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SHORT-TERM FORECASTING OF INDUSTRIAL PRODUCTION WITH BUSINESS SURVEY DATA: EXPERIENCE FROM FINLAND'S GREAT DEPRESSION 1990 - 1993

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ABSTRACT: The severe Finnish recession in the early nineties provides an interesting testing ground for forecasting models specified and estimated before the recession. We use recent data to evaluate some short-term forecasting models for industrial production. The main explanatory variables are from business surveys and the models themselves are based on the use of the Kalman filter. The recession years present difficulties for forecasting especially in the textile industry and metal industry. In the food industry and to some extent in the forest industry the forecasting performance during the recession is actually better than in earlier periods. Mechanical re-estimation of the models yields better forecasting results in four out of six branches studied. The importance of business survey information, however, seems to have increased during the recession. The improvement in prediction accuracy after taking account of relevant business survey information is statistically significant in the forest industry and in manufacturing of non-metallic products when the precision of autoprojective forecasts is used as a baseline.

KEY WORDS: Autoprojective forecasts, forecast comparison, forecast updating, Kalman filter, predictive accuracy

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TIIVISTELMÄ: Suomen talouden syvä lama 1990-luvun alkuvuosina on mielenkiintoinen testausperiodi ennustusmalleille, jotka on laadittu ennen laman alkua. Tässä tutkimuksessa arvioidaan teollisuustuotannon lyhyen ajan ennustusmalleja lama-aineiston avulla. Tärkeimmät selittävät muuttujat ovat teollisuuden suhdannebarometrikyselyn vastauksia ja malleissa käytetään Kalmanin suodinta. Mallien ennustuskyky lamavuosina vaihteli toimialoittain. Ennustuskyky heikkeni tekstiiliteollisuudessa ja metalliteollisuudessa mutta parani elintarviketeollisuudessa ja osittain myös metsäteollisuudessa aiempiin periodeihin verrattuna. Mallien mekaaninen uudelleen estimointi paransi ennustusominaisuuksia neljällä toimialalla kuudesta. Barometrimuuttujien tärkeys näyttää hieman lisääntyneen laman aikana. Verrattuna puhtaisiin autoprojektiivisiin ennusteisiin barometrimuuttujien mukaanotto paransi ennustuskykyä tilastollisesti merkitsevästi metsäteollisuudessa ja savi-, lasi- ja kiviteollisuudessa.

ASIASANAT: Autoprojektiiviset ennusteet, ennustevertailut, ennusteiden korjaaminen, Kalmanin suodin, ennustetarkkuus

SUMMARY

The business surveys conducted in many countries contain questions concerning the firms' plans and expectations for the next period, usually a quarter. Making use of this information in predicting the next quarter's output of an industrial branch is thus an interesting problem.

In this paper we want to reconsider the usefulness of the business survey data in forecasting the output in the next quarter starting from the information the forecaster actually possesses at the end of the previous quarter. The question is of general importance but the main grounds for taking it up now are the recent adverse economic developments in Finland. The volume of the gross domestic product decreased by 13 per cent from 1990 to 1993. At the same time, unemployment rose from about 3 per cent to 18 per cent. These figures give an idea of the magnitude of this recession, which in fact is unparalleled in the history of the country. But they also suggest that this period must form an excellent testing ground for the forecasting problem we are considering. If linear autoprojective models can predict the turbulent period as accurately without additional information in the business survey data as with it, then they are likely to do so also when the series fluctuate less and are thus in general easier to predict. If the business survey data do improve prediction accuracy, then it is important to know for which branches of manufacturing this is the case and how large the gains may be.

We shall modify the approach of Rahiala and Teräsvirta (1993), who dealt with predicting the output of the metal and engineering industries in Sweden and Finland. The idea is to improve the forecast from a purely autoprojective model by new information coming from the business survey. This can be done in the state space framework. The business survey variable representing actual production is modelled to be a function of the actual production volume. When the survey variable is observed but the production volume is not yet available, this model can be used to adjust the forecast for the production volume obtained from a pure autoprojective model. When forecasting two quarters ahead the business survey variable is also unavailable. It is forecast using lagged values of expectations concerning future production volume, obtained from the business survey and already available.

The approach differs from the traditional regression approach in which the production is explained by its own lags and business survey variables. In that approach the business survey information helps explain the production volume and not the other way round. In the present framework the business survey information is used to adjust the forecast from an autoprojective model. In the regression approach it would be incorporated in the autoprojective model as another variable or linear combination of variables.

For the purposes of the study the manufacturing industries are divided into six branches. The results indicate that business survey information improves the accuracy of output forecasts in some but not all branches in manufacturing. Re-estimation of the models improved forecasting accuracy in some but not all cases. Changing seasonal variation further complicated the problem in the food, textile and metal industries. The prediction period under investigation is a very extreme one with a severe recession and the beginning of an upturn. Forecast errors were larger than during normal periods in most branches, but models for the food and forest industries performed better than before. Since obtaining good forecasts may be even more important during such a period than during more normal times, the results are valuable for anyone interested in short-term forecasting of industrial production by branch.

YHTEENVETO

Barometrityyppisiä suhdannekyselyjä tehdään useissa maissa. Lähes aina niissä kysytään yritysten suunnitelmia ja odotuksia seuraavan ajanjakson, yleensä vuosineljänneksen, suhteen. Tällaisen informaation hyväksikäyttö ennustamisessa on mielenkiintoinen ongelma. Tässä tutkimuksessa sovelletaan Rahialan ja Teräsvirran (1993) metalliteollisuuden tuotannon ennustamiseen Suomessa ja Ruotsissa käyttämää lähestymistapaa, jossa autoprojektiivista mallia pyritään parantamaan suhdannebarometrin tietojen avulla.

