

Forecasting Tax Receipts using Time-Series Econometrics

Presentation to IGEES Conference
4th March

Seán Kennedy
Senior Economist
Statistics and Economic Research Branch

“Prediction is difficult...

Niels Bohr

“Prediction is difficult...
especially about the future”

Niels Bohr

Presentation outline

Part I – Overview

1. Introduction | 2. Current Approach | 3. Time-Series Approach

Part II – Results

4. ARIMA | 5. ARMAX | 6. Model Evaluation | 7. Long-Term Forecasts to 2020

Part III – Conclusions

8. Conclusions

Presentation outline

Part I – Overview

1. Introduction | 2. Current Approach | 3. Time-Series Approach

Part II – Results

4. ARIMA | 5. ARMAX | 6. Model Evaluation | 7. Long-Term Forecasts to 2020

Part III – Conclusions

8. Conclusions

1. Introduction

- ❑ Over past 18 months, Revenue has undertaken exploratory work to forecast tax receipts (PAYE, Non-PAYE, VAT) using time-series econometrics (ARIMA, ARMAX)
- ❑ Models based on monthly data spanning Jan '02 to Jan '16 (14 years)
- ❑ At this point, key question for Revenue is whether time-series approach represents a useful complement to current forecasting methodology

2. Current Approach

- ❑ Forecasting tax receipts is led by Department of Finance with significant input from Revenue
- ❑ Revenue estimates net tax receipts for the year on a roll forward basis using macroeconomic projections provided by Finance
 - One-off adjustments and other known tax or economic factors
- ❑ Receipts then apportioned over the year to each month based on:
 - Profile of receipts by month in recent years
 - One-off adjustments and other known tax or economic factors
- ❑ Revenue net receipt estimates provided to Finance to inform Exchequer receipts forecasts
- ❑ Process depends on significant elements of judgement, experience and expertise

3. Time-Series Approach

- ❑ Since most economic data are nonstationary, Box-Jenkins method (1970) begins by transforming forecast variable to ensure stationarity
- ❑ This new differenced data series, now stationary, expresses forecast variable in terms of its own past values
- ❑ General model is known as ARIMA (p, d, q); ARMAX when independent variables added
- ❑ While no economic/tax factors applied to ARIMA, under ARMAX, independent variable is forecast first (e.g. retail sales) and tax receipts forecast based on this first forecast
- ❑ By contrast to current approach, time-series represents a statistically driven and atheoretical alternative that may be useful as a complement to existing forecasting methodologies

