The Economics Of Supply And Demand: An Important Challenge For Conceptual Graphs

Simon Polovina

Department of Computer Studies
University of Technology
Loughborough, UK LE11 3TU
S.M.Polovina@lut.ac.uk

Harry S. Delugach

Computer Science Department
University Of Alabama in Huntsville
Huntsville, AL 35899
delugach@cs.uah.edu

Abstract. Conceptual graphs have been used to model information in many complex domains, but the domain of economics is particularly difficult because its knowledge is based as much on perceptions of people as on physical laws. This paper addresses that problem using as a vehicle one well-known basic economic area: namely, the law of supply and demand. Employing Peirce logic negative contexts, we represent various parts of classical economic theory, e.g., over-supply, over-demand, and equilibrium states. It is shown how tacit knowledge is relevant to the modeling of this information, and why this knowledge requires the conceptual graphs to be built and reviewed by the domain experts directly. Conceptual graph actors are employed to represent relationships between quantities and to represent market forces. Negative contexts are briefly evaluated as a modeling tool. Representing changes in domain assumptions is discussed.

1 Introduction

Conceptual graphs are being used to model information in many complex domains, such as interpreting radiological evaluations, context-searching in documents, playing chess, etc. One of us (Polovina) is using conceptual graphs to model accounting and economic knowledge [1]. Economics is known to be far more extensively based upon the highly elusive dispositions of people rather than definitive physical laws [2,3]. Rhodes illustrates how economics' precarious scientific basis has caused the economist to be the subject of much ridicule [4]. Nonetheless Rhodes also shows that the economist's knowledge remains consequential, because economics is a reality that affects us all [4]. The teaching style of Pool and La Roe's amusing text on understanding economics underscores this actuality, by drawing considerably on the formative, yet imprecise human instincts that their novice readers would already possess [5]. Hence the indomitable conceptual bases that characterize economics provide an excellent proving ground for conceptual graphs [6].

This paper focuses on one economic concept, namely that knowledge comprising what is popularly known as "the law of supply and demand." This aspect of fundamental microeconomic knowledge is a key element in modeling essentially any overall economic theory. As indicated above, it is also a good example of an economics that is well-known by the general public. It therefore represents not only a class of domain-specific knowledge, but also a corpus of "commonsense" general knowledge that should well suit conceptual graphs [6].

With the above in mind, we (a) explore the nature of supply and demand, (b) provide some conceptual graphs models of this area, and (c) identify, from (a) and (b), the kinds of initial but noteworthy challenges for the conceptual graphs technique itself. We are also paying particular attention to the human-understandability of the graphs in capturing economics' conceptual bases, as illustrated below.

The paper is organized as follows. Section 2 discusses the law of supply and demand, with conceptual graphs representations along the way. Section 3 discusses some issues we have identified during the course of this investigation, such as the use of negative contexts and changing domain assumptions. Section 4 concludes the paper.

2 The Law Of Supply And Demand

2.1 Background

Put simply, the law of supply and demand holds that the *price* of some *resource* depends upon relationships between the *supply* of the resource and the *demand* for the resource. A resource might be some person's time, an unmarried person available for dating, or anything valued by another person. In a supply and demand context, that resource becomes an *economic resource*. Ijiri clarifies economic resources as objects that (a) are scare and have utility, and (b) are under the control of an enterprise [7,pp.51-52].

A recent compilation of American cultural information describes supply as "the amount of any given commodity available for sale at a given time," and *demand* as "the amount of any given commodity that people are ready and able to buy at a given time at a given price." The law of *supply and demand* is described as follows:

> "In classical economic theory, the relation between these two factors determines the price of a commodity. This relationship is thought to be the driving force in a free market. As demand for an item increases, prices rise. When manufacturers respond to the price increase by producing a larger supply of that item, this increases competition and drives the price down. Modern economic theory proposes that many other factors affect price, including government regulations, monopolies, and modern techniques of marketing and advertising." [8, p.434]

This description is our starting point — firstly because it concisely characterizes the important parts of supply and demand, and secondly, because it purports to be a view of popular culture based on "common sense."

