

# An agent based model of the evolution of market structure and competition

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# Verification and Validation of ABMs

- Ormerod., P and B Rosewell (2009), 'Validation and Verification of Agent-Based Models in the Social Sciences', in F.Squazzoni, ed., *Epistemological Aspects of Computer Simulation in the Social Sciences - Lecture Notes in Computer Science*, Springer Berlin / Heidelberg, 5466, 130-140, doi: 10.1007/978-3-642-01109-2 \_10
- **Verification:** does the model do what the authors claim it does?
- In principle, it should now be straightforward for the code to be made available
- **Validation:** The process of assessing the degree to which a computer model is an accurate representation of the real world from the perspective of the model's intended applications
- A key aspect is a clear description of what the model is intended to explain (and this should not follow obviously from the rules of the model)
- The behavioural rules should be justified with evidence external to the model
- Validation is not the same as analytical proof. We are therefore seeking for models which are not falsified and which ideally explain more than their predecessors

# Motivation of model

- We have examples of markets dominated by a monopolist being opened to competition
- The privatisations of public utilities in the late 20<sup>th</sup> century – legislation
- IBM dominated mainframe computers, PCs appeared in 1980s – technology
- From the opposite perspective, we see the emergence of near-monopolies in the 2010s e.g. Google
- In the first case, the original monopolist has usually retained a large market share
- But the offer to the consumer has improved in terms of price and quality
- Most new entrants into these markets have failed
- These are the qualitative points we want the model to explain
- It may also then help understand how monopolies emerge
- The model could readily be extended to oligopoly e.g. banks

# ABMs and economic theory

- Economic theory essentially compares equilibria
- It has very little to say about the *process* of moving from the initial equilibrium to the new one
- In this context, this is the decisive advantage of ABMs
- We try to retain many of the assumptions of conventional economics
- Essentially, our model is populated by rational agents acting with imperfect information

# The model (1)

- The model starts with a monopolist offering a price of 1 and a quality of 1
- The lowest possible price consistent with available technology and a normal profit is 0. For convenience, a lower value of the quality variable in the model corresponds to *better* actual quality, so the best quality also has value 0
- Initially, the market price/quality is (1,1). A new equilibrium is established at  $(p^*, q^*)$
- The model evolves in a series of steps
- In each step, firms may enter
- In each step, consumers may switch suppliers
- In each step, firms may adjust their  $(p,q)$  offer to try to deal with competitors