Presentation outline

Part I – Overview

1. Introduction | 2. Current Approach | 3. Time-Series Approach

Part II – Results

4. ARIMA | 5. ARMAX | 6. Model Evaluation | 7. Long-Term Forecasts to 2020

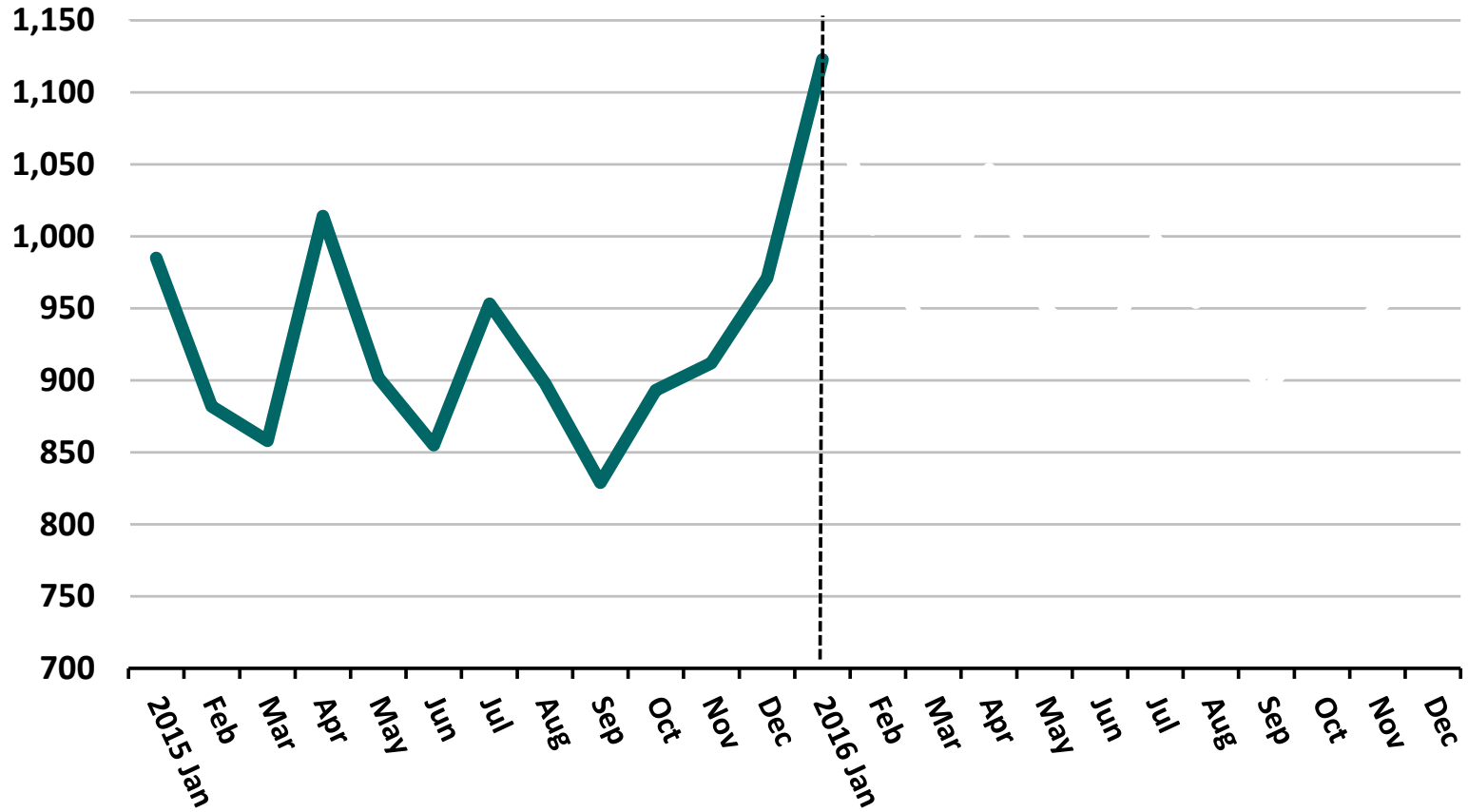
Part III – Conclusions

8. Conclusions

4. ARIMA

PAYE

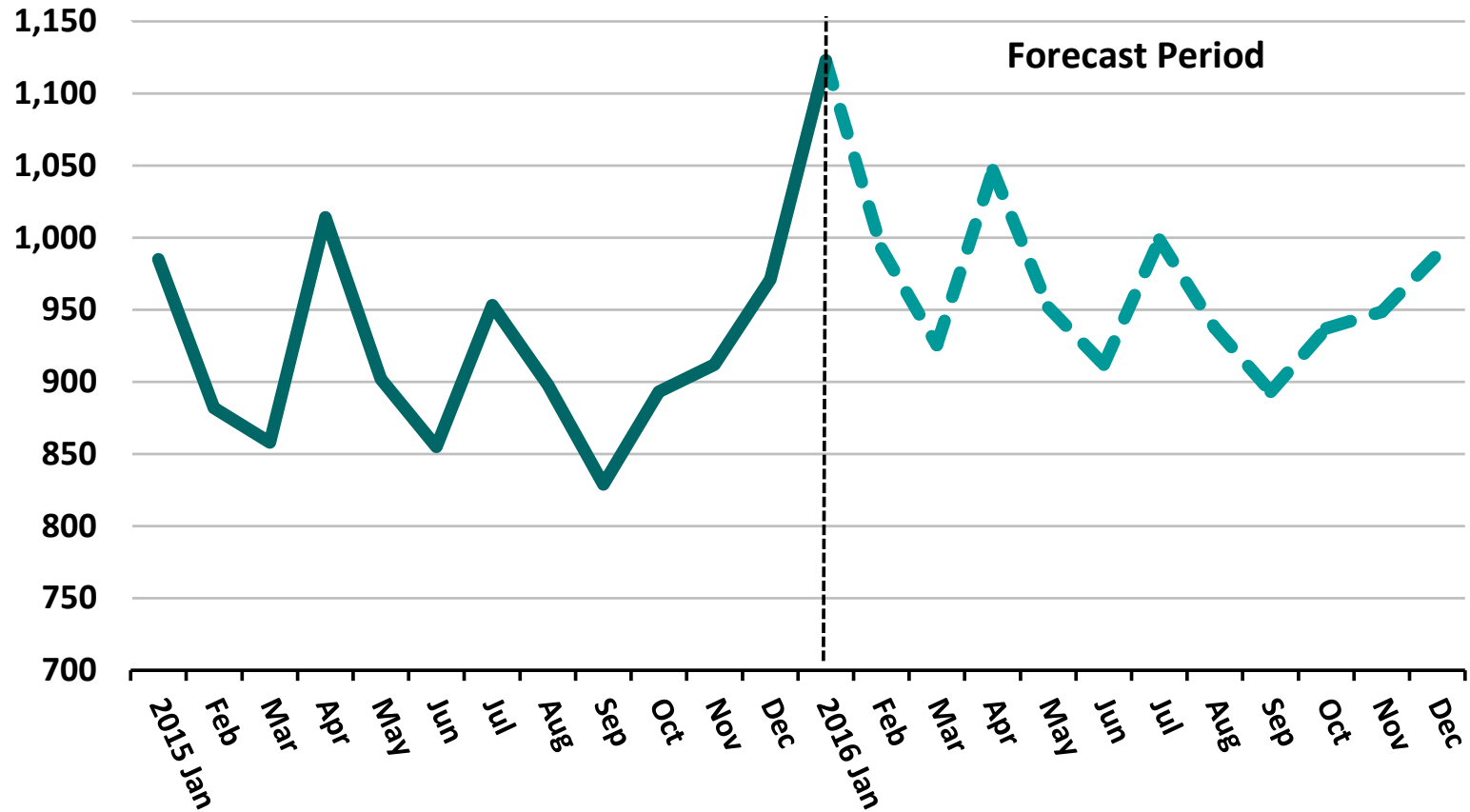
PAYE Tax Receipts (€ millions)



