Estimating changes in adoption dynamics between generations

Oliver Schaer
Nikolaos Kourentzes

INFORMS Annual Meeting 2020

University of Virginia | Darden School of Business

University of Skövde

Adoption of new technologies across generations

Predicting new products and technologies often relies on using analogies from previous generations (Goodwin et al. 2014).

Besides selecting the right analogy, insights into the evolution of the coefficients are required

- Often assumed that parameters remain the same (e.g. Bass & Bass 2004, Norton & Bass 1987)
- However, research suggests that technology adoption accelerates over time (Sood & van den Bulte 2016, Stremersch et al. 2010, van den Bulte 2000, Islam & Meade 1997)

Challenges estimating multi-generation adoption

Estimating large number of model parameters is notoriously difficult. A reason why some studies

- assumed parameters to be fix (Danaher et al. 2001)
- reverted to simpler models (Stremersch et al. 2010)

Very few data points to obtain reliable insights on measuring the acceleration in practice

- Larger panel estimation across multiple-generations might not be available to companies,
- Alternatively some insights about changes in adoption might be derived from reported values in the literature and databases (see van den Bulte 2002, 2000)

Obtaining estimates on small sample

We propose to use a bootstrapping approach to see whether new generation model parameters are significantly different, i.e. contain new information

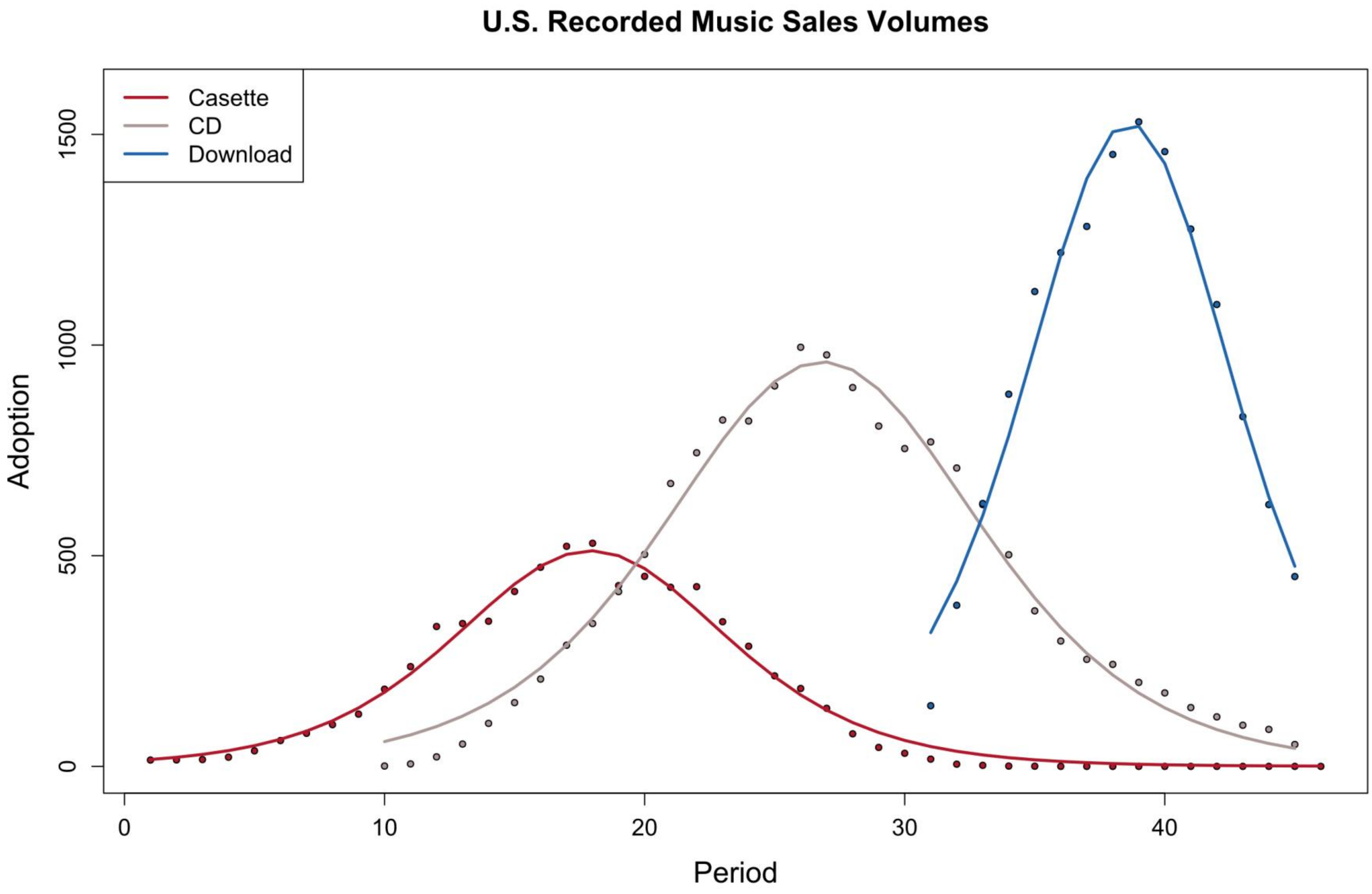
- ✓ More robust than single estimation
- ✓ Requires only 2 generations to measure parameter differences
- ✓ Allows to eliminate insignificant variables which helps the NLS optimizer (see Hong et al. 2016)