Raportissa tarkastellaan barometriaineiston käyttökelpoisuutta tuotannon määrän ennustamiseen. Suomen talouden poikkeuksellisen heikko kehitys vuosina 1990-1993 on luonut erinomaisen ympäristön ennustusmallien testaamiseen. Bruttokansantuote laski toistakymmentä prosenttiyksikköä ja työttömyysaste nousi runsaasta kolmesta prosentista yli 18:aan. Mikäli tavallisella lineaarisella autoprojektiivisella mallilla, jossa barometritiedot eivät ole mukana, pystytään ennustamaan em. kaltaista kaoottista ajanjaksoa, sen ennustuskyky on todennäköisesti hyvä myös tavallisemmalla helpommin ennustettavalla ajanjaksolla. Jos ennustekyky paranee barometri-informaation mukaan ottamisella, on tärkeä tietää, paraneeko se kaikilla vai vain joillakin yksittäisillä toimialoilla ja onko paraneminen tilastollisesti merkitsevää.

Suhdannebarometrissa kysytään tietoja sekä toteutuneesta tuotannosta että tuotanto-odotuksista. Toteutunutta tuotantoa koskeva barometrimuuttuja mallitetaan riippuvaksi kansantalouden neljännesvuositilinpidon mukaisesta toteutuneen tuotannon määrästä. Tämän mallin avulla korjataan puhtaalla autoprojektiivisella mallilla tuotettua ennustetta teollisuustuotannon määrälle yksi havaintoneljännes eteenpäin. Tämä voidaan tehdä silloin, kun barometritieto ao. neljännekselle on olemassa mutta tilastotietoa ei vielä ole. Ennustettaessa kahta havaintoa eteenpäin joudutaan ennustamaan myös toteutunutta tuotantoa koskeva barometrimuuttujan arvo. Tämä tehdään laatimalla malli, jossa toteutuneen tuotannon barometrimuuttujaa selitetään viivästetyillä tulevaa tuotantoa koskevilla barometrin odotusmuuttujilla.

Menetelmä eroaa tavanomaisesta regressiomalliin perustuvasta ennustamisesta, jossa teollisuustuotannon volyymia selitetään samanaikaisesti omilla viiveillään ja barometrin odotusmuuttujilla. Tavanomaisessa mallissa barometrimuuttujat siis selittävät tuotantoa. Tässä tutkimuksessa tuotannolla selitetään barometrimuuttujaa, ja kun barometrimuuttujan havainto saadaan aikaisemmin kuin samaa ajanjaksoa koskeva tuotannon määrä, voidaan tämän mallin avulla tehdä päätelmiä tuotannosta ja korjata autoprojektiivista tuotannon määräennustetta.

Mallit on laadittu kuudelle teollisuuden toimialalle: elintarvike-, tevanake-, metsä-, kemian-, rakennusaine- ja metalliteollisuudelle. Barometriaineiston mukaan ottaminen malleissa paransi ennusteita joillakin toimialoilla, samoin uudelleen estimointi. Ajassa muuttunut kausivaihtelu vaikeutti ennustamista elintarvike-, tevanake- ja metalliteollisuudessa. Tarkasteltu ajanjakso on poikkeuksellisen vaikea ennustaa alussa olevan voimakkaan laman ja lopussa alkavan uuden nousun vuoksi. Tämän takia ennustevirheet olivat yleensä suuremmat kuin aikaisemmin. Elintarvike- ja metsäteollisuuden mallit kuitenkin toimivat tarkastelujaksolla aiempaa paremmin.

1 Introduction

The business surveys conducted in many countries contain questions concerning the firms' plans and expectations for the next period, which, in quarterly surveys, is often but not always a quarter. Making use of this information in predicting the next quarter's output of an industrial branch is thus an interesting problem. Many published studies have concluded (e.g. Batchelor, 1982, and Hanssens and Vanden Abeele, 1987) that business survey information is not useful for this purpose. On the other hand, both Teräsvirta (1986) and Madsen (1993) found predictive survey information useful in short-term forecasting, although the conclusions in the latter paper were just based on the possible significance of a regression coefficient estimate in a linear regression. The results did not include any out-of-sample comparisons between forecasts from models using and from those not using business survey information. We shall adopt the approach of Rahiala and Teräsvirta (1993), who dealt with predicting the output of the metal and engineering industries in Sweden and Finland. Their results indicated that combining business survey information with the history of the output series in an appropriate way increased forecasting accuracy when forecasting one quarter ahead. However, the authors, who were experimenting with a new technique, had simplified the situation. They, as well as Teräsvirta (1986) and Madsen (1993), assumed the output at the end of the previous quarter is known when the next quarter is predicted. In reality the output figure is not available at that time, but, on the other hand, a first estimate may be obtained from the business survey data.

In this paper we want to reconsider the usefulness of the business survey data in forecasting the output in the next quarter starting from the information the forecaster actually possesses at the end of the previous quarter. The question is of general importance but the main grounds for taking it up now are the recent adverse economic developments in Finland. The volume of the gross domestic product decreased by 13 per cent from 1990 to 1993. At the same time, unemployment rose from about 3 per cent to 18 per cent. These figures give an idea of the magnitude of this recession, which in fact is unparalleled in the history of the country. But they also suggest that this period must form an excellent testing ground for the forecasting problem we are considering. If linear autoprojective models can predict the turbulent period as accurately without additional information in the business survey data as with it, then they are likely to do so also when the series fluctuate less and are thus in general easier to predict. If the business survey data do improve prediction accuracy, then it is important to know for which branches of manufacturing this is the case and how large the gains may be.

For the purposes of the study the manufacturing industries are divided into six branches. They are the food and tobacco industry (food in short), textile, clothing, leather apparel and footwear industries (textiles), wood, pulp and paper industries (forest), chemical industry (chemicals), manufacturing of non-metallic products (non-metal), and metal and engineering industries (metal). The quarterly output volume of these branches for 1980/1 - 1993/4 is shown in Figure 1. It is seen that the export-led forest and metal industries have started growing again after the trough in 1991, whereas more domestic branches have lagged behind. The period is thus very well suited for our purposes.