4. ARIMA

PAYE

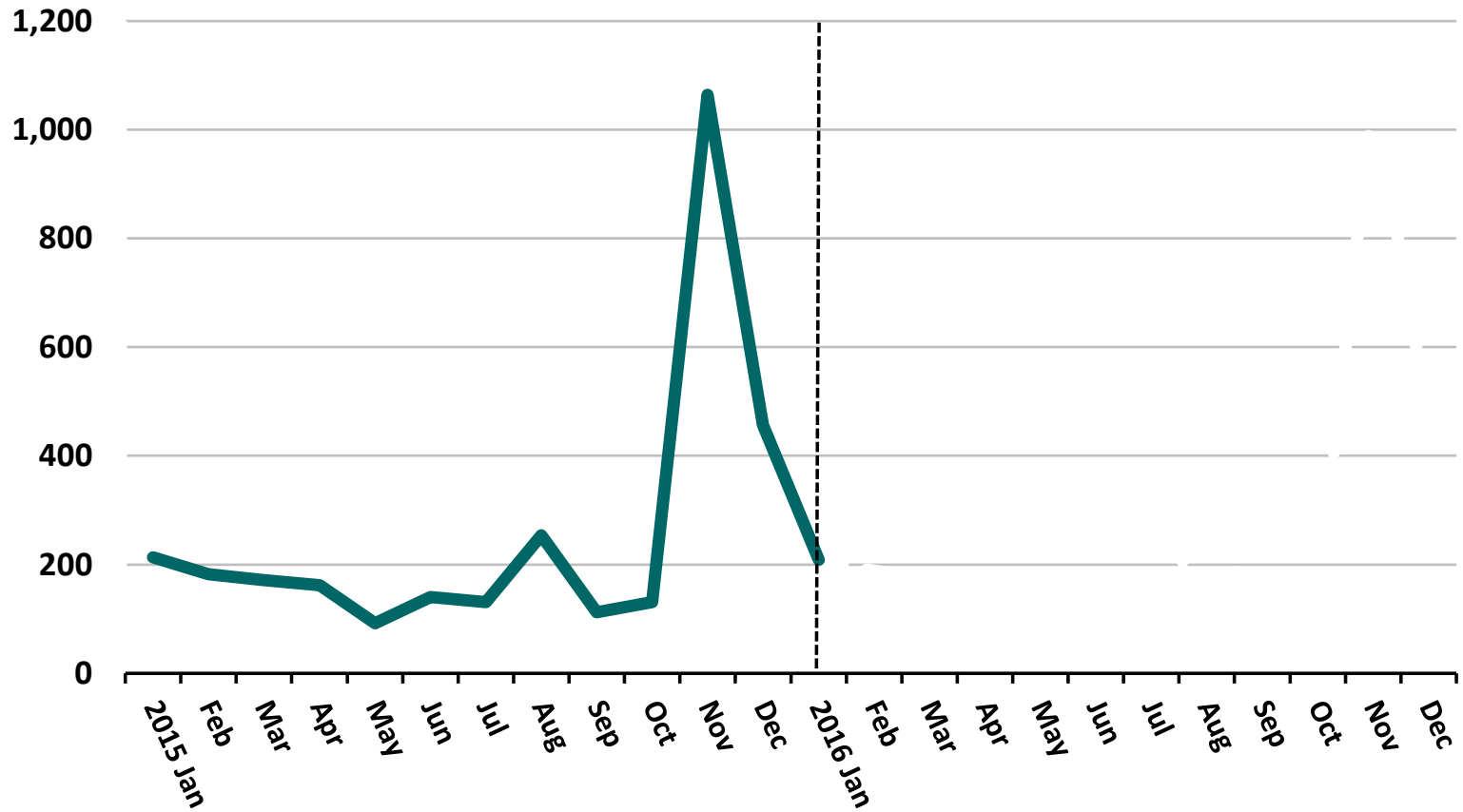
PAYE Tax Receipts (€ millions)



4. ARIMA

Non-PAYE

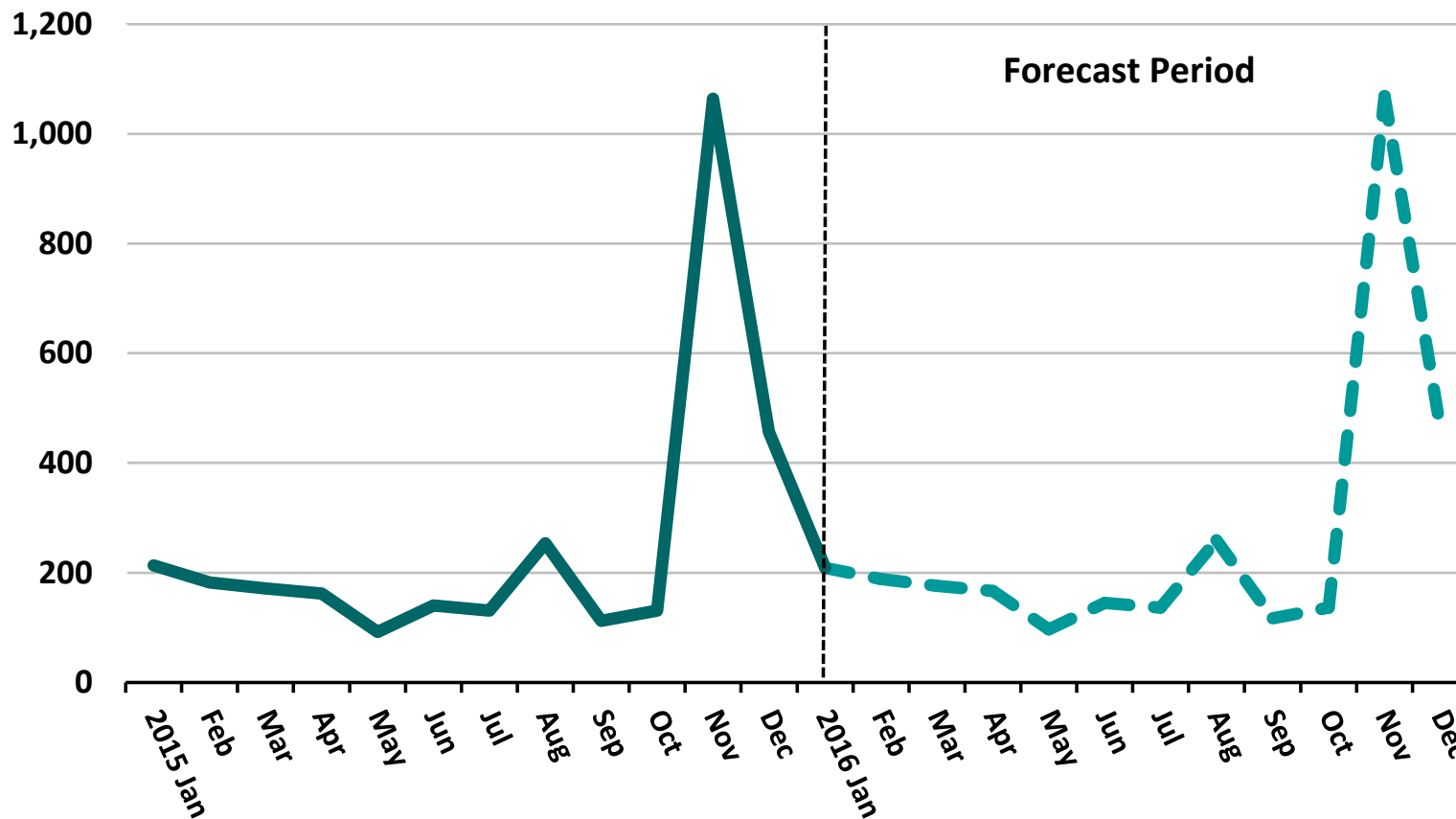
Non-PAYE Tax Receipts (€ millions)