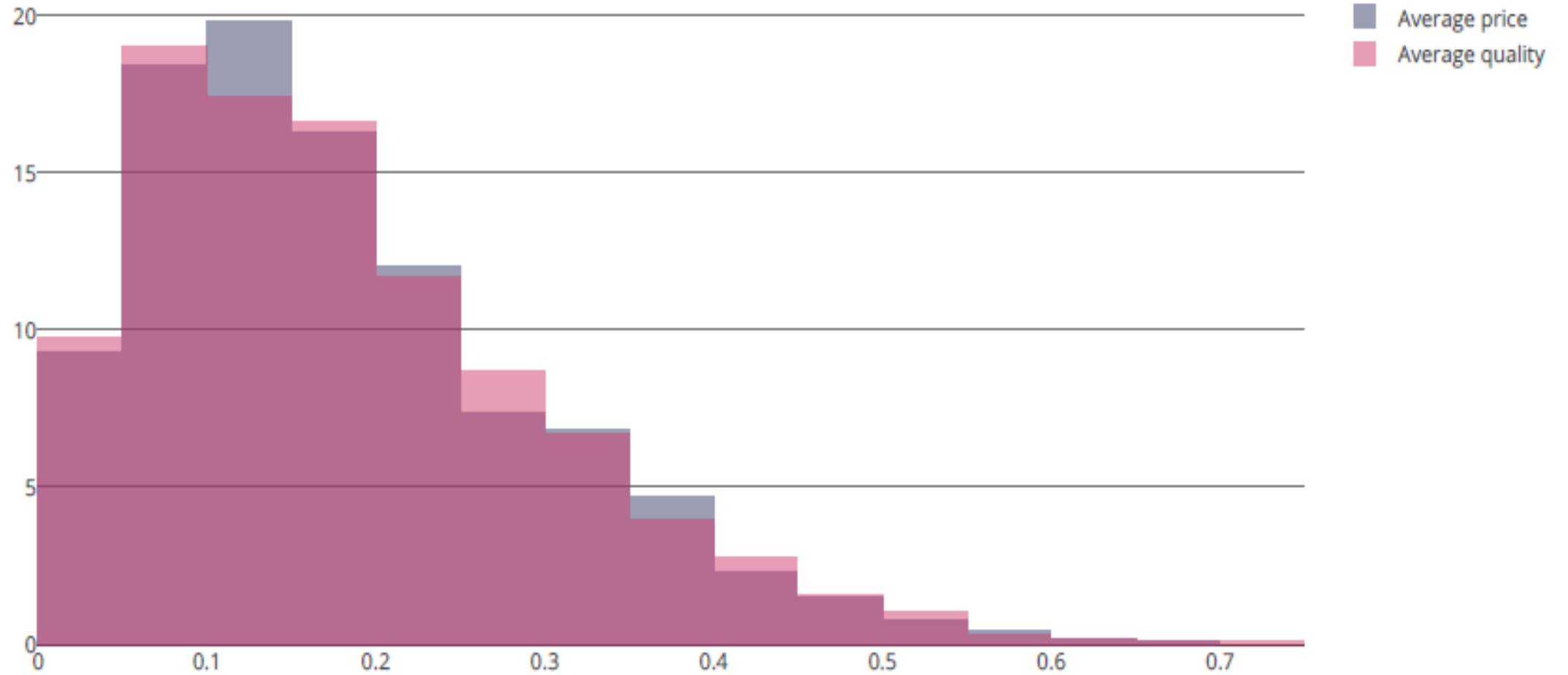
## The model (2)

- We specify the maximum number of firms,  $k-1$ , which can enter the market
- In step 1, one firm is chosen at random to enter the market
- A new market level of both  $p$  and  $q$  will be established
- In step 2 and all subsequent steps, each of the remaining firms decides whether to enter with probability equal to the average of the market  $(p,q)$
- So the lower is price and the higher is quality, the less likely it is that a potential entrant will actually enter
- Each firm on entering gets access to a proportion of the total number of consumers
- This is drawn at random from a uniform distribution on  $(0,1)$
- In other words, only a proportion of consumers will be aware of the offer of any given firm
- By definition, all consumers are aware of the monopolist

## The model (3)

- Each consumer is allocated at random a weight,  $w_i$ , which expresses his/her preference between price and quality
- In each step of the model, each consumer identifies the firm on his/her network with the best  $(p,q)$  offer, given his/her preferences between price and quality
- I.e. the consumer can only make choices amongst firms of which he/she is aware
- The consumer switches to the best offer
- But does so with a fixed probability,  $s_i$
- Firms are aware of the  $(p,q)$  offers of all other firms
- Each firm wants to move to the offer of the firm for which  $\omega * p_i + (1 - \omega) * q_i$  is minimised, where  $\omega$  is the average of the  $w_i$  across all consumers
- But it is only able to do so with fixed probability  $\phi_k$ , where this is drawn at random from a uniform distribution on  $[0,1]$