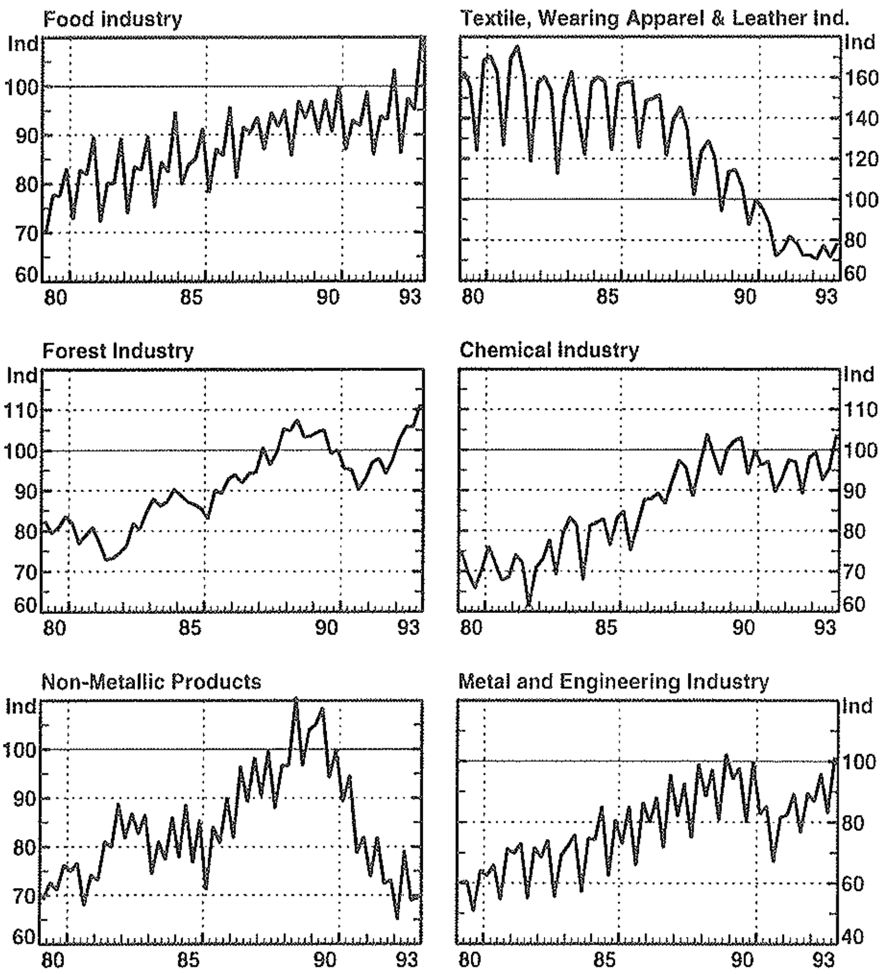
The plan of the paper is as follows. In section 2 we present the model we use to incorporate business survey information into purely historical information about the series to be predicted. Section 3 discusses the data used in the paper. Section 4 contains an empirical example of the model we apply. In section 5 we report results on prediction accuracy and comparisons between forecasts made with and without business survey information. Section 6 concludes. The technical details of the application are found in the Appendix.

2 The model

The starting point is as follows. At the end of quarter t we wish to forecast $y_{t+1} = Y_{t+1} - Y_t$, where Y_t is the logarithmic production volume of a branch in manufacturing. At this point Y_{t-1} is assumed known whereas Y_t is not. However, the business survey conducted at the end of quarter t provides a first estimate of Y_t. The survey also contains information about the firms' plans and expectations for quarter $t+1$ and this information will be used in forecasting y_{t+1}. Rahiala and Teräsvirta (1993) assumed that Y_t and thus y_t was available at the end of t. Because in reality we then only know y_{t-1}, we in fact have to forecast two periods ahead. First we have to obtain a first estimate or prediction of production volume at t and then as the next step forecast the volume at $t+1$.

To do that we shall combine the quantitative information about the past industrial production and the business survey information in the same way as in Rahiala and Teräsvirta (1993). The idea is to improve the forecast from a purely autoprojective model by new information coming from the business survey. This can be done in the state space framework. The business survey variable representing actual production in quarter t is modelled to be a function of the actual production volume of that quarter. This is logical because the relevant information in the survey is obtained by asking the firms about their production in that quarter. (In practice it turns out that past production also influences the answers, and the relationship between the business survey variable and the production will thus also contain lags of the production variable itself.) It differs, however, from the traditional

Figure 1. Industrial output in Finland 1980/1-1993/4 by branch, 1990/4=100



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regression approach in which the production at time t is explained by its own lags and business survey variables. In that approach the business survey information helps explain the production volume and not the other way round. In the present framework the business survey information is used to adjust the forecast from an autoprojective model. In the regression approach it would be incorporated in the autoprojective model as another variable or linear combination of variables.

Because we have to forecast two quarters ahead, the final forecast is generated in two steps, and the Kalman filter is applied as follows. At the end of period t, begin by predicting y_t (whose value is not yet available) with the transition equation using past values of y. Next, update this forecast by using the Kalman filter. This step brings in information in the business survey conducted at the end of period t and leads to an adjustment of the previous forecast. This information is contained in the vector denoted by g_t in the Appendix. The updated forecast is now used in predicting y_{t+1} with the transition equation. The next step to update this forecast involves a slight complication because there is no business survey information directly available about actual production at $t+1$, i.e., g_{t+1} is unobserved. However, we can predict the value of g_{t+1} as will be explained below. The predicted value is then used in place of g_{t+1} itself, and thus the first prediction of y_{t+1} can be updated with the Kalman filter in the same way as before. This is essentially the procedure Rahiala and Teräsvirta (1993) proposed. The only difference is that those authors only performed a single round of prediction and updating whereas we predict two steps ahead and thus have to apply the Kalman filter twice, to obtain our forecast. The technical details are given in the Appendix.

Forecasting g_{t+1} is carried out as follows. The business survey also contains information about the firms' production plans or expectations for period $t+1$ and their future business prospects in general. This information can be quantified in the same way as the information contained in g_t. The business survey variables in the measurement equation at time t (based on the survey conducted at the end of t) are regressed on these predictive variables at time $t-1$ (based on the survey conducted at the end of $(t-1)$). The estimated equation is used for predicting g_{t+1}. An example will be given in Section 4.

