The ESF Model
(ESF: Econometric Semiconductor Forecast)
Real Time Forecasting Lessons-Learned

AUBER ANNUAL MEETING
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*Based on Consensus Economics, Inc. CONSENSUS FORECASTS®
Outline

• Forecast process
• Lessons Learned
• Semiconductor MSI measure
  – Data analysis – pch, unit roots, trends, etc.
  – Seasonal adjustment
• Model philosophy
• Model system & key final demand drivers
• Alternative Models
• ESF historical performance
Forecast Process

• Analyze data after new quarterly MSI data release
• Evaluate past forecasts against latest actual data
• Validate model and equation structures with latest actual data
• Update Consensus Forecasts for World Economy, key U.S. inputs
• Update non-Consensus forecasts
• Produce preliminary forecast for team discussion
• Create alternative model quarterly forecast (ARIMA, Book-to-bill, MIDAS models)
• Develop final forecast for MSI
Lessons Learned

• I will (almost) always be “wrong” – (but not by much).
  – Tetlock: *Superforecasting: The Art and Science of Prediction* is right: open-mindedness is critical.

• Judgment and flexibility regarding modeling techniques and forecast preparation are essential

• The process is as important as the modeling
  – A model I can understand almost always produces better forecasts than a model I can’t understand

• Tracking the forecast and adjusting for errors is key to a good forecast
  – One quarter ahead: use time-series & Midas to adjust
  – Downplay anecdotal evidence not substantiated by any data, but…
  – Pay attention to comments back from the users of the forecasts

• For the MSI and semiconductor industry measures:
  – Seasonal adjustment gets the variability
  – Final demand is more important than immediate markets
    • There is too much “noise” in the immediate markets
    • Data availability in immediate markets is questionable
Semiconductor Measure: MSI From SEMI.ORG

Semiconductor wafers shipped for semiconductor applications

Million Square Inches

- **SEMIMSI**
- **Fitted Trend (Log)**

95Q1-18Q2:
- 2.2% Average quarter change
- 12.5% Standard deviation (+/-)
- 5.8% Trendline growth rate per year
Distribution of MSI Quarterly Percent Changes

Series: PCH_SEMIMSI
Sample 1995Q1 2018Q2
Observations 94

Mean 2.271178
Median 2.636729
Maximum 79.36170
Minimum -36.33527
Std. Dev. 12.39935
Skewness 1.947261
Kurtosis 18.68398
Jarque-Bera 1022.855
Probabilit
Census X-13 Analytical Results:

SIGNIFICANCE OF SEASONALITY

Significance of seasonality is assessed using the variances of the total estimation error, which includes the error in the preliminary estimator (the revision error) and the error in the final estimator. Because the S.E. of the seasonal component estimator varies (it reaches a minimum for historical estimation and a maximum for the most distant forecast), the significance of seasonality will be different for different periods.

An extreme example would be a series showing significant seasonality for historical estimates, that is poorly captured concurrently, and useless for forecasting.

<table>
<thead>
<tr>
<th>SEASONAL COMPONENT</th>
<th>NUMBER OF PERIODS IN A YEAR THAT HAVE SIGNIFICANT SEASONALITY</th>
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<tbody>
<tr>
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<td>90%</td>
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<td>HISTORICAL ESTIMATOR</td>
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<td>PRELIMINARY ESTIMATOR</td>
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<td>FOR LAST YEAR</td>
<td></td>
</tr>
<tr>
<td>FORECAST FOR NEXT YEAR</td>
<td>4</td>
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</table>

For the present series:

FINAL OR HISTORICAL ESTIMATION SHOWS CLEARLY SIGNIFICANT SEASONALITY IN THE SERIES.

CONCURRENT AND PRELIMINARY ESTIMATION SHOW CLEARLY SIGNIFICANT SEASONALITY FOR RECENT PERIODS (LAST YEAR).

ONE-YEAR AHEAD FORECAST FUNCTION CONTAINS CLEARLY SIGNIFICANT SEASONALITY.
Seasonal Factor Analysis

Source: Semi.org
Hilltop Economics LLC seasonal adjustment
Becoming Less Seasonal

SEMI MSI SEASONAL IMPACT
History 1995Q1 to 2018Q2

Means by Season

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Model Philosophy

• Semiconductors a dynamic but maturing industry
  – Technological change (“supply side”) no longer creates large step-changes in MSI demand.
  – Chips ubiquitous in products
  – Products ubiquitous in global regions

• Final Demand a valid driver of MSI
  – Demand driven by “final demand” – consumers and businesses using technology products
    • Consumption
    • Investment
  – Consumers & businesses buy technology products based on economic factors, so MSI can be modeled similar to other dynamic but maturing materials and products.