4. ARIMA

Non-PAYE

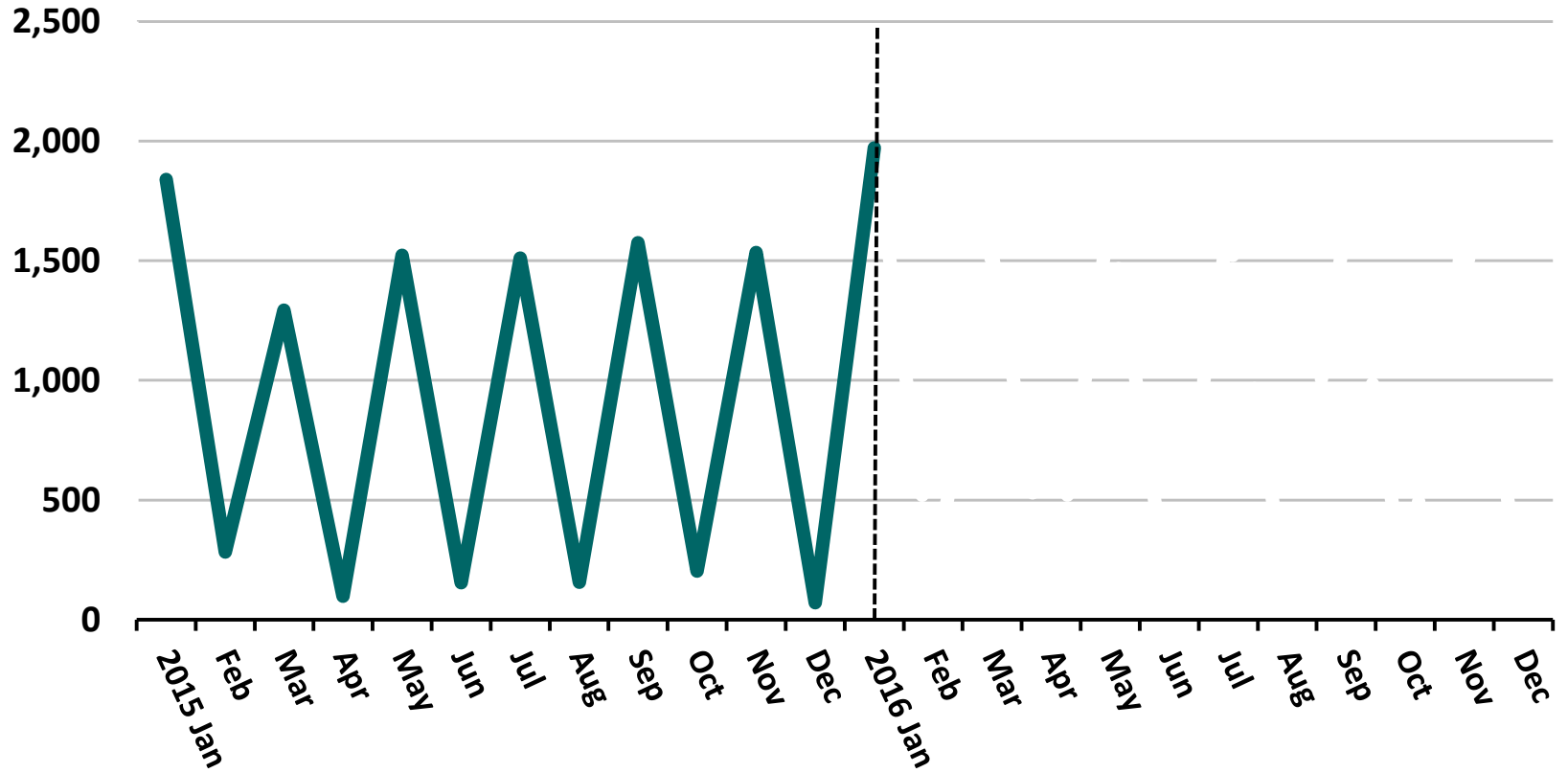
Non-PAYE Tax Receipts (€ millions)



4. ARIMA

VAT

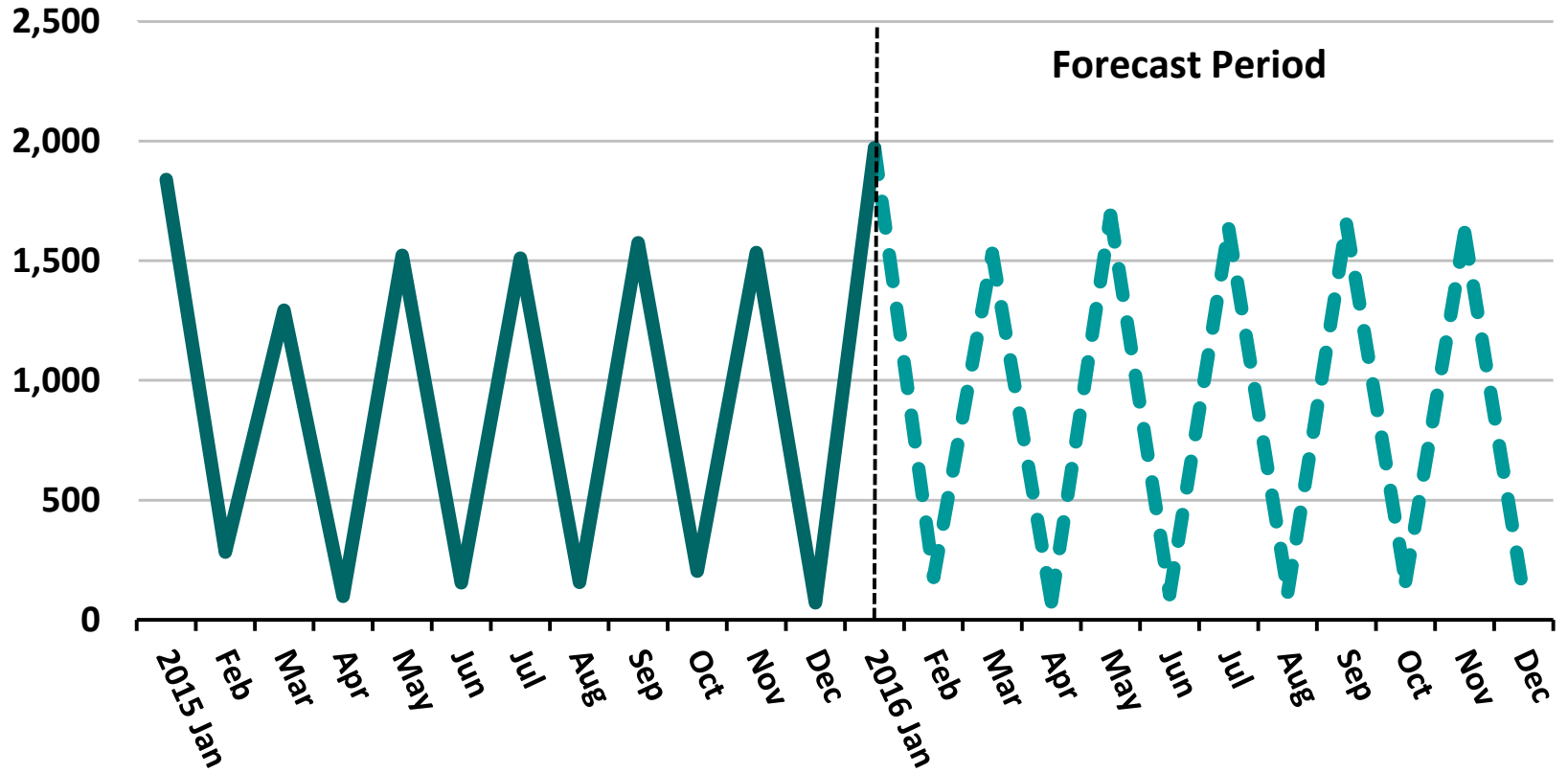
VAT Tax Receipts (€ millions)



