Inventorial econometrics[1]

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1. Introduction

- A familiar observation: Inventories such as (1) are common; ones such as (2) are not.

(1) The consonant inventory of Latvian (Vilks 2003)

p	t	c	k
b	d	ɟ	g
	ts	tʃ	
	dz	dʒ	
f	s	ʃ	h
	z	ʒ	
m	n	ɲ	
	l	ʎ	
	r	r̲	
w		j	

(2) An implausible 27-consonant inventory

ʘ	n͡ʇ							
		t^h			k^h			
			ɖ					
				$ɟ^h$				
	ɗ				ɠ			
p’							q’	
					kx			
bv								
ɸ	θ	ɬ	ʂ					
				ʒ	ɣ	ʁ	ʕ	
ɱ			ɳ			ɴ		
				ʎ	ʟ			
w					ɯ̟			

1. I am grateful to Elan Dresher, Keren Rice, Elizabeth Cowper, Peter Avery, and Sharon Inkelas for their helpful comments on the work presented here, and to Beth Hume for first calling my attention to the papers by Nick Clements that inspired this talk.

- The tendency toward (1) and away from (2) has been variously described as **symmetry** or **economy**.
- Clements 2003, 2004 argues that this tendency is properly viewed as economy (not symmetry), and provides a formula for calculating the feature economy of an inventory.
- Here, I will argue...
  - that the terminological distinction between *symmetry* and *economy* is not so great, **but**
  - that whatever we call it, we need to distinguish different ways of evaluating economy, as they produce notably different results, **and**
  - that feature economy cannot necessarily be evaluated by inspection of the inventory alone.

2. E for economy

What is feature economy?

(3) "the tendency to maximize feature combinations" Clements (2004: 9)

Clements (2003: 289) suggests that feature economy can be quantified by an economy index E, calculated by dividing the number of segments in the inventory (S) by the number of contrastive features (F), as in (4).

(4) Clements's feature economy index E
$E = \frac{S}{F}$ (Clements 2003: 289; Clements 2004: 10)

The E of an inventory increases if more segments are added without an increase in the number of features, or if fewer features are used with no decrease in the size of the inventory.

Counting phonemes is (reasonably) straightforward, but how do we count features?

Clements adopts a method based on successive division of the inventory (Cherry, Halle, and Jakobson 1953; Dresher, Piggott, and Rice 1994), with the order of divisions at least partially constrained by a universal hierarchy of contrasts.

(5) shows how Clements divides the French obstruent inventory:[2]

2. For Clements (2003: 300), the features [Labial], [Coronal], [Dorsal], [Radical], [Spread Glottis], and [Constricted Glottis] are monovalent, while [±sonorant], [±consonantal], [±distributed], [±posterior], [±strident], [±lateral], [±voice], [±nasal], and [±continuant] are binary; (5) reflects this mixture of feature valencies. As Clements (2004: 290) lists [Labial] and [Dorsal] but not [Coronal] as distinctive in French, I assume here that the coronal place of articulation is unmarked.

(5) The French obstruents (Clements 2003: 288, after Dell 1985)

		[Labial]			[Dorsal]
	[−voice]	p	t		k
[−cont]	[+voice]	b	d		g
[+cont]	[−voice]	f	s	ʃ	
	[+voice]	v	z	ʒ	
		[Labial]	[−posterior]	[+posterior]	

Under this analysis, the French obstruent inventory uses five features to distinguish 12 segments, giving it an economy index of $E = \frac{12}{5} = 2.4$.

3. Variations on a theme

In (5), the difference in place of articulation between /k g/ and /ʃ ʒ/ is contrastive, but the place difference between /p b/ and /f v/ is not.

(6) shows what would happen if the feature [±posterior] were given scope over [Dorsal] in the hierarchy:

(6) Divisions in the French obstruent system with [±posterior] ≫ [Dorsal]

		[Labial]	[−posterior]	[+posterior]
	[−voice]	p	t	k
[−cont]	[+voice]	b	d	g
[+cont]	[−voice]	f	s	ʃ
	[+voice]	v	z	ʒ
		[Labial]	[−posterior]	[+posterior]

Promoting [±posterior] makes [Dorsal] redundant, reducing the number of features to 4, and increasing E to 3.