3 The data

The volume indices for industrial production originate from quarterly national accounts compiled by Statistics Finland. The base year is 1990. The indices for metal and engineering and forest industries are the only ones directly available on a quarterly basis. The observations for all the other branches have been aggregated from subbranch data using monthly indices with base years 1980, 1985 and 1990 and chained together. The aggregated quarterly data sum up to annual figures by branch, and all the quarterly branch data sum up to total manufacturing output each quarter. Business surveys are conducted quarterly by the Confederation of Finnish Industry and Employers and the data is obtained directly from the source. In the models we use weighted shares of "increases" and "decreases" answers as variables (see Rahiala and Teräsvirta, 1993, for a description of the trichotomous nature of the firms' answers).

4 A modelling example

In this section we shall give an example of the use of the state space model defined in the appendix. This example shows among other things how the measurement equation ($A2$) may appear and how the forecasts for g_{t+1} are obtained in practice. The forest industries are the sector in which our forecasting technique works best and we thus use it as our example. In the measurement equation, the business survey counterpart of the present change in production is explained by the concurrent difference of the production volume. In theory, this should suffice but in practice lags of this difference help improve the fit. The estimated equation based on the data from 1981/1 to 1990/4 is

$$
\begin{aligned}
pr_t^+ \;=\;& \underset{(42.2)}{300.6y_t} + \underset{(42.1)}{103.0y_{t-1}} + \underset{(43.7)}{122.3y_{t-2}} + \underset{(43.5)}{41.4y_{t-3}} + \\
& \underset{(2.9)}{25.1} + \underset{(4.1)}{2.9d_1} + \underset{(4.2)}{5.3d_2} + \underset{(4.2)}{14.1d_3} + \hat{u}_t \qquad (1)\\
& s.e.e. = 8.6
\end{aligned}
$$

where pr_t^+ is the share of firms reporting that "the volume of output during the present quarter compared with preceding quarter is higher" (as opposed to "the same" and "lower"), y_t is the logarithmic difference of output volume, and $d_{jt}, j = 1,2,3$, are seasonal dummy variables. Thus in this example, $g_t = pr_t^+$. The figures in parentheses are standard deviations and $s.e.e.$ is the residual standard error.

One could extend g_t by also including pr_t^-, the share of firms reporting that "the volume of output during the present quarter compared with prededing quarter is lower", or the so-called "balance", $pr_t^+ - pr_t^-$, in g_t. Those were tried as well but did not contribute anything to the forecasting accuracy. Thus g_t was simplified to its present form (1).

In order to predict the volume at $t+1$ we need $g_{t+1}(= pr_{t+1}^+)$. As mentioned above, this observation is not available at t but an estimate is obtained using predictive information in the survey. This is done outside the Kalman filter. The variable pr_t^+ is thus explained by relevant predictive variables from the previous survey. The estimated equation for forest industry based on the period 1981/1 to 1990/4 is

$$
\begin{aligned}
pr_t^+ \quad = \quad & \underset{(8.0)}{27.1} + \underset{(4.0)}{6.8d_1} + \underset{(3.7)}{0.26d_2} + \underset{(3.7)}{3.3d_3} - \\
& \underset{(44.3)}{86.1y_{t-1}} + \underset{(0.21)}{0.56bpr_{t-1}^+} - \underset{(0.07)}{0.32bp_{t-1}^-} + \hat{u}_t \\
& s.e.e. = 8.2.
\end{aligned} \tag{2}
$$

In (2), bpr_t^+ is the relative share of the firms planning higher output next quarter compared to the ending quarter. It is thus a direct prediction of pr_{t+1}^+. Furthermore, bp_t^- is the share of firms expecting the general business conditions to deteriorate in the near future. The corresponding question in the survey is not directly related to production but the answers to it nevertheless seem to contain useful predictive information in various branches under consideration here. These predictive variables were selected from a larger set using model selection criteria. For instance, bp_{t-1}^+ had no predictive power in (2). In fact it fluctuates considerably less (never exceeds 0.2) than bp_{t-1}^- and is thus less informative of the two. As is seen from (2), the equation yields a conditional forecast of pr_{t+1}^+ when bpr_t^+ and bp_t^- are available from the business survey at time t. The seasonal dummies are not significant but are retained because their presence marginally improves the forecasts.

Similar equations are constructed for the other branches. They are available from the authors upon request. The equations were originally specified and estimated in 1991. We have not changed the specifications, so that the observations of the recession period are truly 'out of sample'.

Finally, we would like to draw attention to seasonality present in y_t. From Figure 1 it may seem that at least for some branches the seasonal pattern changes over time. The parameter constancy of the autoprojective model (first row of the transition equation) was tested against the alternative of deterministically changing parameters. This was done by applying one of the tests in Lin and Teräsvirta (1994). It tests parameter constancy against smoothly and monotonically changing parameters. Because the number of observations was rather low, the other tests in that paper with respect to more flexible patterns were not considered. If the null hypothesis was rejected, the (parametric) alternative was estimated. In forecasting, the parameter values were set equal to those at the end of the estimation period. This was done in modelling the output of the metal and engineering industries (for more details see Rahiala and Teräsvirta, 1993) and the textile industry. The null hypothesis of parameter constancy was also rejected for the food industry. However, modelling the parameter change as above led to poor forecasts. The reason is obvious from Figure 1: the seasonality seems to resume its previous pattern during the prediction period. The forecasting results reported in Section 5 for the food industry are based on the assumption of constant parameters. For the remaining industries, the null hypothesis of constant parameters in the transition equation was not rejected.

5 Main empirical results

Next we shall turn to the empirical results, which are summarized in Table 1. Two different prediction periods are considered. The first one from 1991/2 to 1993/4 contains the recession and the beginning of a recovery. The second one included for comparison contains almost two years of pre-recession observations and the first quarters of the downturn from 1988/2 to 1990/4. The forecasts are "real" one quarter ahead forecasts (forecasting $t+1$ at t). As mentioned above, this means predicting two quarters ahead because the output volume for t is not yet available at the end of t. Rahiala and Teräsvirta (1993) predicted the quarters 1988/1 to 1989/4 using a model based on data until 1987/4 and assumed that the output volume for t was available at the end of t.

The models have not been re-estimated each time a new observation has become available. On the other hand, models based on both an estimation period ending at 1987/4 and another one ending at 1990/4 have been used in the forecasting exercise. Our main findings are as follows.