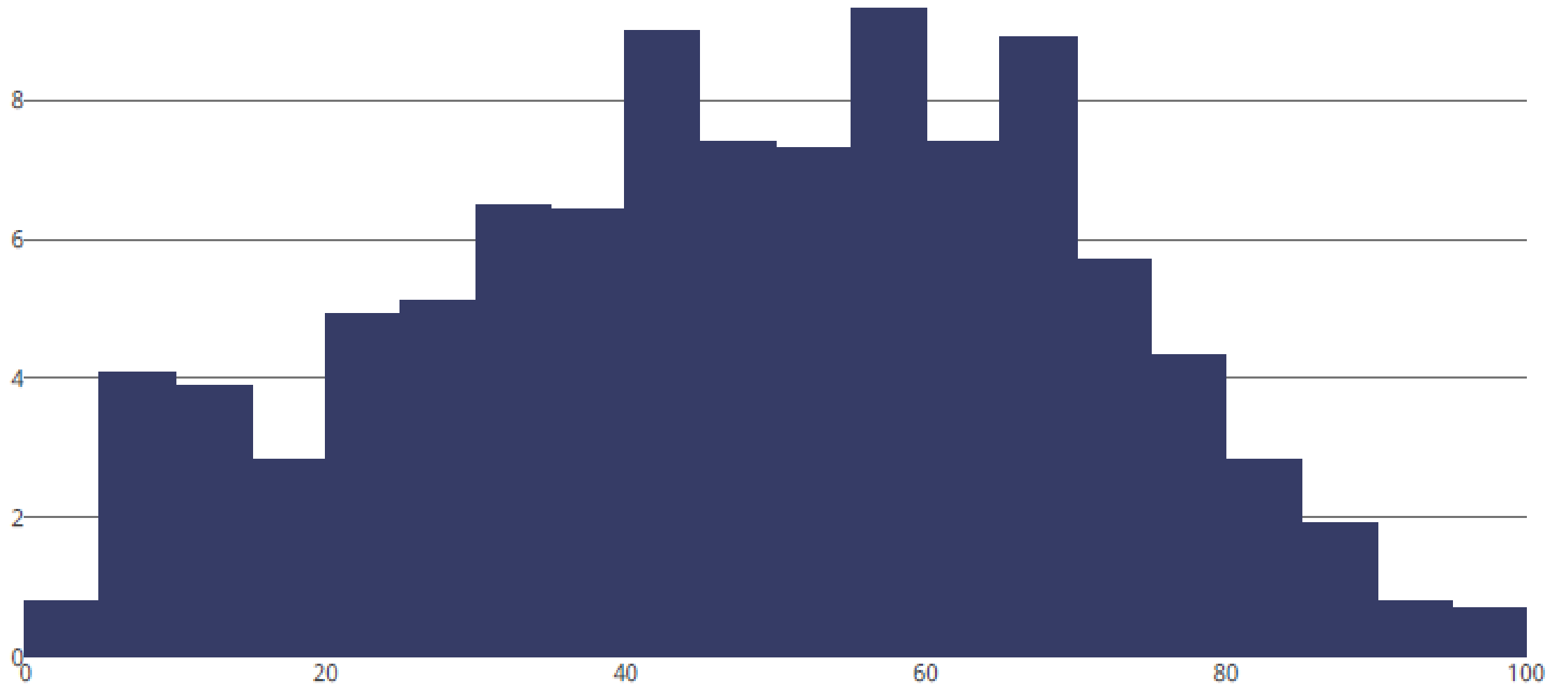
Average price and quality after 40 periods