Another alternative: Dresher (2003), citing earlier analyses by Trubetzkoy (1939) and Martinet (1964), suggests that place contrasts might be more important in French rather than less so, and shows that if the obstruents are organized as in (7), the feature [±continuant] ceases to be contrastive.

(7) The French obstruents (based on Dresher 2003: 54, after Martinet 1964)

p	f	t̪	s	ʃ	k
b	v	d̪	z	ʒ	g

If the French obstruent inventory is organized as in (7), then at least three place features are required (to distinguish six places of articulation), and at most five. So the feature economy of (7) may be $\frac{12}{4} = 3$, or $\frac{12}{5} = 2.4$, or $\frac{12}{6} = 2$.

Clements's feature accessibility hierarchy predicts that (5) is the correct set of divisions, but this is at least potentially an empirical question. If we want to know which features are actually contrastive in the French obstruent inventory, we should investigate the phonological behaviour of the segments, and see which sets of segments are treated as natural classes by the phonology of French.

4. Economy *vs.* symmetry

Clements (2003: 291):

> [The principle of symmetry] may sometimes have heuristic value in leading the analyst to useful hypotheses. When unconstrained by feature analysis, however, it reduces to the subjective exercise of lining up phonemes on the page. (For instance, the 'symmetry' of the French consonant system could be increased by putting postalveolar consonants and velar consonants in the same column [...], in spite of their different place features.)

The distinction Clements makes between economy and "the subjective exercise of lining up phonemes on the page" is reminiscent of the distinction drawn by Twaddell (1962) between true phonological symmetry and "merely ordinal parallelism."

Twaddell (1962: 136):

> [M]erely ordinal parallelism does not constitute symmetry in itself, nor does a merely ordinal parallelism of itself lead to discovering valid linked-unit components. For example, by setting up a mode-of-action unit "sealing of oral–nasal channel" (plus subsequent unsealing) one arrives at the possibility of an ordinal parallelism for certain English obstruents:
>
> | | | | |
> |---|---|---|---|
> | p | t | č | k |
> | f | θ | s | š |
>
> That is diagrammatic symmetry, but of a merely ordinal sort. For any specification of the linked-unit component which differentiates /č/ from both /t/ and /š/, and which is shared by both /č/ and /s/, will be uneconomical, to put it mildly.

Phonological symmetry is symmetry in an abstract phonological space whose dimensions are features; it has much more in common with economy than with diagrammatic symmetry.

Is there a real difference between true phonological symmetry and feature economy?

Clements(2003: 292):

system A				*system B*				*system C*			
p	t	c	k	p	t	c	k	p	t	c	k
b	d	ɟ	g	b	d	ɟ	g	b	d	ɟ	g
f	s	ʃ	x	f	s	ʃ	x	f	s		x
v	z	ʒ	ɣ					v		ʒ	

System A is symmetrical and fully economical ($E = 16/5 = 3.20$); the manner features [continuant] and [voiced] are used to maximum effect across all four places of articulation. System B is also symmetrical, but it is not fully economical, as [voiced] does not combine with [continuant] ($E = 12/5 = 2.40$). System C is more economical than B since it obtains more phonemes with the same features ($E = 13/5 = 2.60$), but it is not fully symmetrical due to the gaps. Thus full symmetry does not necessarily imply full economy (system B), nor does an increase in economy necessarily imply an increase in symmetry (system C vs. system B). The two concepts are quite different.

But...

- System B is **not** as symmetrical as System A, even diagrammatically. (A square is more symmetrical than a non-square rectangle.)
- Although System C is diagrammatically less symmetrical than System B, it does, in a more abstract way, more closely approximate the ideal represented by System A.

A suggestion: Economy and symmetry are not so different after all; rather, feature economy is the proper formalization of symmetry.

5. Exploitation *vs.* frugality

"Meanness inherits a set of silverware and keeps it in the bank. Economy uses it only on important occasions, for fear of loss. Thrift sets the table with it every night for pure pleasure, but counts the butter spreaders before they are put away."
—Phyllis McGinley, *Sixpence in Her Shoe*

What does it mean to say that System A is "fully economical"?