4. ARIMA

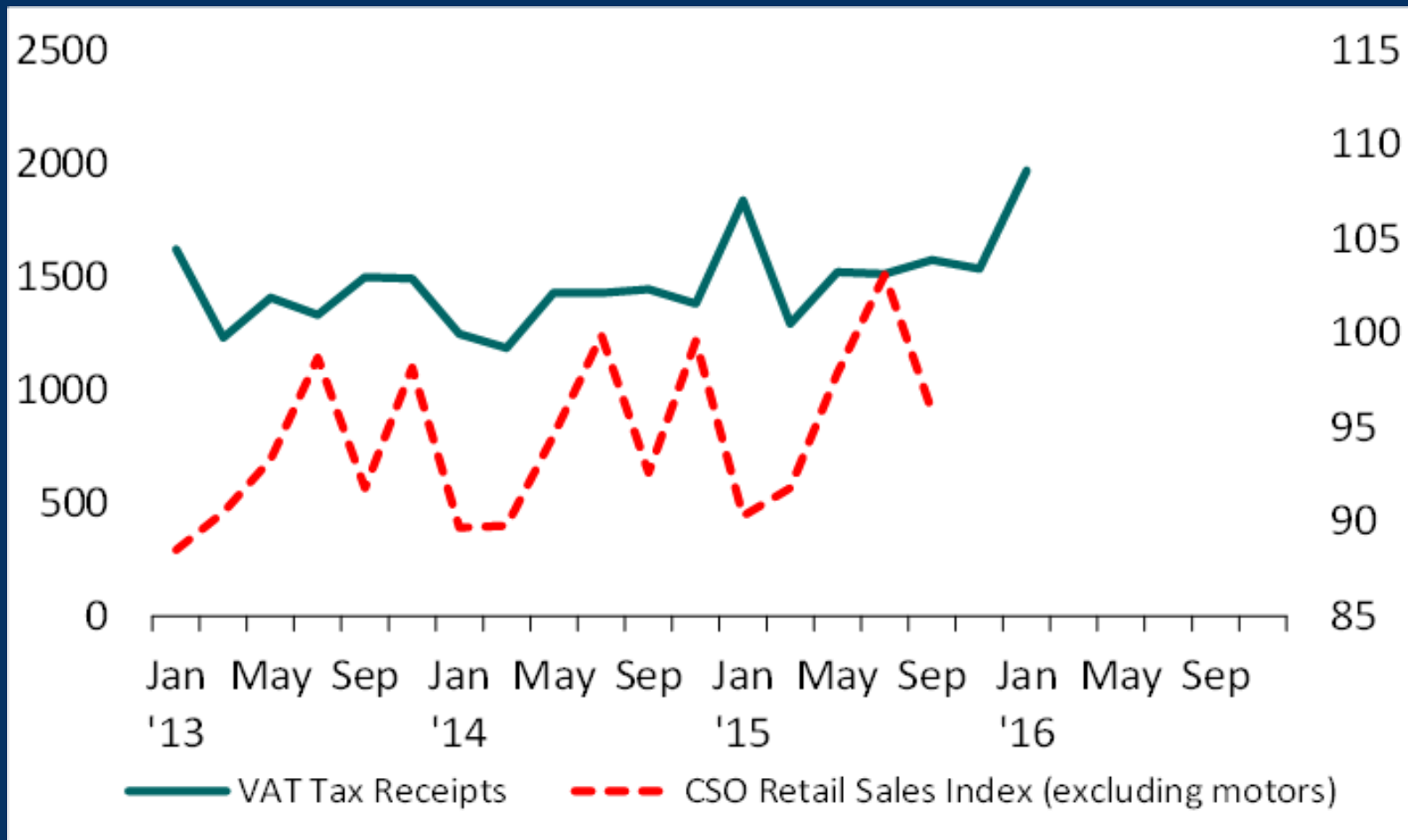
VAT

VAT Tax Receipts (€ millions)