Forecasting accuracy deteriorated during the depression. But we have two exceptions. In the forest industry the accuracy was better in 1991 - 93 than in 1988 - 90 with respect to the models where the Kalman filter was used to update the autoprojective forecasts in the second period. This was true both in terms of the root mean square error (RMSE) and in median absolute error (MAE). An even more noticeable improvement took place in the food industry. This may have to do with the changes in seasonality at the end of the 1980's.

Re-estimation may improve forecasting accuracy but does not always do so. This can be seen by comparing columns (a) and (b) in Table 1. The longer estimation period includes information about the early phases of the recession, so that one might expect an extension at the estimation period to be beneficial. Improvements can be noticed in forest, chemical, non-metal and metal industries. The differences are generally small, which is just an indication of the stability of the parameters of the models over time.

Business survey information may improve forecasting accuracy but does not always do so. In the forest, non-metal and metal industries the smallest RMSEs and MAEs are usually obtained by models where business survey

Table 1. Summary statistics of predictive accuracy*

		RMSE			MAE			GN test		
		(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Food	AP	0.028	0.031	0.050	0.021	0.016	0.038	0.508	0.139	0.109
	KF	0.028	0.031	0.049	0.020	0.015	0.037			
Textile, Wearing Apparel and Leather	AP	0.077	0.078	0.049	0.061	0.064	0.032	0.829	0.596	0.521
	KF	0.091	0.081	0.049	0.049	0.056	0.026			
	AP-NL	-	0.081	-	-	0.044	-	-	0.521	-
	KF-NL	-	0.082	-	-	0.061	-			
Forest	AP	0.034	0.030	0.031	0.020	0.020	0.024	0.024	0.045	0.081
	KF	0.019	0.018	0.023	0.017	0.013	0.018			
Chemical	AP	0.056	0.050	0.034	0.015	0.013	0.024	0.233	0.164	0.922
	KF	0.054	0.049	0.036	0.018	0.014	0.026			
Non-Metallic Products	AP	0.070	0.057	0.067	0.061	0.051	0.036	0.010	0.054	0.259
	KF	0.058	0.050	0.065	0.040	0.038	0.039			
Metal and Engineering	AP-NL	0.076	0.069	0.055	0.060	0.057	0.037	0.072	0.144	0.046
	KF-NL	0.068	0.064	0.047	0.054	0.046	0.029			
Total	AP	0.036	0.034	0.016	0.026	0.024	0.010			
	ag-AP	0.036	0.033	0.023	0.029	0.027	0.017	0.456	0.312	0.846
	ag-KF	0.035	0.032	0.016	0.027	0.021	0.010			

*The table contains root mean square errors (RMSE) and mean absolute errors (MAE) of one quarter ahead predictions for first differences in logarithmic volume of industrial output, and p-values of the Granger-Newbold test statistic (GN-test), for testing that the mean square error (MSE) of autoprojective model predictions equals the MSE of Kalman filter model predictions, against the alternative that the latter MSE is smaller. In the group "Total" the test is between AP and ag-KF model predictions.
Model type: AP=autoprojective, KF=autoprojective, using business survey information (Kalman filter), NL=nonlinear change in seasonal variation, ag=aggregated from branch-level AP- or KF-models.
Column (a): Estimation period up until 1987/4, forecasts 1991/2-1993/4
Column (b): Estimation period up until 1990/4, forecasts 1991/2-1993/4
Column (c): Estimation period up until 1987/4, forecasts 1988/2-1990/4

information is used. In other branches the results are mixed. In the textile industry the pattern is reversed: models using business survey information predicted worse during the recession than pure autoprojective models. A likely explanation is clearly visible in the Figure 1: the strong seasonal variation of the output almost disappeared in the early nineties.

Is the improvement in accuracy statistically significant? We used the test by Granger and Newbold (1986) to test the hypothesis that the mean square errors (MSE) of the forecasts with and without business survey information are equal, against the alternative that the forecasts obtained using business survey information have the lower MSE of the two. The p-values of the test are reported in Table 1 as well.

Rahiala and Teräsvirta (1993) noted that in the metal and engineering industry business survey information increased the forecasting accuracy significantly. Our results for the forecasting period 1991/2 - 1993/4 are weaker but still positive. Rahiala and Teräsvirta used a different model in which g_t was based on the question of changes in the order stock. Since the order stock does not contain as much seasonal variation as the output volume, firms are able to answer the corresponding question better than the one concerning changes in the volume. The orders and the output being strongly correlated, their model worked well before the recession. Nevertheless, the considerable fall in output in 1990 - 91 caused the transition equation to break down. We thus resorted to the more conventional equation in which g_t was based on the question about changes in the production volume. At the end of the 1980s such a transition equation had worked less well than the one Rahiala and Teräsvirta (1993) had employed but it continued to do its job during the recession.

For the other branches, in the forest industry the improvement is significant at the 5 % level and in the non-metallic products at the 5 % or 10 % level, depending on the period of estimation, for the period 1991/2 - 1993/4. For the remaining branches the results are not encouraging. Although the time period under investigation is very dramatic, the information in the business survey fails to improve the prediction accuracy over that of purely autoprojective forecasts. For these, maintaining Kalman filter models for forecasting one quarter ahead does not seem worthwhile.

There may be several reasons for the results being so mixed. First, two of three branches for which the business survey data carry information useful in short-term forecasting are export-led branches. It may be that the firms in such sectors of the economy monitor their performance better than firms mainly active in domestic markets. Second, the metal industry is a large branch and the number of firms in the sample reflects that fact. The survey aggregates for small branches may simply contain so much uncertainty that the information is not useful in quantitative forecasting. On the other hand, the forest industry is a small branch in that, although its output is large, the number of firms is relatively small. But this branch has a specific advantage: its quarterly output contains little seasonal variation. In the questionnaire, the firms are asked to give "seasonally adjusted" answers when comparing the ending quarter with the previous one and when predicting the next quarter. This has proved to be a remarkably difficult request for the firms to satisfy in practice when seasonal variation in output has been strong; see Teräsvirta (1993) for discussion. Thus the information on the production volume in the survey answers may have been more reliable in forest industry than elsewhere. This in turn would explain at least some of the results.

