The Need for Product Space Complexity for Agent-based Computational Economics

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Agent-based Computational Economics (ACE) offers a bottom up approach to the modeling of economies. By modeling economic entities as agents and defining their micro-economic interactions, assumptions of equilibrium can be disregarded and the emergence of macro-economic phenomena can be observed. ACE models are useful for testing the outcomes of policy experiments that cannot be performed in the real world due to the uncertainty of outcomes and the possible negative impact on society, if not predicted beforehand.

Empirical studies performed by Hausmann et al. [1] have shown that the product space of an economic system plays an important role in macro-economic performance. The product space is defined as a knowledge map of the similarity of available product types traded within an economy. The product space complexity, or the coverage of the product space within a given economy has been shown to be correlated to its macro-economic performance [1, 2].

In this work we shed light on the importance of enabling diversity in the product space for ACE models that are to be used for policy experimentation. Classical ACE models use representative modeling of households and banks, and tend to have a restrictive product space (for example, labor and a generic consumer good). We argue that ACE models should allow for diversified product types if they are to be successful in simulating policy experiments such as entrepreneurial support policies. To this end, we use a model of innovation ecosystems introduced in our previous work, EconoSim [3, 4], in order to simulate two economies with restrictive and diverse product spaces, respectively. Additionally, we perform two types of entrepreneurial support on a classical representative ACE model from the literature, JAMEL.

EconoSim, an agent-based model of innovation ecosystems, represents economic entities as adaptive resources transformers (ARTs). ARTs purchase or harvest resources (input products) and transform them into an output product type. This output product is then bought by ARTs which require the transformed product type as resources (input product). ARTs exist in a spatial environment and must search and discover viable trade partners before they run out of resources and

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are removed as bankrupt. The input to output product conversion is governed by a transformation rule and the total number of possible transformation rules is determined by the maximum product space allowed by the model. Once an ART gains sufficient energy through trading, it may reproduce creating a new ART with a mutated transformation rule. Survival of new transformation rules within the ecosystem represents innovations.

In previous studies we have utilized the concept of transformation networks to represent a network of the existing resource/product transformation rules within the simulated ecosystem [4], comparable to the product space of an economy. The weights of the edges (transformation rules) between networks represents the abdundance of a particular transformation rule within the ecosystem. A highly innovative ecosystem will achieve a larger number of edges within the transformation network, in comparison to a less innovative ecosystem. However, if a restrictive product space is used in the model, the node count of the transformation network will be smaller resulting in a reduced maximum number of possible transformations. In other words, there is little room for innovation.

Two cases of EconoSim were used, one with a binary product space (two products) and the other with a less restrictive product space (32 products). The binary product space only allowed for two transformation rules, while the less restrictive product space allowed for 992 possible transformation rules. Entrepreneurial support experiments were performed on both cases similar to that described in [3]. During the incubation period, a similar portion of the youngest firms were selected for support, in both cases, and provided with energy (money and resources) externally.

In the binary product space, prior to the incubation period, both transformation rules existed at equally high popularity, such that together the total number of agents was near the maximum population count supported by the environment. Upon entrepreneurial support, the simulation reacted by simply increasing the number of agents for both rules and no change in the transformation network configuration was possible. Subsequently, this reflected almost no change in the macro-economic measure of the economy (GDP in this case). In contrast, the unrestricted product space, upon entrepreneurial support, saw a burst in the abundance of several types of transformation rules and an immediate increase in the complexity of the transformation network. This reflected a significantly large improvement in the macro-economic measure (GDP) which was sustained for a period significantly longer than the incubation period itself.

Finally, we performed similar entrepreneurial support experiments on JAMEL [5, 6] which employed the classical representative ACE approach. The version of JAMEL used essentially contained a product space limited to labor and a generic consumer good. Entrepreneurial support was performed through two approaches, internally by re-routing resources from high-performing agents into low-performing ones, and externally by providing money and resources externally. No change in the macro-economic measures was seen when entrepreneurial support was performed internally. When external support was provided, the macro-economic measure (e.g. gross profit) showed a sharp increase during the incubation period and decreased at the same rate to the original state, as soon as the incubation period was over. In other words, the agents were unable to utilize the provided support to achieve

a better configuration for sustained improvement of the macroeconomy.

In conclusion, this study provides evidence supporting the requirement of larger product spaces to provide room for innovation, if ACE models are to be used for policy experiments such as entrepreneurial support.

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