5. ARMAX

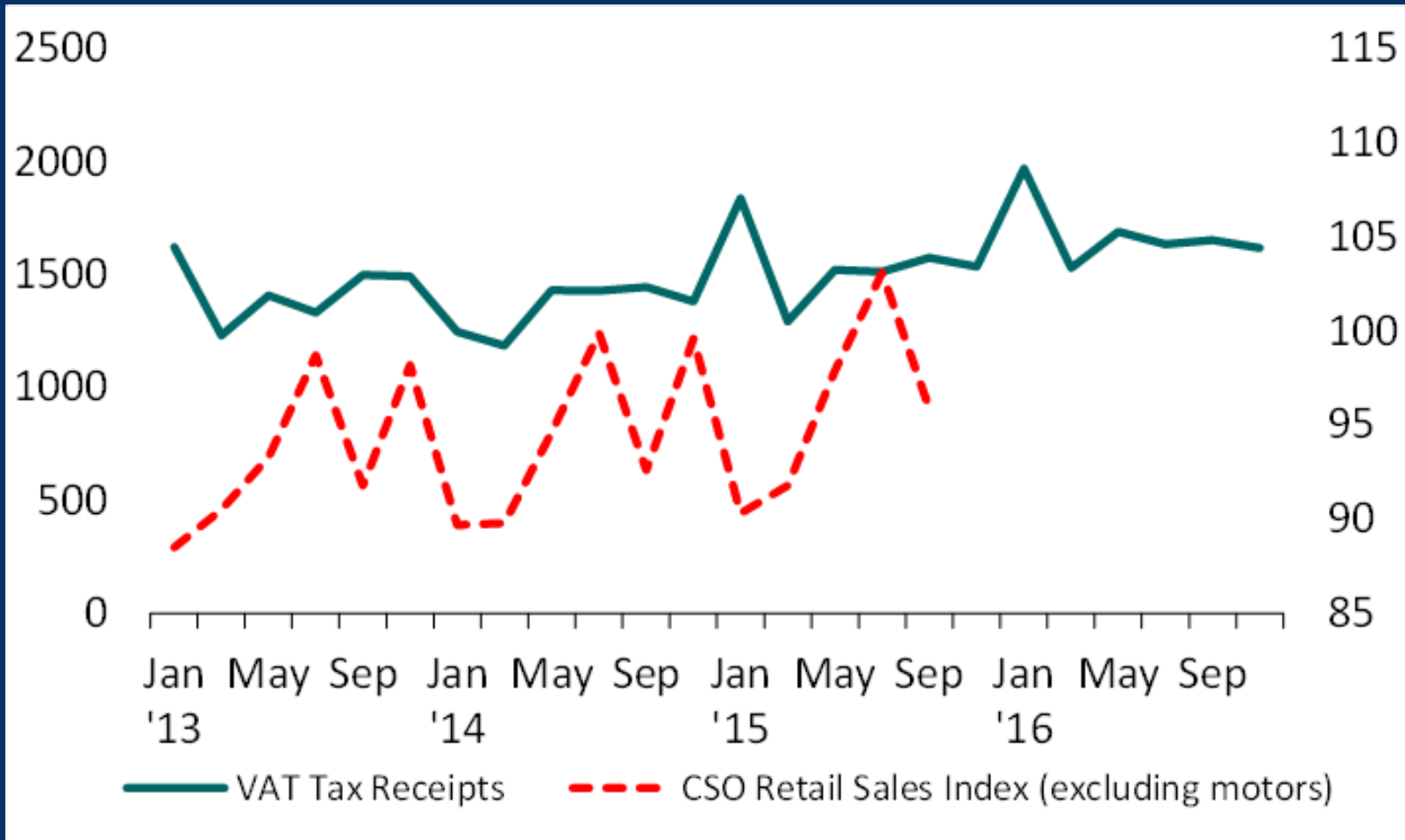
VAT



- CSO Retail Sales Index (ex motors) good explanatory variable for VAT because strong positive correlation with VAT tax (- 0.7; 01 Jan '02 - 01 Nov '15) measured bimonthly. For illustration, chart shows relationship from Jan '13 - Jan '16.