2.2 Initial Conceptual Graphs Model

We will attempt in stages to describe supply and demand using conceptual graphs. The graph in Figure 1(a) shows, employing Peirce logic negative contexts, that if there is an economic resource then it has both a supply and a demand. Figure 1(b) shows that if there is an economic resource whose demand quantity x is less than its supply quantity y, then that economic resource is in a state of over-supply. Similarly, in Figure 1(c), if there is an economic resource whose demand quantity x is more than its supply quantity, then it is in a state of over-demand.

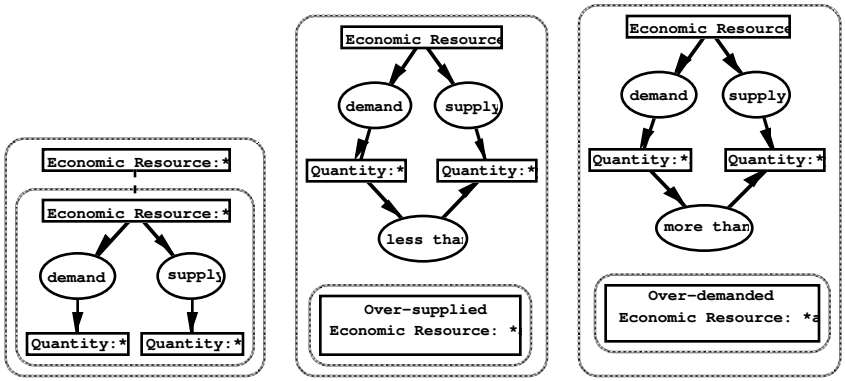

Figure 1. Representing Over-Demand And Over-Supply

2.3 The Appropriateness of Conceptual Graphs

A psychological study by Novak and Gowin demonstrated how the structured diagrammatic nature of their simple "concept maps" elicited key concepts and relationships even to young children [9]. Sowa explains however that concept maps, unlike the equally diagrammatic conceptual graphs, cannot express all of logic and natural language for serious analysis [10]. The tough problem domain of economics would certainly require such levels of analysis, but the particular significance of the above psychological basis is that our representations extend beyond strictly logical issues. This is because the model must also enable the economist, accountant or strategic planner to build and review their own knowledge bases in view of the high level of continually shifting tacit knowledge that economics embodies. Hence the above argued readability of conceptual graphs is as important as the graphs' technical power.

The above should become more evident as this discussion progresses but, to give an initial illustration, we debated the choice whether to employ "quantity" or "units" in our graphs. We discovered that a case could be made for either, merely according to individual inclination. As a result we decided that a deep semantic analysis of "quantity" or "units" outright mattered substantially less than what those terms symbolize psychologically to each user through his or her own conceptual graphs models. Of course as corporate knowledge bases evolve there could be some standardization effort amongst the users to gain the benefits of wider scale knowledge. This would, as a consequence, involve standardizing terms as well as graphs. Nevertheless, all would still be as agreed by a consensus of the users, not as dictated by some well meaning knowledge engineer.

2.4 Further Aspects

Figure 1 shows other examples of how conventional terms are used. For example, the terms *under-demand* and *over-supply* would have essentially the same meanings. Which one should be chosen? We believe that no *a priori* decision is possible. An empirical study might show a preference among Western economists for one over the other. Even if such a preference was found, the claim could not be made that one is

somehow "better" or "more natural" than the other; future empirical studies, or studies of economists in other cultures might show a different preference.

The spatial arrangement of these graphs is also significant. The "(supply)" relation and the "(demand)" relation are both in the same spatial location in both Figure 1(b) and Figure 1(c). The authors wonder if there is any escaping a significant degree of similarity between the two. For instance, the term "less than" could have been used instead of "more than" in the right hand graph but there would still remain that visual similarity. Are the conceptual structures thereby telling us something here?