• Final Demand is best forecast by the global Consensus Forecasts of key (85) economies
  – “Wall Street credibility”
Some Key Immediate End-use Markets
(The “typical” industry forecast drivers)

Estimated Global PC Sales

Source: Hilltop Economics
Shaded area indicates main period of tablet penetration

Annual Percent Change
2016 2017 2018 2019 2020
-7.0% -2.3% 1.1% -0.4% -2.3%

Estimated Global Smartphone Sales

Source: Gartner & IDC news releases
Forecast: Hilltop Economics, September 2018 Update

Annual Percent Change
2016 2017 2018 2019 2020
5.2% 2.6% -0.8% -1.7% 4.5%
MSI VS “World” Real GDP
.94 Correlation From 95Q1 to 18Q2, Level Log-Log
Note, however, penetration moderation 2011-2016

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MSI VS Real Investment

.952 Correlation From 95Q1 to 17Q3, Level
Slightly better correlation, slightly lower growth multiple

95-17Q3
95.2% correlation
MSI Multiple: 1.7X
MSI Block: The Core Model Structure

• Error Correction Model (ECM) system
  – MSI seasonal adjustment model (Census X-13 Tramo/Seats) to capture “typical” seasonal patterns.
  – Long run MSI-final demand embedded equation
  – Short run MSI-dynamic cyclical equation to capture excursions from underlying long-run relationships

• Driven by exogenous inputs and models of final demand, plus any necessary supply-side developments.
ESF Model System

(ESF: Econometric Semiconductor Forecast)

Consensus Forecasts:
- Global Real GDP
- Investment
- Consumption
- US Real GDP & Potential GDP
  - Real Investment
  - Real Consumption
- Inflation & Interest Rates

MSI Block of Equations

- Tablet Penetration, WinXP, Win10 Timing, Replacement Cycles, Financial crash behavior
- Seasonal Factors (Census X-13)
- Economic Policy Uncertainty (US, EU, China)
- Semiconductor: Capacity: Total, 300
  - Reclaim: % Total

US Investment & Consumption Equations

PC & Smartphones

US Tech Goods

Spending Propensity:
- Business Tech
- Consumer Tech

Inventory-Shipment:
- * PCs & Peripherals
- * METI Wafers

Tablet Penetration, WinXP, Win10 Timing, Replacement Cycles, Financial crash behavior

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Long Run Embedded Equation

• Seasonally-adjusted MSI modeled as a function of key inputs:
  – “Global” ex US investment and consumption
  – US technology goods spending (business & consumer)
  – Global PC and smartphone unit sales
  – Economic Policy Uncertainty (Global)
  – Interest rates
  – Semi wafer capacity estimates (total, VNAND introduction)
  – METI I-S ratios (wafers)
  – Behavioral dummies: financial collapse & 9/11
Short Run Cycle Equation

• Quarterly rate of change in MSI modeled as a function of key inputs:
  – Deviation from long run embedded equation estimates
  – Rate of change in key long run inputs:
    • Global final demands
    • US Tech
    • PCs & smartphones
    • Economic policy uncertainty
  – Rate of change in US inventory-shipments ratio for computers & peripherals, METI I-S ratio
  – Special events measures (9/11, Financial Crisis onset, Win10)
  – Rate of change in SEMI capacity measure and impacts from 300mm and VNAND introductions (lagged one Qtr)
Unit Root Test:

Log(SEMI MSI) does not have a unit root
The Long-run Embedded MSI Equation

Aug 18: Adjusted R-square: .986  D-W: 1.76  SER: 4.2%  MAPE: 3.9%

Model as of Aug 2018
The Long-run Embedded MSI Equation

Nov 17: Adjusted R-square: .986  D-W: 1.76  SER: 4.2%  MAPE: 3.9%

Forecast: SEMIMSI  
Actual: SEMIMSI
Forecast sample: 1998Q1 2018Q4  
Adjusted sample: 1998Q3 2018Q2
Included observations: 80
Root Mean Squared Error 94.44383
Mean Absolute Error 71.75130
Mean Abs. Percent Error 3.936223
Theil Inequality Coef. 0.023122
Bias Proportion 0.002753
Variance Proportion 0.019712
Covariance Proportion 0.977535
Theil U2 Coefficient 0.436134
Symmetric MAPE 3.941310
**Long-run Embedded Equation**

The model presents a long-run equation with a dependent variable as `LOG(SEMIMSI)-LOG(SEMIMSI_SF)` using a Least Squares method. The data was collected on 08/11/18 with a fixed bandwidth of 4.0000. The sample is adjusted to 1998Q1-2018Q2, and the model includes 82 observations after adjustments. The HAC standard errors & covariance use Bartlett kernel and Newey-West fixed bandwidth.