5. ARMAX

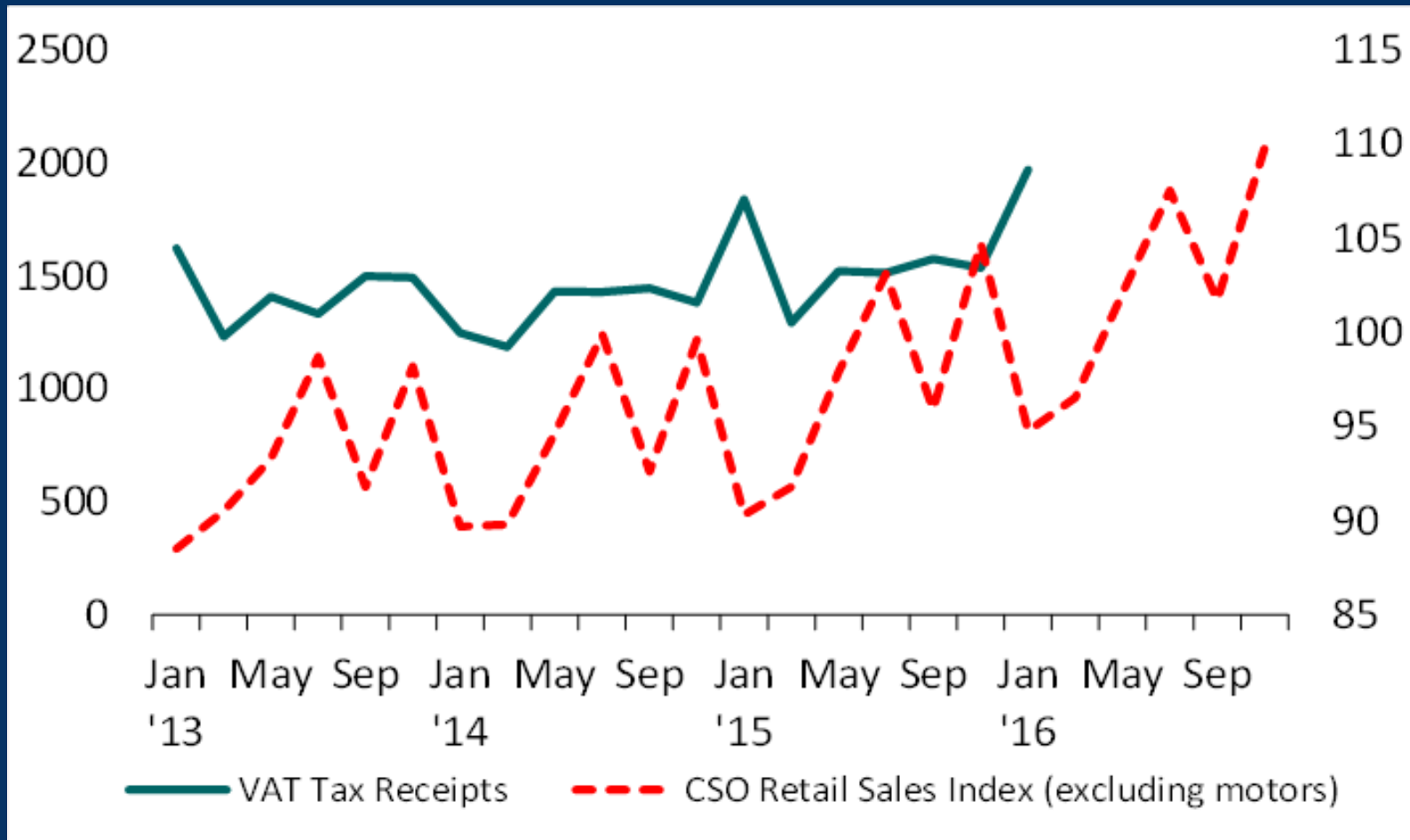
VAT



□ As before, could simply apply the ARIMA process to forecast tax receipts...

5. ARMAX

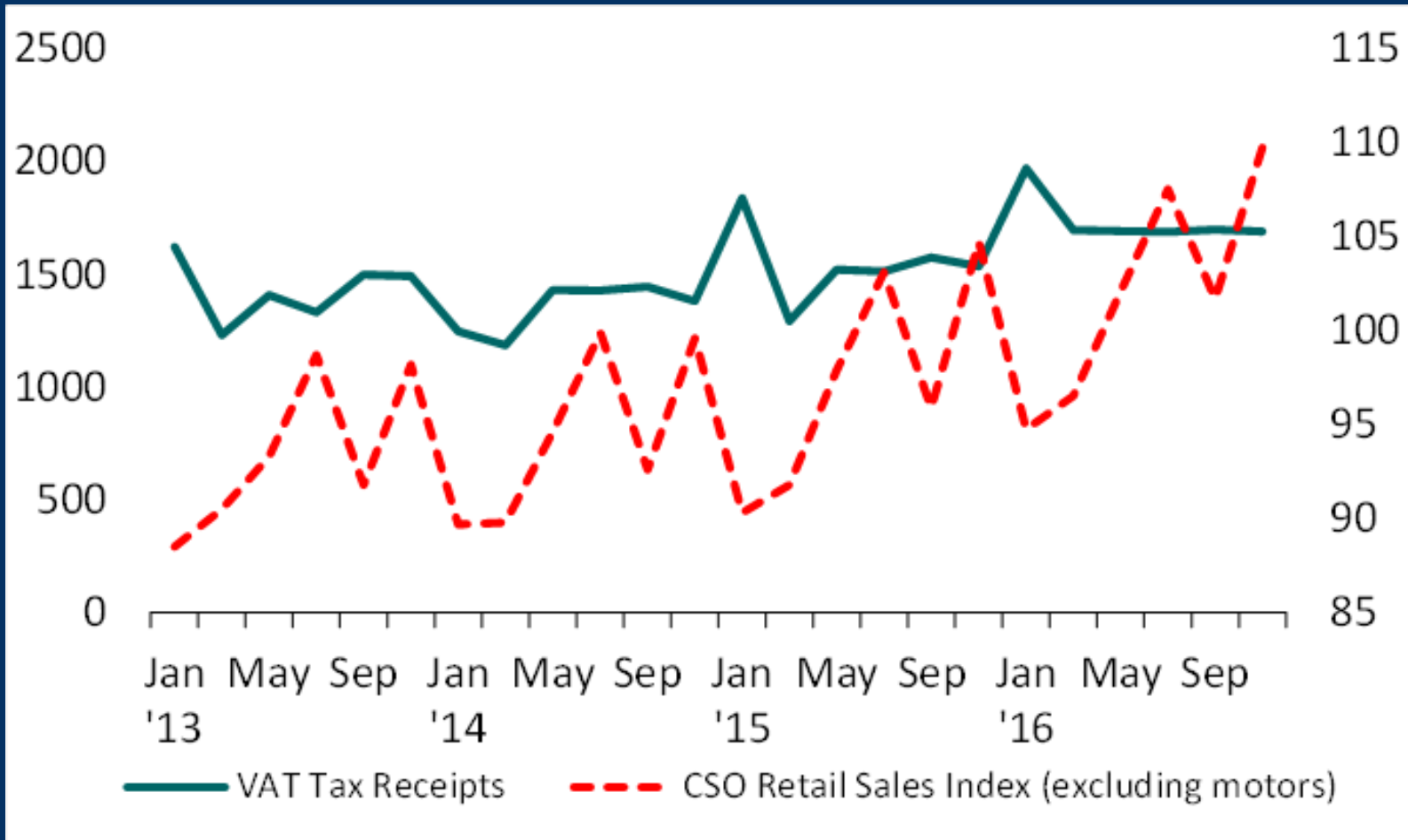
VAT



- Alternatively, under ARMAX, first forecast Retail Sales for the forecast period (ARIMA to Dec '16 shown here). Could have also considered imputing scenario forecasts here (e.g. low, medium and high retail sales growth).

5. ARMAX

VAT



- Having forecast Retail Sales, ARIMA now applied to VAT receipts using these forecast values. Forecasts now higher compared to ARIMA (10.4bn v 10.1bn), due to expected improvement in performance of retail sales

6. Model Evaluation

2015 Model Evaluation

	PAYE (€m)		Non-PAYE (€m)		VAT (€m)	
Quarter 4 2015	Forecast	Actual	Forecast	Actual	Forecast	Actual
October	873	893	222	131	207	204
November	883	912	1,068	1,064	1,545	1,535
December	928	971	69	457	184	71

- ❑ As new tax data becomes available each month, performance of forecasts can be evaluated (and new models can be updated)
- ❑ Table shows performance of Sep '15 forecasts for Oct, Nov and Dec '15
 1. PAYE ARIMA forecasts well, 2 – 5% of actual receipts for any given month
 2. Non-PAYE spikes in Nov each year; forecast is within 0.5% for this month but however challenging to forecast smaller receipt amounts outside of Nov
 3. VAT ARIMA forecasts well for on-months but poorly for off-months; on-month forecast for Nov is within half a percent, much larger errors for Oct and Dec