Suggested estimation flow

For each new generation

- We bootstrap n samples from an empirical distribution of the adoption curve errors of series j
- For each bootstrap we fit the growth curve with the parameters of the previous generation as initial
- We measure the change in model parameters between the previous generation (e.g. Bass model $p_j - p_{j-1}$,…)
- From all those samples we then test whether any of the parameter changes are significantly different from 0, i.e. no change in adoption (null)

A illustrative example



RIAA 2019, https://www.riaa.com/u-s-sales-database/

Coefficient estimates at each iteration

	Generation 1		Generation 2				Generation 3		
Coef.	Estimate	p-value	Estimate	p-value	Total	Elim.	Estimate	p-value	Total
Iteration 1									
m	7141	NA	8244	0.003	15385		1296	0.002	15632
p	0.002	NA	0.001	1.000	0.003	X	0.015	< 0.001	0.017
q	0.283	NA	-0.040	0.996	0.243		0.074	< 0.001	0.357
Iteration 2									
m			7281	< 0.001	14422				
p			0.000	.	0.002				
q			-0.003	0.310	0.280	X			
Iteration 3									
m			7196	< 0.001	14337				
p			0.000	.	0.002				
q			0.000	.	0.283				
Final model									
m	7141	NA	14337	< 0.001			15632	0.002	
p	0.002	NA	0.002	.			0.017	< 0.001	
q	0.283	NA	0.283	.			0.357	< 0.001	

No bootstrapping done on the first generation

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1st iteration p and q non-different → Eliminate p

2nd iteration q non-different → Eliminate q

3rd iteration Market potential remains significantly different

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All coefficients significantly different to generation 2

Forecasting exercise

Predict adoption per period for each new generation:

- at 15%, 30% and 50% of observed life-cycle.
- Total of 22 technologies and products (2^{nd} gen. +)

Benchmarks:

- First generation parameters (B.1)
- Last generation parameters (Random Walk, B.2)
- Estimate with available to date adoption (B.3)

Performance metrics:

- Average Relative Mean Absolute Error (AvgRelMAE, Davydenko & Fildes 2013) against B.3

Forecasting performance

AvgRelMAE forecasting performance for different life-cycle stages

	All parameters estimated			Market potential known		
	15%	30%	50%	15%	30%	50%
B.1 (first gen.)	1.016	1.309	1.944	1.218	1.512	1.885
B.2 (last gen.)	1.040	1.365	2.072	1.486	1.857	2.309
B.3 (to date)	1.000	1.000	**1.000**	**1.000**	1.000	1.000
Proposed method	**0.978**	**0.980**	1.091	1.061	**0.956**	**0.989**

Small changes in the market potential estimate can impact the forecasts substantially

- In practice the market potential is likely to be derived by some form of expert judgment

Forecasting performance

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Why the decrease in the early forecast scenario?

- Percentage of identical models with B.3 increases from 18% to 36% for the 50% adoption scenario
  → p and q parameter are sign. different more often

The story so far

Parameters between generations vary substantially

- Agreeing with the marketing literature

The suggested approach offers

- a robust way to measure changes in parameters between consecutive generations;
- improved estimation of parameters as insignificant ones can be removed;
- mitigates overfitting.

Preliminary forecasting results indicate improvements if the market potential is known, i.e. expert judgment

Next steps

Explore options to increase dataset

Analyse the change of parameters during the adoption. In particular with regards to shorter time series as discussed in van den Bulte (2004)

Further potential applications

- Pre-launch forecasting (Schaer et al. 2019)
- Adoption across countries (see Islam & Meade 2019, Sood & van den Bulte 2016)

R package 'diffusion'

Package for forecasting with growth curves

- Variety of growth curves (Bass, Gompertz, Weibull etc.)
- Model parameters can be fixed
- Allows sequential fitting
- Available on CRAN Soon!

os9vu@virginia.edu | @oliverschaer | github.com/mamut86