Although obtaining output forecasts by branch is important, predictions of the aggregate output of manufacturing are also of great interest. The question of how well the aggregated branch forecasts predict the total output therefore merits an answer. We aggregated the predictions made by both autoprojective models and models containing business survey information. The total output was also constructed by aggregating the six branches. This leaves out a very small group of other industries that is included in the ofiicial production volume of manufacturing output as defined by Statistics Finland.

The three bottom rows in Table 1 show the results. Aggregating the forecasts based on the information from the business survey seem to be slightly more accurate than forecasts from a purely autoprojective model for the logarithmed total output. However, the difference is far too small to be significant. On the other hand, Table 1 shows that predicting the total production volume by aggregating the autoprojective branch forecasts is not such a good idea. Thus, if the total output is predicted by aggregating branch forecasts, the Kalman filter forecasts should be preferred to purely autoprojective ones.

6 Conclusions

In this paper we consider the use of business survey information in short-term forecasting of industrial output in Finland by branch. The results indicate that this information improves the accuracy of forecasts in some but not all branches in manufacturing. Re-estimation of the models improved forecasting accuracy in some but not all cases. Changing seasonal variation further complicated the problem in the food, textile and metal industries. The prediction period under investigation is a very extreme one with a severe recession and the beginning of an upturn. Forecast errors were larger than during normal periods in most branches, but models for the food and forest industries performed better than before. Since obtaining good forecasts may be even more important during such a period than during more normal times, the results are valuable for anyone interested in short-term forecasting of industrial production by branch.

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Appendix 1. The Kalman filter in forecasting: prediction and updating the predictions

The general idea of combining the quantitative information about the past industrial production $\mathcal{F}_t = \{y_{t-1}, y_{t-2}, ..., y_0\}$ with business survey information is based on the use of the state space framework. Define the state vector $\alpha_t = (y_t, y_{t-1}, ..., y_{t-k+1}, 1, d_{1t}, d_{2t}, d_{3t}, d_{4t})'$ where $d_{jt}, j = 1, 2, 3, 4,$ are the four seasonal dummy variables. The first element of the state vector at time t is the unobserved y_t which has to be predicted first. The movements of the state vector are governed by the transition equation

$$(A1) \qquad \alpha_t = T\alpha_{t-1} + Ru_t$$

where

$$T = \left[\begin{array}{cccccccccc} \phi_1 & \phi_2 & \cdots & \phi_k & \mu & \delta_1 & \delta_2 & \delta_3 & 0 & 0 & 0 \\ & I_{k-1} & & 0 & & & & 0 & & & \\ & & & & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ & & & & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ & & & & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ & & 0 & & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ & & & & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ & & & & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{array}\right].$$

The first row of T contains the coefficients of the autoprojective equations for y_t. These parameters are estimated from the data by ordinary least squares. The remaining companion matrix updates the other already known elements of α_t. Thus $R = (1, 0, ..., 0)'$ while u_t is a scalar random variable with mean zero so that only the first element in Ru_t is stochastic.

The measurement equation describes how the k business survey variables g_t of interest depend on the actual production y_t. The equation has the form

$$(A2) \qquad x_t = Z\alpha_t + Sv_t \ .$$

The relationship is defined in first differences y_t because the questions in the business survey are formulated in terms of changes. In (2), the variables observed at (the end of) t are

$$x_t = (y_{t-1}, g_t')' .$$

Furthermore,

$$Z = \begin{bmatrix} z_1 \\ z_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & \ldots & 0 & 0 \\ z_{21} & z_{22} & & \ldots & z_{2,p-1} & 0 \end{bmatrix}$$

and

$$S = \begin{bmatrix} 0 \\ I_d \end{bmatrix}, \quad d = \dim(z_2)$$

where Z is a $(k+1) \times p$ matrix. Typically, $k = 1$; see for instance Section 4. The first row of Z just indicates that y_{t-1} is observed in quarter t. The elements of z_2 are estimated from the data by ordinary least squares. For the error terms u_t and v_t we assume

$$\begin{bmatrix} u_t \\ v_t \end{bmatrix} \sim \text{nid}\left(0, \begin{bmatrix} \sigma^2 & 0 \\ 0 & H \end{bmatrix}\right).$$

where H is positive definite. When the Kalman filter is applied the estimated values $\hat{\sigma}^2$ and $\hat{H}$ replace the unknown parameters.

As mentioned in Section (2) the first step is to forecast y_t. At time $t-1$ the relevant information in $\mathcal{F}_{t-1}$ appears in a_{t-1}, the estimate of α_{t-1}. In our case, α_{t-1} is observed directly, i.e. $\alpha_{t-1} \equiv a_{t-1}$. Thus $P_{t-1} = \text{cov}(a_{t-1}) = 0$. From the transition equation $(A1)$ we obtain the forecast $a_{t|t-1} = Ta_{t-1}$. The covariance matrix of the prediction error $e_t = a_{t|t-1} - \alpha_t$ is

$$(A3) \qquad \text{cov}(e_t) = P_{t|t-1} = \sigma^2 T P_{t-1} T' + \sigma^2 RR' = \sigma^2 RR'.$$

The autoprojective forecast $a_{t|t-1}$ is updated by incorporating the information in x_t (Harvey, 1981, p. 110). The updating equation for α_t is

$$(A4) \qquad a_t = a_{t|t-1} + K_t(x_t - Za_{t|t-1})$$

where $K_t = P_{t|t-1}Z'F^-$ is the so-called Kalman filter gain matrix,

$$(A5) \qquad F = ZP_{t|t-1}Z' + SHS' = \sigma^2 ZRR'Z' + SHS' = \text{diag}(0, F_2)$$

and

$$(A6) \qquad F^- = \text{diag}(0, F_2^{-1}).$$

As mentioned above, Z, σ^2 and H are estimated. The correction to $a_{t|t-1}$ is a function of the prediction error made in forecasting x_t using the information in $\mathcal{F}_{t-1}$. The first element of a_t is the updated forecast for y_t.