### Variable Coefficients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-8.173018</td>
<td>1.697363</td>
<td>-4.815126</td>
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<td>LOG(WORIF10C+WORCE10C)</td>
<td>0.976460</td>
<td>0.180174</td>
<td>5.419538</td>
<td>0.0000</td>
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<tr>
<td>LOG(USTECH(-1))</td>
<td>0.197409</td>
<td>0.124508</td>
<td>1.585519</td>
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<td>LOG(DGS10)</td>
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<td>LOG(JPNMSI_I_S)</td>
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<td>LOG(PC_NEW)</td>
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<td>0.035831</td>
<td>3.961303</td>
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<td>@MOVAV()(LOG(SMARTPHONE)-LOG...</td>
<td>0.009843</td>
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<td>LOG(@MOVAV(JPOLUNC_GLOBAL(-...)</td>
<td>-0.059712</td>
<td>0.032828</td>
<td>-1.818925</td>
<td>0.0735</td>
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<tr>
<td>LOG(KSEMI)</td>
<td>0.138483</td>
<td>0.063161</td>
<td>2.192528</td>
<td>0.0319</td>
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<tr>
<td>DVNAND</td>
<td>0.085792</td>
<td>0.013515</td>
<td>6.348004</td>
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</tbody>
</table>

### Model Statistics

- R-squared: 0.989449
- Adjusted R-squared: 0.986852
- S.E. of regression: 0.042128
- S.D. dependent var: 0.367396
- Akaike info criterion: -3.313915
- Schwarz criterion: -2.814961
- Hannan-Quinn criterion: -3.113593
- Durbin-Watson stat: 1.737848

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Dynamic Error Correction Equation

<table>
<thead>
<tr>
<th>Variable</th>
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<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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<td>DLOG(SEMIMSI_SF)</td>
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<td>DLOG(PC_NEW/PC_NEW_SF)</td>
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<td>-0.266936</td>
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<td>0.0139</td>
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<td>DLOG(KSEMI(-1)-KSEMI300(-1))</td>
<td>0.396333</td>
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<td>0.235292</td>
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<td>D(DVNAND)</td>
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R-squared: 0.895851
Adjusted R-squared: 0.873419
S.E. of regression: 0.043684
Sum squared resid: 0.124039
Log likelihood: -45.2522
F-statistic: 39.93631
Prob(F-statistic): 0.000000
Prob(Wald F-statistic): 0.000000

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Dynamic Fit 98Q3-18Q2
In-sample Forecast

Forecast: SEMIMSI_DLF
Actual: SEMIMSI
Forecast sample: 1998Q1 2018Q2
Adjusted sample: 1998Q3 2018Q2
Included observations: 80
Root Mean Squared Error 94.45136
Mean Absolute Error 71.62486
Mean Abs. Percent Error 3.931765
Theil Inequality Coef. 0.023124
Bias Proportion 0.002779
Variance Proportion 0.019538
Covariance Proportion 0.977683
Theil U2 Coefficient 0.436239
Symmetric MAPE 3.936958

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Consensus Forecasts®

©Consensus Economics, Inc. produces four major reports covering the world economy:

1) Developed World
2) Asia-Pacific
3) Latin America
4) Eastern Europe

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ESF customers are encouraged to subscribe to Consensus Forecasts® for the macroeconomic information needs.
Typical Country Output:

Key concepts for ESF forecast:

- Gross Domestic Product
- Personal Consumption
- Business Investment
- Consumer Prices
- Producer Prices

Interest Rates (on second page of document, not shown)
Examine Changes to Consensus Forecasts

World* Real GDP Growth

2017: 3.1%  2018: 3.1%  2019: 3.0%  2020: 2.7%

*World: 85 major economies. Source: November Consensus, IMF, Hilltop Economics

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Increased Uncertainty Raises Downside Risk