7. Long-Term Forecasts

PAYE, Non-PAYE and VAT Receipts to 2020

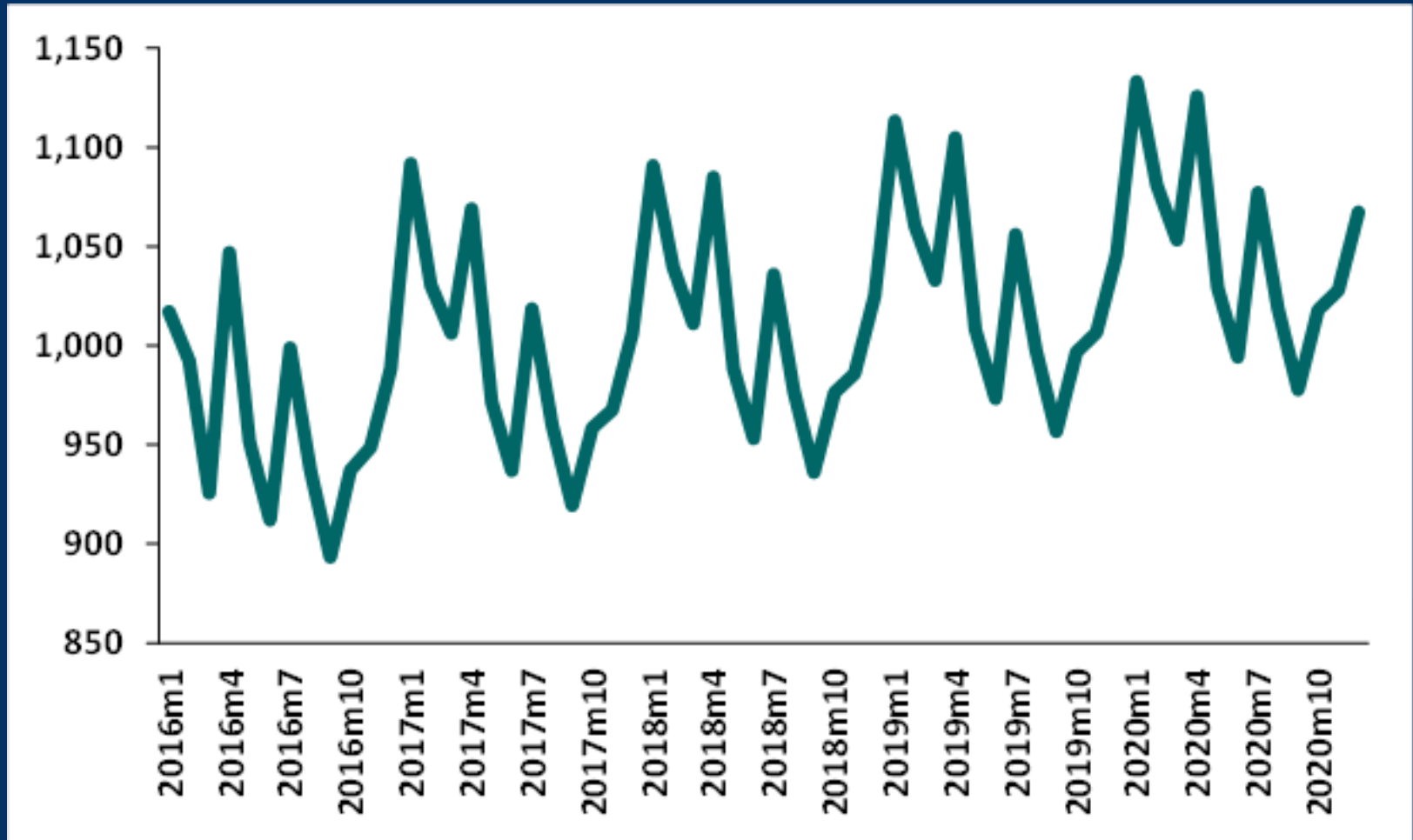
Month	PAYE (€m)	Non-PAYE (€m)	VAT (€m)
2015	10,952	3,109	10,244
2016	11,549	3,159	11,426
2017	11,936	3,153	12,124
2018	12,103	3,213	12,534
2019	12,351	3,273	12,946
2020	12,602	3,333	13,358

Notes: VAT SARIMA (2, 2, 1) (2, 2, 1, 2); PAYE SARIMA (1, 1, 0) (1, 1, 2, 12); Non-PAYE SARIMA (1, 0, 0) (0, 1, 0, 12)

- ❑ Dynamic ARIMA forecasts produce forecasts based on their own predicted values and can therefore continue indefinitely. However, forecasting over long periods of time is challenging and imperfect and the results should be interpreted with such limitations in mind
- ❑ Table shows annual aggregation of a set of ARIMA model forecasts to 2020. For example, VAT forecast to grow sharply in 2016 and steadily at 3% thereafter

7. Long-Term Forecasts

PAYE to 2020



Notes: PAYE SARIMA (1, 1, 0) (1, 1, 2, 12)

Presentation outline

Part I – Overview

1. Introduction | 2. Current Approach | 3. Time-Series Approach

Part II – Results

4. ARIMA | 5. ARMAX | 6. Model Evaluation | 7. Long-Term Forecasts to 2020

Part III – Conclusions

8. Conclusions

8. Conclusions

- ❑ Current tax receipt forecasting approach works very well but reliant on high degree of judgement, expertise and experience
- ❑ Time-series methods, highly data driven, are a sophisticated method of extrapolation, forecasting future values based on past values; but difficult to incorporate expertise and knowledge or include changes in economic factors
- ❑ ARMAX a step closer to incorporating economic factors, perhaps by imputing scenarios of expected projections
- ❑ Time-series approach may be complementary because it has strengths where traditional approaches have weaknesses, and vice versa
 - Based on 2015 evaluation, time-series improves on current forecasting for certain more predictable taxes (VAT on-months and PAYE) but not for less predictable ones (off-months VAT & Non-PAYE)

Thank You

skennedy@revenue.ie