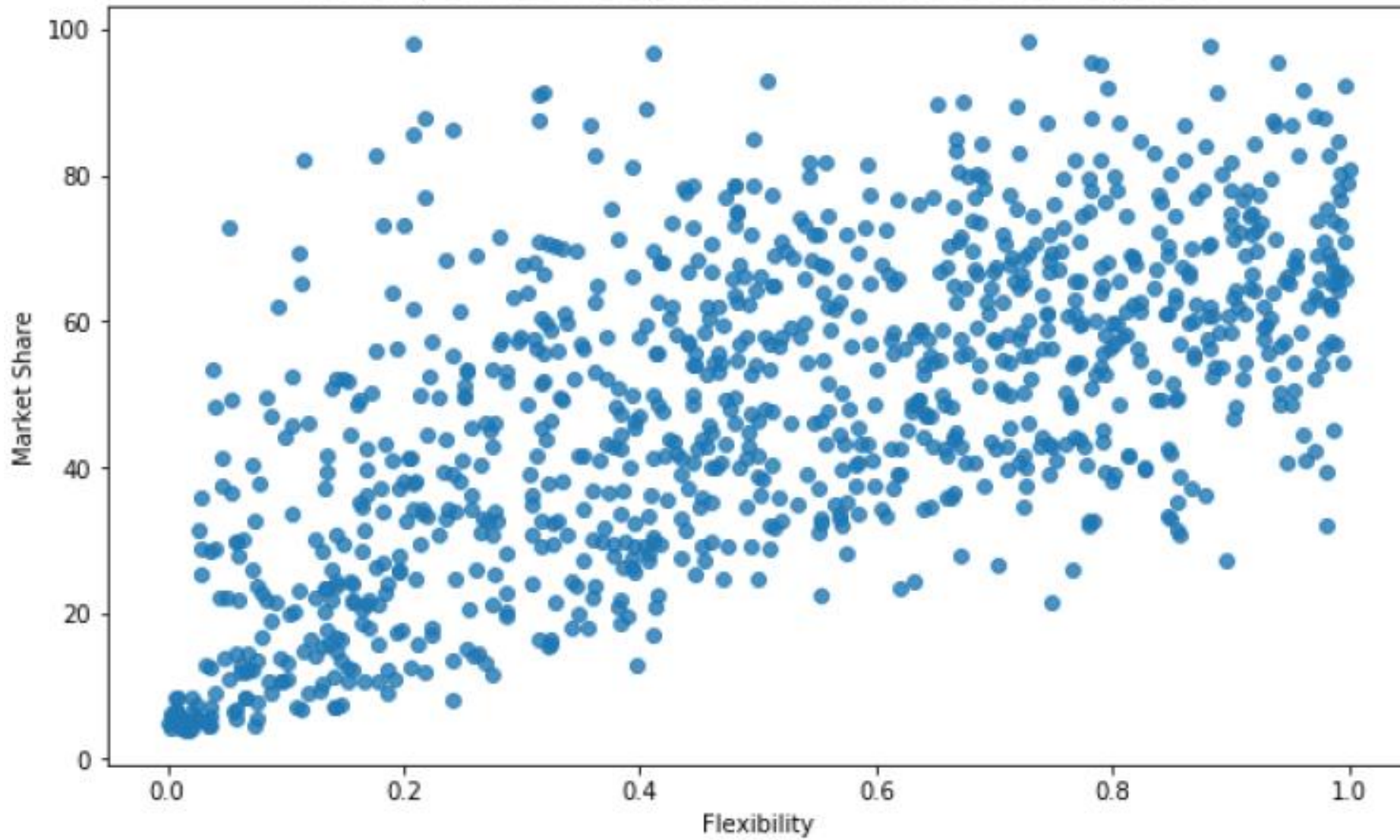


	<b>P Outcomes</b>	<b>Q Outcomes</b>
<b>count</b>	1000.000000	1000.000000
<b>mean</b>	0.181437	0.184174
<b>std</b>	0.117202	0.120725
<b>min</b>	0.000298	0.000369
<b>25%</b>	0.092694	0.091381
<b>50%</b>	0.158084	0.159854
<b>75%</b>	0.244056	0.251958
<b>max</b>	0.686856	0.741502