- An inventory with 16 segments could, in the best case, use just 4 features ($E = \frac{16}{4} = 4$).
- An inventory with 5 features could, in the best case, have 32 segments ($E = \frac{32}{5} = 6.4$).
- System A is "fully economical" for an inventory that has labial, apical, palatal, and dorsal places of articulation and that has contrasts in voicing and continuancy.

E has no upper bound, which is a problem if we want to test the hypothesis that inventories tend to be more, rather than less, economical.

Assuming that features make binary distinctions, the maximum possible value of E ($\frac{S}{F}$) occurs when $S = 2^F$, and thus increases rapidly and unboundedly as F and S increase. This is illustrated in figure 1:

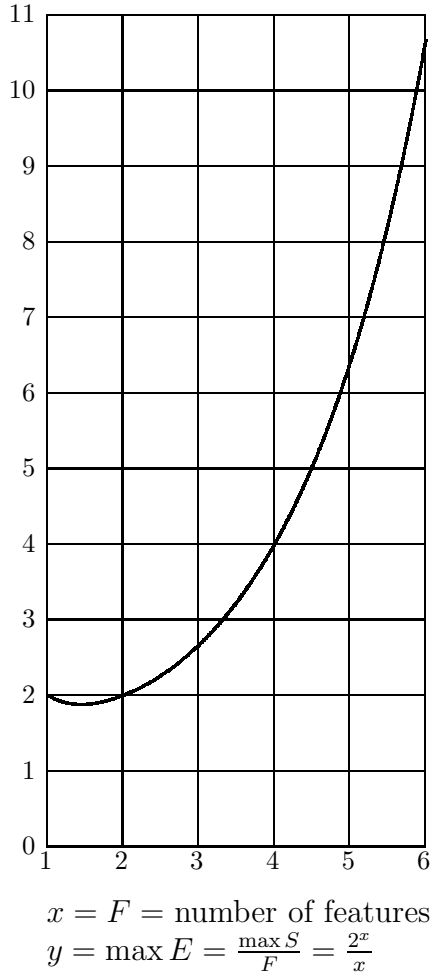

Figure 1: Maximum possible values of E for inventories using 1–6 features

Unwanted prediction: Feature economy should favour large inventories.

In order to obtain an index with an upper bound, we need to hold one of F or S constant, and compare the actual value of the other with the ideal value of the other. This gives us two possibilities:

(8) a. **Feature exploitation index:** $\frac{S}{2^F}$
To what extent does the inventory approach the ideal of getting as many segments as possible out of its features?

b. **Feature frugality index:** $\frac{\log_2 S}{F}$
To what extent does the inventory approach the ideal of using no more features than mathematically necessary to specify its segments?

- Each of the indices in (8) has a maximum value of 1, and thus establishes a delimited scale along which the relevant type of economy can be measured.

- Each of the indices in (8) preserves the property of E that it increases whenever S increases and F does not, and whenever F decreases and S does not.

However, the three indices produce radically different results for the consonant inventories used by Clements (2003) as illustrations:

(9)

	Features F	Consonants S	Clements's E $\frac{S}{F}$	Exploitation $\frac{S}{2^F}$	Frugality $\frac{\log_2 S}{F}$
Hawaiian	5	8	1.600	0.250	0.600
French	7	18	2.571	0.141	0.596
Nepali	10	27	2.700	0.026	0.475

- E seems to favour larger inventories (as might be expected from fig. 1).

- Exploitation and frugality both decrease with inventory size in these examples.

- Frugality does seem to be a reasonably robust property of inventories.

- Exploitation does not.

- We really can't tell about E.

6. Conclusions: A view of economy

- The interesting kind of phonological symmetry, which is evaluated in abstract feature-space, is essentially economy.

- In order to evaluate economy, we need to examine the phonological—rather than the phonetic—shapes of inventories.

- Abstract analyses are nonetheless constrained in some directions by phonetic reality—the place difference between /k/ and /ʃ/ in French may or may not be contrastive, but if the French inventory also included /x/ and/or /ʧ/, we would not have the same indeterminacy.

- Establishing an upper bound creates a more useful quantification of economy.

- Frugality is the particular kind of feature economy that natural languages exhibit.

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