Economic Modelling 39 (2014) 221–231

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/ecmod

Semiconductor industry cycles: Explanatory factors and forecasting☆

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ARTICLE INFO

Article history:
Accepted 21 February 2014
Available online 29 March 2014

JEL classification:
C53
L63

Keywords:
Univariate and multivariate models
Forecasting accuracy
Industry cycles
Semiconductor industry

ABSTRACT

This paper aims to suggest the best forecasting model for the semiconductor market. A wide range of alternative modern econometric modeling approaches have been implemented, and a large variety of criteria and tests have been employed to assess the out-of-sample forecasting accuracy at various horizons. The results suggest that if a VECM can be an interesting source of information, the Bayesian models are superior forecasting tools compared to univariate and unrestricted VAR models. However, for decision makers a spectral method could be a useful tool, which can be easily implemented. In addition, MS-AR models make it possible to obtain valuable forecasts on turning-points in order to adjust the programming of heavy capital and research investments.

1. Introduction

The semiconductor industry differs from other industries not only in the progression of technological advances but also in the cyclical dynamic of the variables structuring the market. Semiconductors are high-tech products and the rapidity of innovation, which plays a central role in this industry, tends to make products quickly obsolete. Substantial and growing investments in R&D (Research and Development), which represented in 1970 almost 8% of the revenue of firms and have now reached nearly 20%, have enabled innovations to succeed in the interaction with a demand which is increasingly diverse. The products are then quickly replaced by others, and actors of the market observe constantly new product families appearing and old ones disappearing. In the early 1990s, IC Insights, a market research company specializing in the semiconductor market, highlighted alternating periods during which the production capacity of enterprises increases, and prices and investment fall, with periods during which these variables move in the opposite direction. These recurring movements characterized by regular amplitude and periodicity demonstrate that industry-specific variables exhibit a cyclical behavior. Indeed we can observe that sales have been experiencing huge fluctuations, and for firms involved in this industry it is a necessity to anticipate the dynamic behaviors of the global semiconductor industry which impacts the timing of investment and the competitive structure of the entire sector.

Although the worldwide semiconductor industry provides an excellent illustration of research into industry cycles, little work has been done on modeling and forecasting sales of semiconductors (Chow and Choy, 2006; Liu, 2007; Liu and Chyi, 2006; Liu et al., 2013). The complex structure of the market and the difficulty of accessing the data make it a particularly challenging subject for research. Forecasting the stochastic processes governing semiconductor billings is relevant both at a company level and at a macroeconomic level. Indeed, decision-makers of this high-tech industry need to assess the future trends and anticipate the turning points in order to adjust the programming of their heavy capital and research investments. Forecasts need to be quickly obtained by firms and updated as soon as new observations are published. At the macroeconomic level, the importance of the semiconductor on the global economy and the fact that the sector is seen as a leading indicator of the world's economic health (Chow and Choy, 2006) highlight the need to provide accurate forecasts. Such a variable is thus a very good indicator for forecasts of future global economic activity.

This paper focuses on the best way to predict the evolution of the global chip industry. Sector specific studies are important because the success of a type of forecasting model cannot be applied to all markets and the cyclical behavior of semiconductor sales may require particular methodologies. This is the reason why we search for appropriate semiconductor sales modeling techniques to improve forecasting accuracy. Standard univariate models such as exponentially smoothing and ARMA models have been implemented. Then the study has been enriched with other techniques which have varying degrees of complexity. As the Markov switching approach can be employed to identify

☆ For useful constructive comments and suggestions, we are grateful to the ISF 2011 Conference Participants; all errors remain ours.
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http://dx.doi.org/10.1016/j.econmod.2014.02.039
0264-9993/

and date the electronics cycles, we have tried here to find out if the Markov switching autoregressive models can be useful tools to generate forecasts.[2] We have also proposed a spectral analysis to produce forecasts. In addition, different multivariate models have been developed to incorporate explanatory factors and the possible interactions between variables: a vector autoregressive model (VAR), a Bayesian vector autoregressive model and a vector error correction model (VECM). Indeed, diverse indicators can impact fluctuations: cycles could be explained in part by macroeconomic variables through the industrial production; specific industry factors such as new orders, investments or inventories provide information about diverse aspects of the activity (demand, supply, or price). Financial variables must also be taken into account as a proxy for firms' anticipations.

Our aim here is to propose forecasting models which can be used to support decisions, and which can become arguments to convince investors: "Forecast accuracy is of obvious importance to users of forecasts because forecasts are used to guide decisions" (Diebold and Mariano, 1995). It is the reason why we particularly focused on the ability to predict turning points: those moments have to give rhythm the investment policy. We have employed a wide array of forecast statistics. The out-of-sample forecasting performances of models have been evaluated by standard forecast summary statistics like root mean squared error (RMSE), mean absolute percentage error (MAPE) and Theil's U statistics. The Diebold and Mariano test has been used. Evaluating whether a series will move up and down is important too, especially if these movements are involved in the decision to invest. Thus, Henriksson and Merton's (1981) test has been employed to focus on the capacity of forecasts to predict the direction of change in a series, allowing us to obtain information that is not limited to a quantitative evaluation of forecasts.