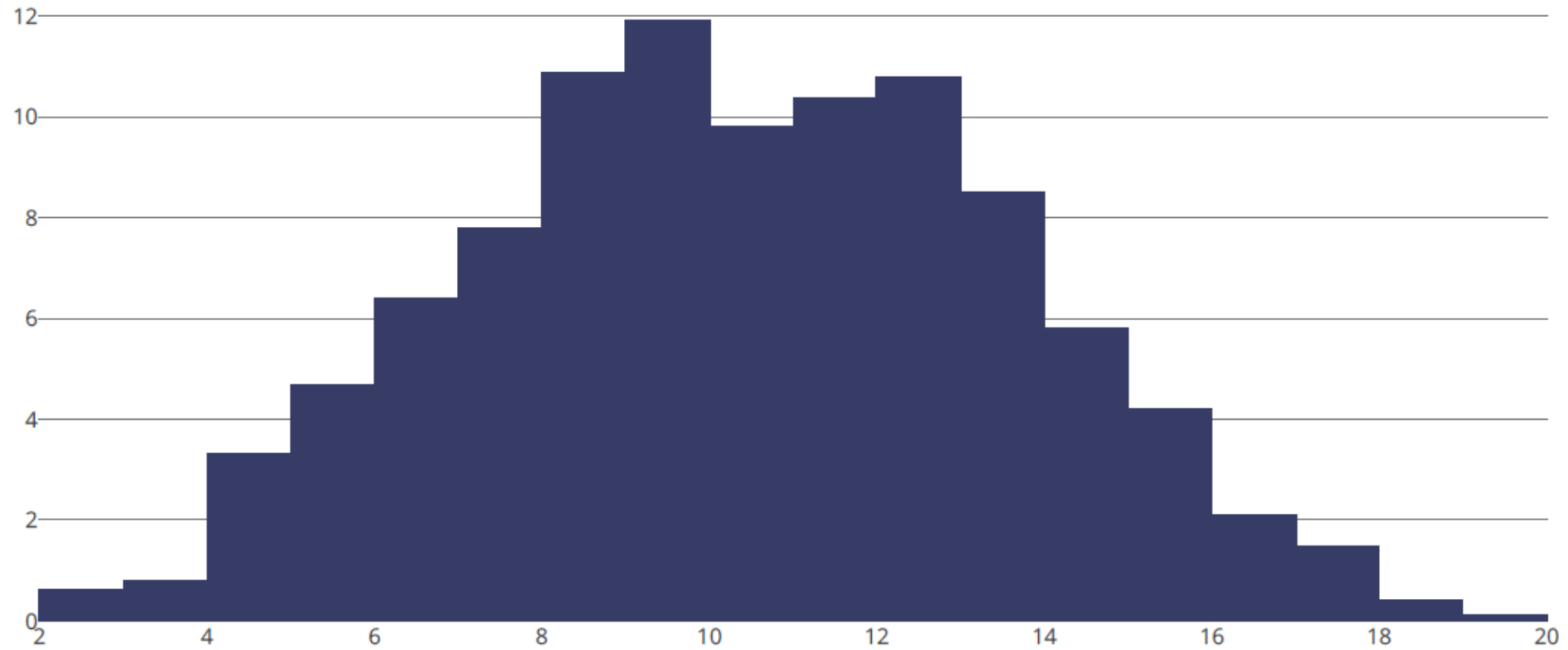
Market share of initial monopolist histogram