2.5 Capturing Natural Meaning

The (less than) and (more than) relations are of course not merely arbitrary ones. In fact, they are related through our tacit common-sense knowledge. Figure 2(a) captures the natural meaning of "If measure *x* is less than measure *y* then *y* is more than *x.*" Likewise, Figure 2(b) captures "If *y* is more than *x* then *x* is less than *y.*"

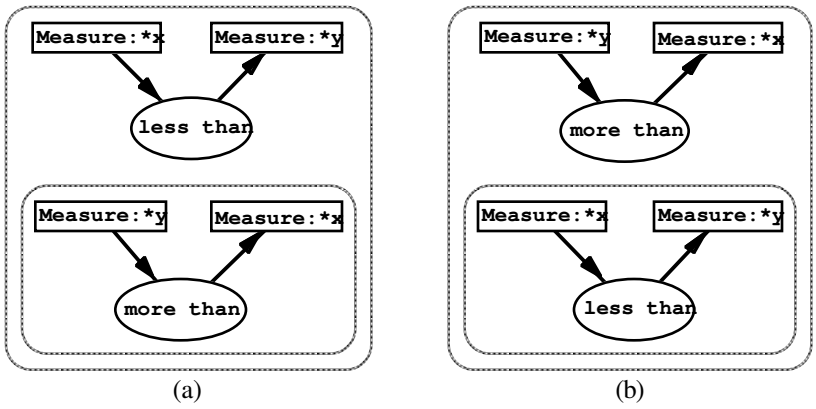

Figure 2. Representing Relationships Between Relationships

Figure 3 shows relationships between the notions of over-demand and under-supply, so that the economist may use any terms that are convenient. Figure 3(a) represents "If over-demanded economic resource *a* then not over-supplied economic resource *a* and vice versa". Figure 3(b) represents "If under-demanded economic resource *a,* then not under-supplied economic resource *a* and vice versa." Figure 3(c) represents "If over-demanded economic resource *a,* then under-supplied economic resource *a.*" Figure 3(d) represents "If under-demanded economic resource *a* then over-supplied economic resource *a.*"

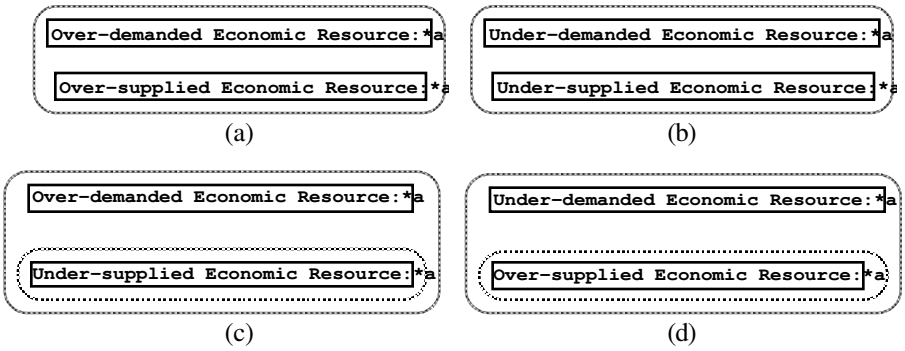

Figure 3. Relationships Between Supply and Demand

The above would chain together backwards, forwards, or appropriate combinations thereof. The above simple examples vividly show that Peirce logic makes all these relationships much more evident to the domain expert than if-then rules. It may also suggest alternative viewpoints to the economist, once he or she is shown some alternate representations that are relevant.

2.6 Incorporating Actors

To continue, economists are interested in more than just whether or not there is a state of over-supply or over-demand, but also the actual measure of difference and the consequences of being in either of those states. Figure 4 uses actors to explicitly show the functional relationship between the demand and supply quantities.

Figure 4(a) characterizes the situation of an over-supplied resource. The demand quantity x is less than the supply quantity y, as denoted by the relation (less than). The actual amount of over-supply is obtained by the functional relation <subtract> between x and y which determines z to be the over-supply quantity of resource a. Similarly, Figure 4(b) characterizes the situation of an over-demanded resource. Figure 4(c) characterizes the equilibrium situation. Since in this situation, there is no difference between the demand and supply quantities, they can be represented by the same quantity x, which is also the equilibrium quantity.

Figure 4 illustrates one powerful feature of conceptual graphs. The same graph can represent qualitative relationships (e.g., *less-than*) as well as quantitative relationships (e.g., the difference between two quantities). For some purposes the qualitative relationship will suffice; for other purposes, the measure of over-supply (or over-demand) may be desired.