Economic Policy Uncertainty

Source: Scott Baker, Nicholas Bloom and Steven J. Davis at www.PolicyUncertainty.com. Data through Sep 18

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Conservative Projections of U.S. Behavior 15Q4

Percent of Consumption/Investment
Spent on Technology Goods (US)

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Conservative Projections of U.S. Behavior
A judgmental input based on recent trends

Based on U.S. Bureau of Economic Analysis data to 18Q2
Shaded areas indicate U.S. recessions (NBER)
Updated Monthly For U.S. NIA Releases

U.S. Business Investment (P&E)
U.S. Technology Equipment

%CH VS YR AGO, 4QMA

History: U.S. Bureau of Economic Analysis
Sep 2018 Forecast: Hilltop Economics
Shaded areas indicates official U.S. recession
# Tracking the Alternatives

<table>
<thead>
<tr>
<th></th>
<th>2018q2</th>
<th>2018q3</th>
<th>2018q4</th>
<th>2019q1</th>
<th>2019q2</th>
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<tbody>
<tr>
<td>SEMIMSI</td>
<td>3,160</td>
<td>--</td>
<td>3,197</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>SEMIMSI (Scenario 2 Mean)</td>
<td>3,160</td>
<td>3,213</td>
<td>3,197</td>
<td>3,255</td>
<td>3,367</td>
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<tr>
<td>SEMI MSI (Scenario 2)</td>
<td>3,160</td>
<td>3,210</td>
<td>3,187</td>
<td>3,237</td>
<td>3,366</td>
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<tr>
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<td>3,198</td>
<td>3,190</td>
<td>3,238</td>
<td>3,367</td>
</tr>
</tbody>
</table>

- **Actual “ESF” Ranges**
- **ARIMA 2 Std Dev**
- **Book-to-Bill: Latest 3 months**
- **MIDAS: Latest 3 months**
- **Add factors**
- **Seasonal factors**
- **Previous month’s forecast**
# Tracking the Alternatives

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**Actual “ESF” Ranges**

**ARIMA 2 Std Dev**

**Book-to-Bill: Latest 3 months**

**MIDAS: Latest 3 months**

**Add factors**

**Seasonal factors**

**Previous month’s forecast**

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**Actual**
- "ESF" Ranges

**ARIMA**
- 2 Std Dev

**Book-to-Bill: Latest 3 months**

**MIDAS: Latest 3 months**
- Add factors
- Seasonal factors
- Previous month’s forecast
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Graphic Examination of Forecasts

- SEMIMSI
- SEMI MSI (Scenario 2) - ECM
- SEMIMSI_2M+SEMIMSI_2S
- SEMIMSI_2M-SEMIMSI_2S
- SEMIMSI_2M+SEMIMSI_2S*2
- SEMIMSI_2M-SEMIMSI_2S*2
- SEMIMSI_F_18Q3 - ARIMA
How Well Does this Forecast Process Work?

The August ESF forecast a weaker Q3 than developed

ESF 18Q2 over-forecast by 1.5% (3207 forecast vs 3160 actual)

History: SEMI to 18Q2
Forecast: ESF 2018 Q2 (May)
How Well Does this Forecast Process Work?

Last November’s Forecast VS Actual

![Graph showing forecast vs actual performance from 2012 to 2016. The graph compares SEMI MSI to 16Q3 and 2015 Q4 Forecast.]
Now 23 Forecasts Since the First Forecast (of 2012Q4)
# Summary Performance

<table>
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<th>1 Quarter Ahead</th>
<th>2 Quarters Ahead</th>
<th>3 Quarters Ahead</th>
<th>4 Quarters Ahead</th>
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Lessons Learned

• I will (almost) always be “wrong” – (but not by much).
  – Tetlock: Superforecasting: The Art and Science of Prediction is right: open-mindedness is critical.

• Judgment and flexibility regarding modeling techniques and forecast preparation are essential

• The process is as important as the modeling
  – A model I can understand almost always produces better forecasts than a model I can’t understand

• Tracking the forecast and adjusting for errors is key to a good forecast
  – One quarter ahead: use time-series & Midas to adjust
  – Downplay anecdotal evidence not substantiated by any data, but…
  – Pay attention to comments back from the users of the forecasts

• For the MSI and semiconductor industry measures:
  – Seasonal adjustment gets the variability
  – Final demand is more important than immediate markets
    • There is too much “noise” in the immediate markets
    • Data availability in immediate markets is questionable