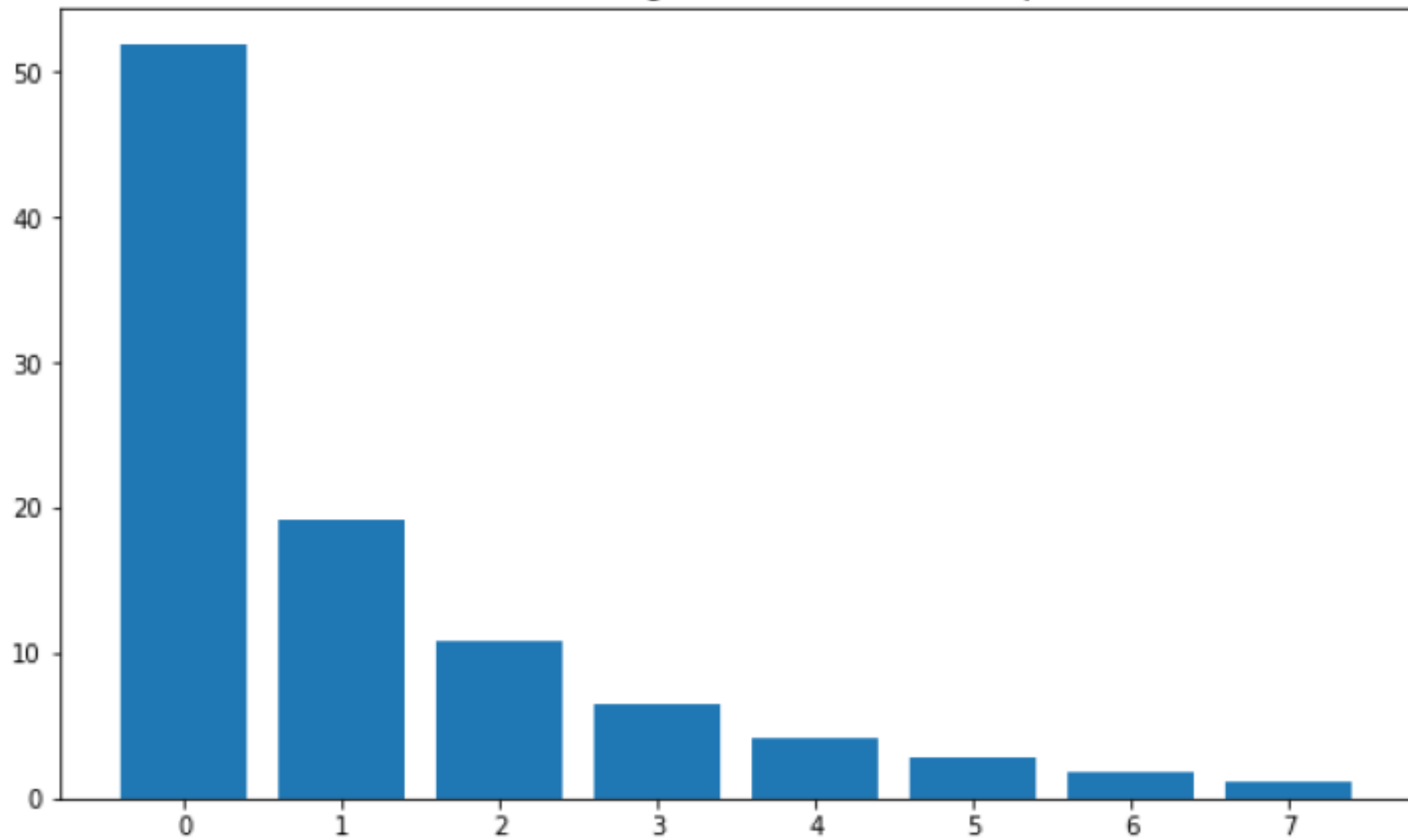
Flexibility of initial monopolist and market share after 40 periods