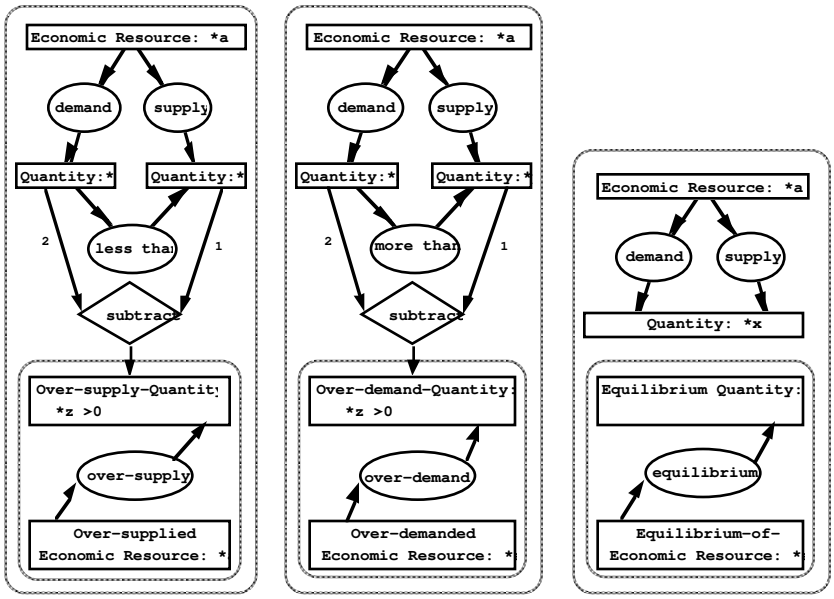

Figure 4. Representing Quantities Of Demand And Supply

Figure 5 reveals that if an economic resource is in over supply then its price decreases or less units of it are produced. Note that the term "price" is used instead of "money." This is because price may be derived from a non-monetary exchange, and that money itself is anyway fluid through exchange rate movements and inflation. Of course even this seemingly clear-cut point should not be treated as a completely hard and fast rule, for the reasons of user tacit awareness already outlined. Figure 5 shows how the state of having an over-supplied economic resource causes the price and quantity to decrease toward their equilibrium amount. Figure 6 shows a similar result for the over-demanded economic resource. Both Figures 5 and 6 show the use of actors to represent the effect of market pressure.

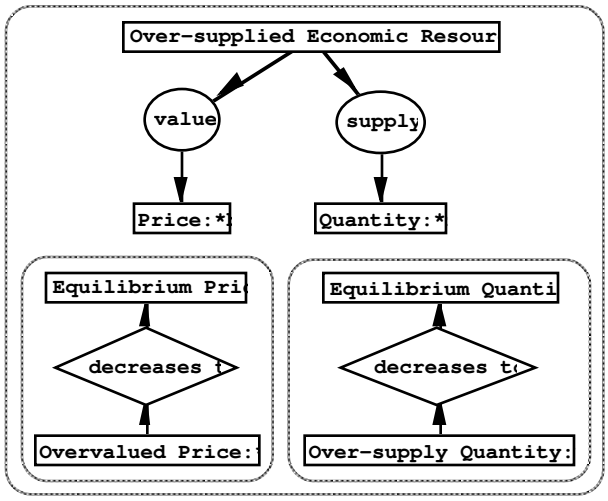

Figure 5. Representing Over-supply

Figure 6 describes the over-demand case. As with over-supply there is the effect on price or units produced, albeit now an increase not a decrease.