The originality of this work lies in the scope of the study. This paper presents a wide comparison of the performances of econometric forecasting models concerning the semiconductor industry on recent data including the financial crisis from November 1996 to June 2010. It addresses a number of important questions. First of all, we have tried to verify whether some methodologies mainly developed to predict business cycles could be adapted to industry cycles. Secondly, the rankings of these models have been established based on a wide variety of criteria and tests. Thirdly, the forecasting performances of models have been evaluated both in the short and medium terms since we have focused on forecast horizons from one to twelve months.

The organization of the paper is as follows. After a quick review of literature concerning the semiconductor industry in Section 2, the properties of the data set used are examined in Section 3. Section 4 discusses the specifications of the models used in the forecasting comparison. Section 5 presents the out-of-sample forecasting results analyzed using a wide range of measures. The concluding remarks are given in Section 6.

2. Literature review

Most studies about cyclical dynamics have focused on macroeconomics. Business cycles interest economists who want to understand and anticipate fluctuations. They try to predict the timing of peaks that symbolize the start of an expansion or recession phase. At the beginning of each phase, decision-makers have to adapt their organization. Schumpeter (1911), who worked on the oscillatory behavior of the capitalist economic development, was the first to highlight the importance of the change of scale when analyzing cyclical industrial dynamics. In fact, each industry has its own movement of growth and decline; they are not necessarily identical to business cycles, and the decisions of market participants depend on those movements. Moreover, such a study is not without interest for research into business cycles: the cyclical behavior of the semiconductor market has become one of the major impact factors for world economic performance. Worldwide GDP and worldwide growth of the semiconductor industry are indeed closely related.

Despite the great importance of semiconductors for the world economy, there are few academic studies on this sector. Difficulty obtaining data relating to sales[3] could explain that the first to establish models are market experts or professionals. McClean (2010), for example, publishes annual reports that present various indicators graphically: investments, orders, inventories, productions, shipments and profits that must be monitored and can announce future evolutions of the market. He applies what Liu (2005) calls the "rules of thumb". His subjective assumptions from the direct observation of market conditions highlight potentially significant variables for econometric models (Liu, 2005). More recently, economists have explored the semiconductor industry cycles and proposed models to explain and forecast semiconductor sales. As this field of research, which developed in order to add weight to the macroeconomic literature, is still in an embryonic stage, the methodologies are derived from business cycle research (Stock and Watson, 1999).

The Macroeconomic Review of the Monetary Authority of Singapore has developed a summary index of activity that can be employed to predict turning points in global industry cycles (Ng et al., 2004). The authors have used monthly time series data from January 1989 to March 2003. The particularity of their study is that it focuses on quantitative forecasts of the performance of the Singapore electronics industry. Nevertheless Ng et al. have utilized global semiconductor sales and mostly American data. This a priori paradoxical choice is explained by the fact that these series are the only available data for researchers. Moreover, the series appear statistically relevant. Indeed, the indicators combined to form Electronic Leading Indices (ELIs), and were selected thanks to a procedure using cross correlation analysis, causality tests and marginal predictive content tests. Finally, Ng et al.'s choice was directed toward a model taking into account US new orders for electronics, US book-to-bill ratio of semiconductor equipment, US Producer Price Index for DRAM,[4] US electronics shipments to inventory ratio, Singapore's retained imports of electronics and the electronics finished goods purchasing manager index.

Liu (2005) is the first author to emphasize the cyclical behavior of the semiconductor industry, which appears as a perfect example for studies on industrial cycles. He uses monthly data from May 1994 to December 2001 to explore market dynamics and construct a vector autoregressive model (VAR). The interest is to capture supply and demand dynamics taking into account variables relating to the agents' anticipations or the health of the sector. Information issued from market reports and studies conducted by industry experts have enabled the author to select indicators (macroeconomic and industry variables) that allow the identification of the global semiconductor industry cycles. The paper reveals that both the semiconductor inventory and the industry capacity play an important role in signaling the future state of the semiconductor business. The results are consistent with the industry practitioners' observations. Liu (2007) has completed this analysis and provided forecasts of the semiconductor industry cycles using bootstrap prediction intervals. He offers a real tool for strategic decisions. He succeeds in enhancing predictions offered by private institutes and market actors. These innovative studies on the semiconductor market have

[2] Unlike Liu and Chyi (2006) and Liu et al. (2013), we do use Markov models not only to predict the probability of the industry being in recession, but also to produce forecasts on sales of semiconductors. The forecasting ability of this non-linear time series model has been established by Clements and Krolzig (1998). The choice of this model is based on the desire to introduce a non-linear model in order to take into account the cyclicality of our series. The MS-AR model is known for the ease with which forecasts can be obtained; this advantage, which is not shared with the multivariate version, is very important for practitioners.

[3] World Semiconductor Trade Statistics (WSTS), the source of the semiconductor market data, limits the access to its data to participant firm.

[4] Dynamic random access memory, reference chip.