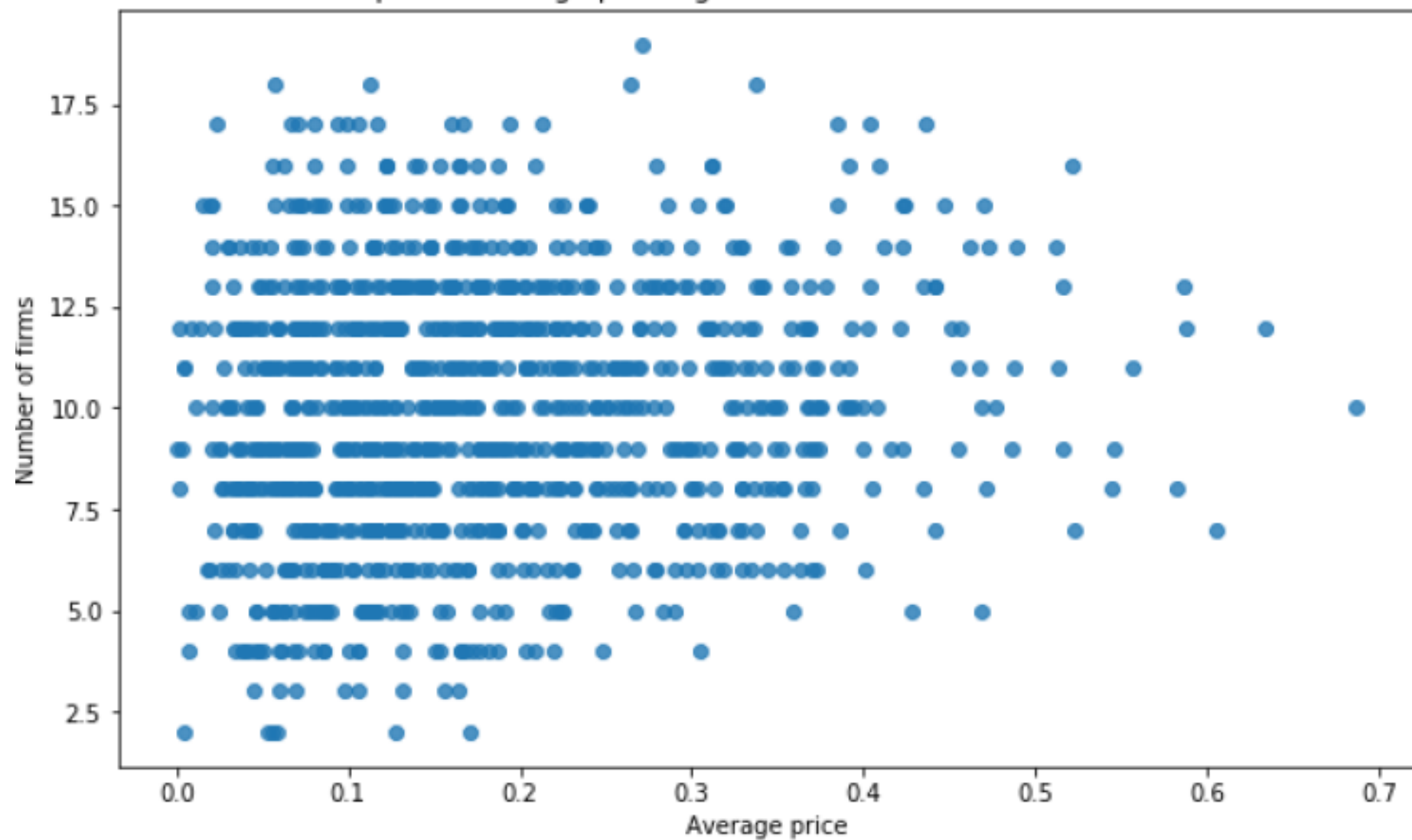
Histogram of number of selling firms in the end