To forecast the industrial production at $t+1$ we need the covariance matrix

$$(A7) \qquad P_t = \mathrm{cov}(a_{t|t-1}) + K_t F K_t' = \sigma^2 RR' + K_t F K_t'.$$

Matrix $(A7)$ is a combination of the covariance matrix of the prediction error and that of the updating error. Unlike P_{t-1} it is nonzero because α_t is only partly observed. The forecast for $t+1$ from $(A1)$ equals $a_{t+1|t} = Ta_t$, so that the corresponding prediction error is

$$(A8) \qquad e_{t+1} = a_{t+1|t} - \alpha_t = T(a_t - \alpha_t) + Ru_{t+1}$$

with covariance matrix

$$(A9) \qquad P_{t+1|t} = T\mathrm{cov}(a_t)T' + \sigma^2 RR' = \sigma^2 TRR'T' + TK_t F K_t' T' + \sigma^2 RR'.$$

The autoprojective forecast $a_{t+1|t}$ is updated to obtain a_{t+1} as indicated by $(A4)$, $(A5)$ and $(A6)$, taking account of the new information x_{t+1} and covariance matrix $(A7)$. The results of the business survey at $t+1$ are not available, but the relevant component g_{t+1} of x_{t+1} is obtained using the predictive information in the business survey conducted at the end of period t. This is discussed in the text, and an example is also given there.

Appendix 2. Branch equations

Food industry

The estimated autoprojective equation for the logarithmic difference of output volume y_t is

$$\begin{aligned} y_t \quad = \quad & \underset{(0.16)}{-0.48y_{t-1}} - \underset{(0.16)}{0.47y_{t-2}} + \underset{(0.02)}{0.12} - \underset{(0.02)}{0.23d_1} - \\ & \underset{(0.03)}{0.05d_2} - \underset{(0.04)}{0.16d_3} + \hat{u}_t \\ & s.e.e. = 0.03 \end{aligned}$$

where $d_{jt}, j = 1, 2, 3$, are seasonal dummy variables.

The measurement equation for business survey question pr_t^+ "the volume of output during the present quarter compared with corresponding quarter year ago is higher":

$$\begin{aligned} pr_t^+ \quad = \quad & \underset{(83.8)}{56.2y_t^{(4)}} + \underset{(3.05)}{38.0} + \hat{u}_t \\ & s.e.e. = 15.9 \end{aligned}$$

where $y_t^{(4)}$ is the fourth-order logarithmic difference of output volume.

The prediction equation for pr_t^+ is

$$\begin{aligned} pr_t^+ \quad = \quad & \underset{(67.4)}{-22.0y_{t-1}^{(4)}} + \underset{(0.13)}{0.57pr_{t-1}^+} - \underset{(0.26)}{0.33bp_{t-2}^-} + \\ & \underset{(7.20)}{21.0} + \hat{u}_t \\ & s.e.e. = 12.7 \end{aligned}$$

where bp_t^- is the share of firms expecting the general business conditions to deteriorate in the near future.

Textile, Wearing Apparel and Leather Industry

The estimated autoprojective equation for the logarithmic difference of output volume $y - t$ is

$$\begin{aligned} y_t &= \underset{(0.13)}{-0.34y_{t-1}} - \underset{(0.13)}{0.33y_{t-2}} - \underset{(0.13)}{0.32y_{t-3}} + \\ &\quad \underset{(0.13)}{0.61y_{t-4}} - \underset{(0.01)}{0.02} + \hat{u}_t \\ &\quad s.e.e. = 0.05 \end{aligned}$$

The measurement equations for business survey questions emp_t^- "the number of employees are now lower than three months ago" and pr_t^- "the volume of output during the present quarter compared with preceding quarter is lower" are

$$\begin{aligned} emp_t^- &= \underset{(23.6)}{-92.6y_t^{(4)}} + \underset{(1.77)}{38.2} + \hat{u}_t \\ &\quad s.e.e. = 9.13 \\ pr_t^- &= \underset{(20.4)}{-110.5y_t} - \underset{(20.2)}{107.6y_{t-1}} - \underset{(20.0)}{101.5y_{t-2}} - \\ &\quad \underset{(19.8)}{92.8y_{t-3}} + \underset{(1.46)}{17.6} + \hat{u}_t \\ &\quad s.e.e. = 7.49 \end{aligned}$$

where $y_t^{(4)}$ is the fourth-order logarithmic difference of output volume.

The prediction equations for emp_t^- and pr_t^+ are

$$\begin{aligned} emp_t^- &= \underset{(21.2)}{-34.6y_{t-1}^{(4)}} + \underset{(0.14)}{0.33emp_{t-1}^-} + \underset{(0.07)}{0.34bp_{t-1}^-} + \\ &\quad \underset{(5.82)}{20.2} - \underset{(3.11)}{6.44d_1} - \underset{(3.09)}{5.63d_2} - \underset{(3.15)}{0.51d_3} + \hat{u}_t \\ &\quad s.e.e. = 6.75 \\ pr_t^- &= \underset{(0.12)}{0.45bpr_{t-1}^-} + \underset{(0.08)}{0.22bp_{t-1}^-} + \underset{(2.62)}{6.70} + \hat{u}_t \\ &\quad s.e.e. = 6.80 \end{aligned}$$

where $d_{jt}, j = 1, 2, 3$, are seasonal dummy variables, bp_t^- is the share of firms expecting the general business conditions to deteriorate in the near future and bpr_t^- is expectations of output volume is lower in next quarter compared with this quarter.