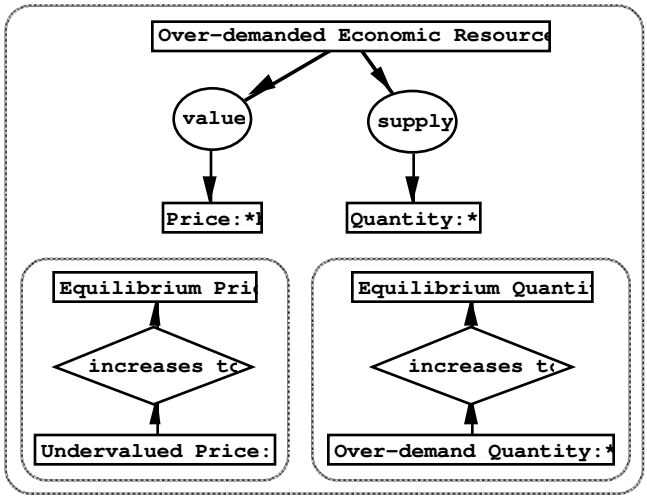

Figure 6. Representing Over-demand

The above graphs as a basis from which more refined graphs would need to be constructed perhaps according to particular situations. Suggestions as to ways the graphs might need to be modified are discussed later on, under the next section of "Further Issues."

3 Further Issues

In the course of developing these ideas, we have encountered several further issues that have implications to the larger conceptual graphs community. This section summarizes some of those issues we have recognized.

3.1 Negative Contexts

Inferencing in conceptual graphs employs negative contexts, adapted by Sowa from the logic of Charles Sanders Peirce [6]. To illustrate, the rule "$P \Rightarrow Q$" could also be expressed as "$\neg(P \wedge \neg Q)$". This transformation may appear to be initially counter-intuitive to non-logicians, but Peirce relied on converting other logical relationships into AND and NOT form to obtain the visuality of his logic. To bridge the gap, Sowa consequently proposed explicit relations in conceptual graphs such as one for "implication" [6]. Therefore in the linear notation:

[P] —> (implication) —> [Q]

essentially means:

(not) —> [[P] (not) —>[Q]]

Farques et al. go further and dismiss Peirce logic completely, replacing this aspect of conceptual graphs with "if-then" rules on the grounds that Peirce logic is unnecessarily complicated [11]. However one of us (Polovina) is currently exploring the value of retaining Peirce's negative contexts. For instance, Peirce logic explicates even the simple *modus tollens* relationships obscured somewhat by the procedural nature of an "if-then" implication. Hence, say, *what if* it is false that *quantity "x" is less than 'quantity "y"* , then *quantity "y" is more than quantity "x"* would be asserted as false. Careful examination of the graphs presented in this paper will reveal such and more involved "what if" interrelationships not evident from if-then rules alone. Furthermore the method of negation in Peirce is arguably similar to that in the accountant's bookkeeping model, where figures are negated by surrounding them in brackets. For example the complementary double entry of "$3,000" is "($3,000)". This and other similarities have been discussed in previous work [1].

3.2 Changes in Domain Assumptions

Not surprisingly, there is much more to supply and demand problems than we have discussed. For example, for the over-demand case already denoted by Figure 6, a slightly more complex situation is described in Figure 7. From Figure 6, it can be seen that over-demand leads to either an increase in price or units produced. However it may be that these two parameters are fixed, say by government policy. Therefore a third possibility can be introduced that states a certain amount of demand for that economic resource could remain unsatisfied instead.