Distribution of average market share after 40 periods

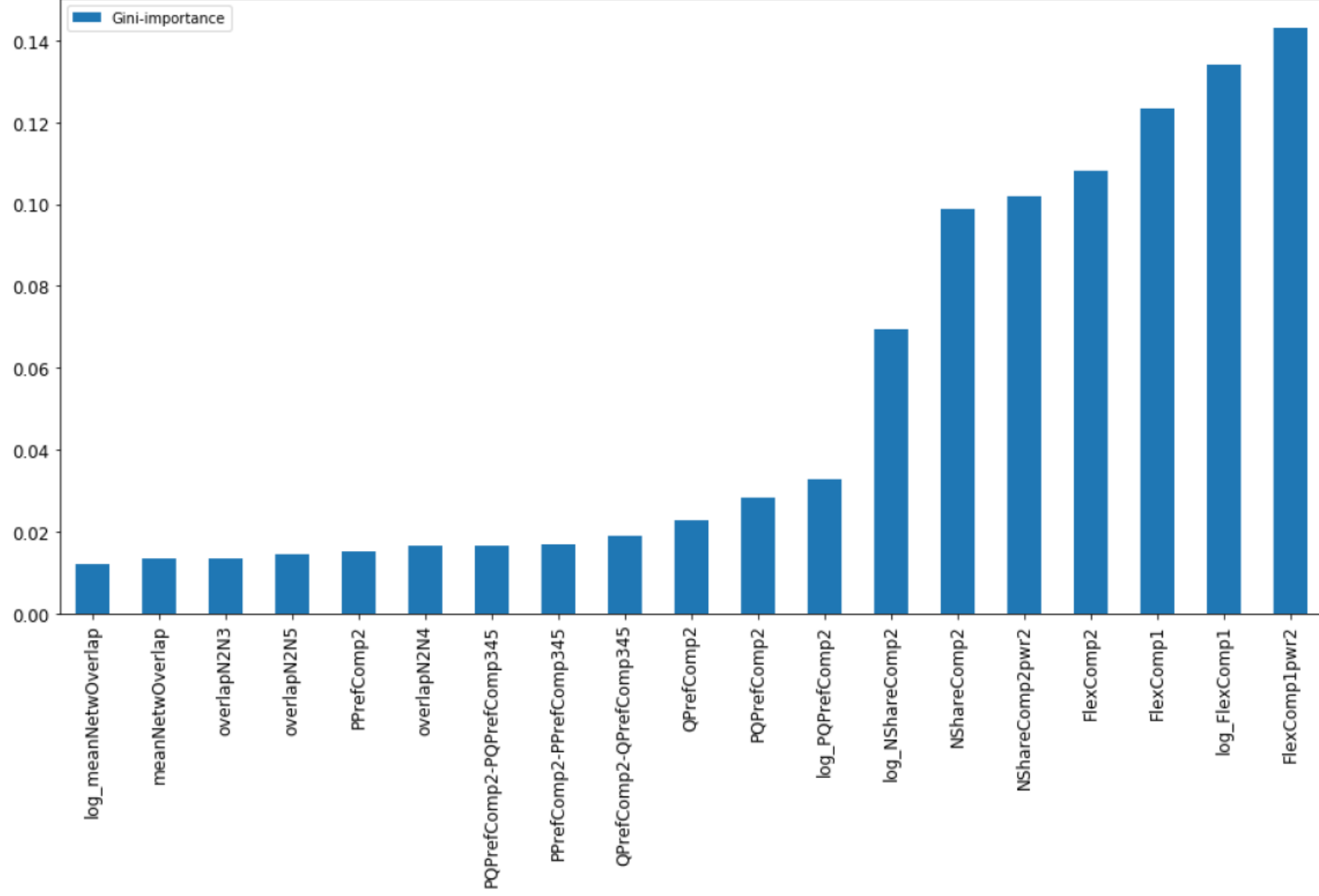


Scatter plot of average price against the number of firms in the market



# Determinants of market share of first entrant

- Initially, a linear regression of the market share (10,000 simulations) against flexibility of monopolist, first entrant itself, second and third entrants, market reach,  $(p,q)$  on entry,  $(p,q)$  initially offered etc
- Local linear regression indicates the presence of substantial non-linearity
- Introduce logs of variables and squared values. This improves the fit substantially
- Further refinement by applying a range of ML algorithms





# Discussion

- The results are obtained in a framework in which agents are recognisably operating within the framework of economic rationality
- Imperfect information of consumers (“reach”) and the fact the firms often face constraints on being able to respond to competitors in due time are key features
- Judged on the conventional criterion of the distribution of market shares, at any point in time the market structure is, in general, anti-competitive. But, as the outcome on market price and quality shows, the model is competitive in any meaningful sense of the word.
- The potential range of outcomes for the model is wide, reflecting the importance of contingency in the *process* of the evolution of market structure