Forest industry

The estimated autoprojective equation for the logarithmic difference of output volume y_t is

$$\begin{array}{rclllllll} y_t & = & 0.02 & - & 0.02d_1 & - & 0.03d_2 & - & 0.03d_3 & + & \hat{u}_t \\ & & (2.06) & & (0.02) & & (0.02) & & (0.02) & & \\ & & s.e.e. = 0.04 & & & & & & & & \end{array}$$

where $d_{jt}, j = 1, 2, 3$, are seasonal dummy variables.

$$\begin{array}{rcllllllll} pr_t^+ & = & 300.6y_t & + & 103.0y_{t-1} & + & 122.3y_{t-2} & + & 41.4y_{t-3} & + \\ & & (42.2) & & (42.1) & & (43.7) & & (43.5) & \\ & & 25.1 & + & 2.86d_1 & + & 5.27d_2 & + & 14.1d_3 & + \ \hat{u}_t \\ & & (2.89) & & (4.14) & & (4.23) & & (4.19) & \\ & & s.e.e. = 8.64 & & & & & & & \end{array}$$

where pr_t^+ is the share of firms reporting that "the volume of output during the present quarter compared with preceding quarter is higher" (as opposed to "the same" and "lower"), y_t is the logarithmic difference of output volume.

$$\begin{array}{rcllllllll} pr_t^+ & = & 27.1 & + & 6.79d_1 & + & 0.26d_2 & + & 3.29d_3 & - \\ & & (7.95) & & (3.99) & & (3.71) & & (3.74) & \\ & & 86.1y_{t-1} & + & 0.56bpr_{t-1}^+ & - & 0.32bp_{t-1}^- & + & \hat{u}_t & \\ & & (44.3) & & (0.21) & & (0.07) & & & \\ & & s.e.e. = 8.24. & & & & & & & \end{array}$$

where bp_t^- is the share of firms expecting the general business conditions to deteriorate in the near future and bpr_t^+ is expectations of output volume is higher in next quarter compared with this quarter.

Chemical industry

The estimated autoprojective equation for the logarithmic difference of output volume y_t is

$$\begin{aligned} y_t \quad = \quad & \underset{(0.12)}{-0.41 y_{t-1}} - \underset{(0.03)}{0.12 d_{863}} + \underset{(0.02)}{0.06} + \underset{(0.03)}{0.02 d_1} - \\ & \underset{(0.02)}{0.05 d_2} - \underset{(0.02)}{0.16 d_3} + \hat{u}_t \\ & s.e.e. = 0.04 \end{aligned}$$

where $d_{jt}, j = 1, 2, 3$, are seasonal dummy variables and

$$d_{863} = \begin{cases} 0, & \text{if t} \neq 1986/3 \\ -1, & \text{t} = 1986/3 \end{cases}$$

The measurement equation for difference of business survey question pr_t^- "the volume of output during the present quarter compared with corresponding quarter year ago is lower".

$$\begin{aligned} pr_t^- - pr_{t-1}^- \quad = \quad & \underset{(59.0)}{37.0 y_t} - \underset{(65.1)}{9.90} + \underset{(9.14)}{21.8 d_1} + \\ & \underset{(10.6)}{7.61 d_2} + \underset{(13.0)}{10.4 d_3} + \hat{u}_t \\ & s.e.e. = 18.6 \end{aligned}$$

Non-Metallic Products

The estimated autoprojective equation for the logarithmic difference of output volume y_t is

$$\begin{array}{rcl} y_t & = & \underset{(0.17)}{-0.10 y_{t-1}} - \underset{(0.17)}{0.18 y_{t-2}} - \underset{(0.18)}{0.21 y_{t-3}} + \underset{(0.18)}{0.23 y_{t-4}} + \\ & & \underset{(0.03)}{0.06} - \underset{(0.06)}{0.10 d_1} + \underset{(0.02)}{0.01 d_2} - \underset{(0.06)}{0.12 d_3} + \hat{u}_t \\ & & s.e.e. = 0.05 \end{array}$$

where $d_{jt}, j = 1, 2, 3$, are seasonal dummy variables.

The measurement equation for business survey question pr_t^- "the volume of output during the present quarter compared with corresponding quarter year ago is lower".

$$\begin{array}{rcl} pr_t^- & = & \underset{(49.6)}{-201.6 y_t^{(4)}} + \underset{(3.88)}{42.8} + \hat{u}_t \\ & & s.e.e. = 22.0 \end{array}$$

where $y_t^{(4)}$ is the fourth-order logarithmic difference of output volume.

The prediction equation for pr_t^- is

$$\begin{array}{rcl} pr_t^- & = & \underset{(46.2)}{-155.4 y_{t-1}^{(4)}} + \underset{(0.12)}{0.42 pb_{t-2}^-} + \underset{(6.78)}{23.7} + \hat{u}_t \\ & & s.e.e. = 18.3 \end{array}$$

where bp_t^- is the share of firms expecting the general business conditions to deteriorate in the near future.

Metal and Engineering

The estimated nonlinear autoprojective equation for the logarithmic difference of output volume y_t is

$$\begin{aligned} y_t = \; & \underset{(0.14)}{0.27} - \underset{(0.09)}{0.52d_1} - \underset{(0.07)}{0.28d_2} - \underset{(0.07)}{0.25d_3} + \\ & \tfrac{1}{1+e^{z_t}} \cdot \Big(\underset{(0.08)}{-0.06} - \underset{(0.04)}{0.02y_{t-1}} + \underset{(0.05)}{0.09d_1} + \\ & \underset{(0.05)}{0.17d_2} - \underset{(0.09)}{0.52d_3} \Big) + \hat{u}_t \\ & s.e.e. = 0.04 \end{aligned}$$

where $d_{jt}, j = 1, 2, 3$, are seasonal dummy variables.

$$z_t = \underset{(0.01)}{-2.69} \cdot s^{-1}(\tfrac{i}{n}) \cdot (\tfrac{i}{n} - \underset{(0.04)}{0.49})$$

where $i = t - t_0 + 1 = 1, \ldots, n =$ number of observations and $s(\frac{i}{n})$ is the standard deviation of $\frac{i}{n}$.

The measurement equation for business survey question pr_t^- "the volume of output during the present quarter compared with corresponding quarter year ago is lower".

$$\begin{aligned} pr_t^- = \; & \underset{(29.1)}{-210.3y_t^{(4)}} + \underset{(1.90)}{35.4} + \hat{u}_t \\ & s.e.e. = 11.1 \end{aligned}$$

where $y_t^{(4)}$ is the fourth-order logarithmic difference of output volume.

The prediction equation for pr_t^- is

$$\begin{aligned} pr_t^- = \; & \underset{(30.9)}{-141.3y_{t-1}^{(4)}} + \underset{(0.09)}{0.38pb_{t-1}^-} + \underset{(3.48)}{22.6} + \hat{u}_t \\ & s.e.e. = 9.6 \end{aligned}$$

where bp_t^- is the share of firms expecting the general business conditions to deteriorate in the near future.

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