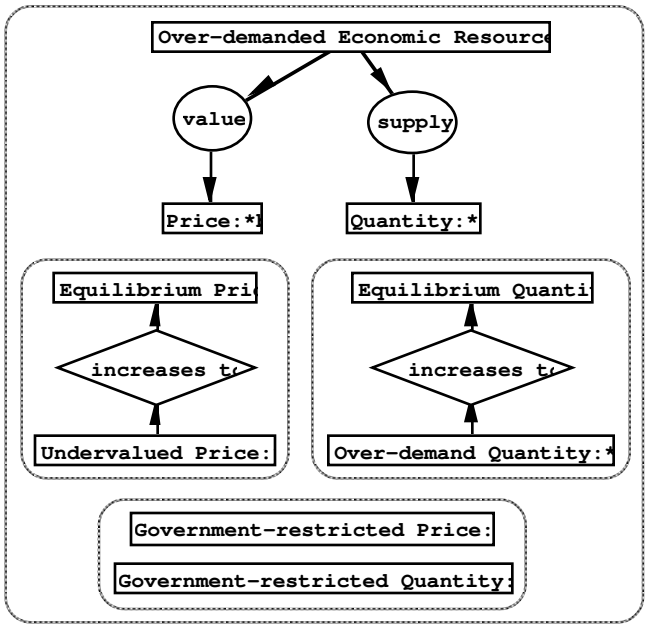

Figure 7. Further Representing Over-demand

Moreover there are instances where supply and demand do not follow the expected pattern, such as the decreasing of the price of an economic resource may turn out to *decrease* its demand. This may be because dropping the price of a product may cause customers to believe it is now second-rate and thereby avoid buying it. Hosking reports on the concern of the luxury fragrance houses that large discount health and beauty retail chains wish to sell those houses' perfumes at a substantial discount of up to 50%. Hosking notes that the advertising media take the houses' attitude so seriously that they will not accept advertisements by the discount retailers, for fear of losing the lavish advertising business of the houses [12]. Becker [13], and *The Economist* magazine [14, p.85], describe in a similar vein the highly-fashionable, or "in" commodities which, as their price increases, their demand *increases*. However this only occurs if demand is *never* satisfied, otherwise the price and quantity demanded drops again.

The above dynamic well exemplifies how the pervasive yet elusive tacit/implicit knowledge in a problem domain (here in terms of what is presently in fashion) affects the fundamental methodology that attempts to model that domain, and underpin the reasons why is it important that the models are built by the domain experts directly. Figure 8 is presented lastly as one thought-provoking way towards how such scenarios might eventually be captured by an economist using conceptual graphs.

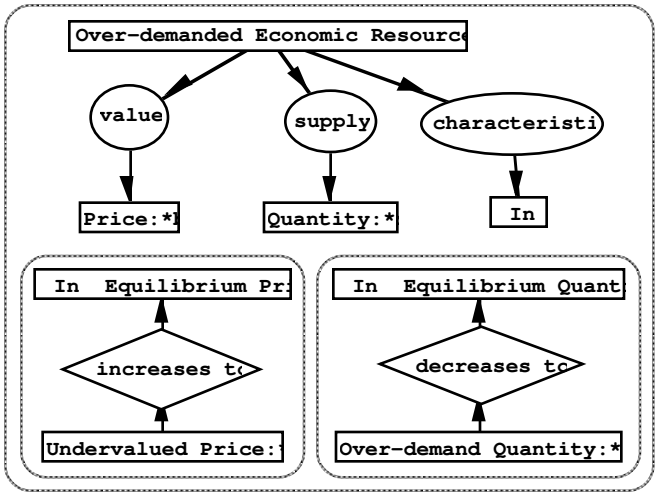

Figure 8. Representing Equilibrium for "In" Economic Resources

4 Conclusion

This paper has shown how some basic common knowledge, namely, the law of supply and demand, may be represented naturally through conceptual graphs. We relied heavily on negative contexts to convey relationships between facts, and upon actors to convey functional relationships. We took a highly user-centered approach with economists, accountants or strategic planners building and reviewing conceptual graphs that are familiar to them. We found that even some rather esoteric marketing notions may thus be effectively modeled. Nonetheless we believe that further empirical studies are needed on the understandability of these representations by practicing domain experts. Such studies will provide further evidence for or against the claims made here.

We made much use of conceptual graph actors. Since economics deals with processes and many cause-and-effect relationships, we believe that actors are an appropriate way to represent this information. In particular, we note the usefulness of actors in representing both quantitative relationships and even the somewhat elusive notion of market pressure. Further work is needed to be able to specify precisely the behavior of actors in our graphs.

Although we would accept that this paper has only touched upon the economics of supply and demand, let alone economics in general, the discussion reveals that this problem domain gives conceptual graphs not merely a rich but also a meaningfully real avenue to vent the technique's worth. The graphs presented within this paper illustrate the possible directions in which conceptual graphs-based modeling could proceed. An economics knowledge-base that usefully captured the endlessly baffling dimensions of economic activity would be quite useful, and clearly bring the formalism employed to the forefront of eminence. The chance offers conceptual graphs to take that much-awaited lead.

Acknowledgements

One of us (Polovina) would like to thank Chris Hinde, Computer Studies, LUT for his help towards the content of this paper.

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