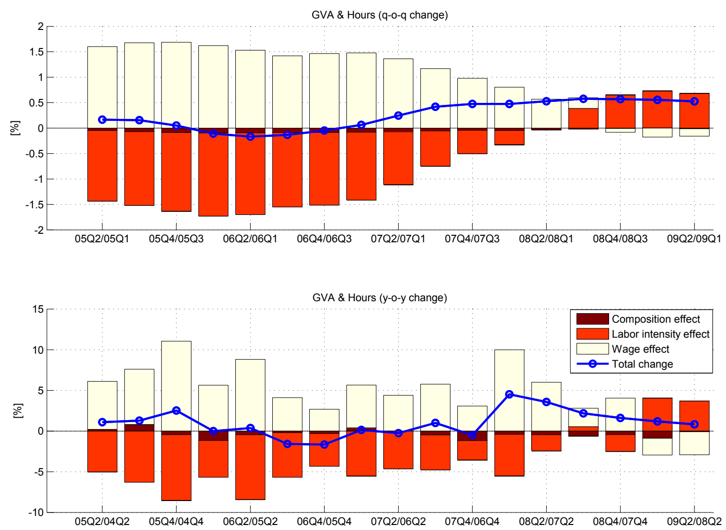
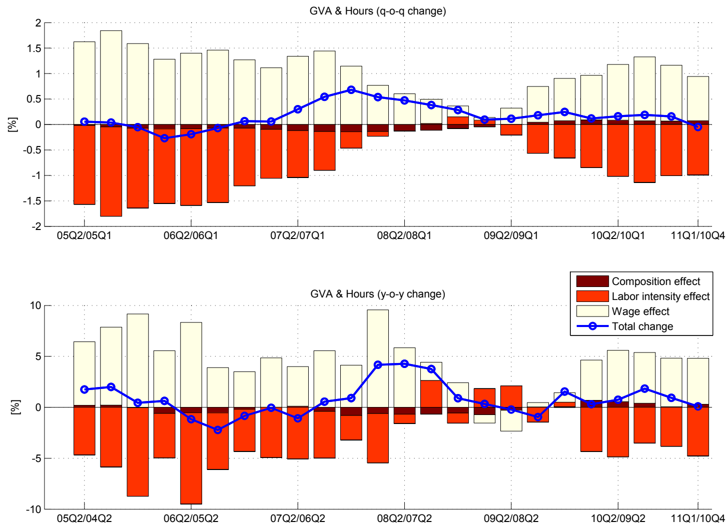


Figure B.2 shows the results of the decomposition on October 2009 data both for quarterly changes (seasonally adjusted data) and for yearly changes. The results reveal that the increase in the labour share cannot be explained by the sectoral shift in the economy. In fact, the composition effect, although weak, seemed to be going in the opposite direction. In fact, the shift was caused by the increase in the average wage (the wage effect), which was higher than the labour productivity increase (which is given by the negative of the labour intensity effect). Prior the recession, the labour productivity growth offset the wage increases (fully or at least partially),

[49] In principle, one can also consider the decomposition, in which the labour intensity effect would be measured with sectoral deflators. The decomposition then should be accompanied by the factor which accounts for different dynamics of sectoral deflators.

Figure B.3: Decomposition using 2011 August Data



but as the recession hit, the labour productivity growth collapsed, which resulted in the unit labour cost growth.

The FT interpreted this as an evidence of the danger of the future inflation, which will be necessary to bring the wage growth in balance with the productivity. The question (unknown at that time) was, when the balancing mechanism would take place.

However, after data revisions, the now-available data suggest another story: the most significant increase in the labour share occurred before the second quarter of 2008, and while the share continued to increase after 2009, the wage effect is almost counterbalanced by the labour intensity effect, which means that the wage inflation was associated with the increase in labour productivity (see Figure B.3). The composition effect remains quantitatively weak, but under the revised data it works in the expected direction, i.e., it supports the notion of the then reallocation of economic activity. Therefore, if today's revisions were known in October 2009, the threat of inflation would be considered less important.

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