Top-down, Middle-out, and Bottom-up Processes: A Cognitive Perspective of Teaching and Learning Economics

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Abstract

The pedagogical value of graphical representations and analyses (GR and GA) in economics education is examined in a framework of top-down and bottom-up processes of thinking. We argue, with the support of two illustrative examples, that they are useful to the extent that they provide bridges between economic theories and facts. We also note that over-reliance on GR and GA may lead to misconceptions on the students' part. Hence, the challenge for educators and students of economics is to connect GR and GA upwardly with theories and downwardly with the empirical world.

Top-down, middle-out, and bottom-up processes: A cognitive perspective of teaching and learning economics

Graphical representations (GR) and graphical analyses (GA) are often used by teachers of economics and authors of economics textbooks to help students understand economic theories, models and concepts. For example, GR and GA are commonly used to explain the concepts of quantity demanded, quantity supplied, and price equilibrium, as well as the law of demand, or the relationship between price

and quantity demanded. Most students find GR easier to understand than written explanations (MacDonald-Ross, 1977). Recently, Dickinson (2003), Lai, Chang and Kao (2004), Trandel (2003) and Yanchus and de Vanssay (2003), for example, advocated the use of GR and GA for both pre-college and college levels of economic education.

Why are GA and GR useful? Economics is a science in which both qualitative and quantitative analyses play important roles. Unfortunately, students who prefer qualitative analysis may consider quantitative analysis "tedious mathematics", while students who prefer quantitative analysis may consider qualitative analysis "imprecise, if not empty." We would argue in this paper that GR and GA can bridge the gap between qualitative and quantitative analyses by quantifying the concepts and conceptualizing the quantities.

In this paper, GR and GA are examined in the framework of top-down and bottom-up processing, which is a major framework used in cognitive psychology and cognitive science to understand thinking. Since GR and GA are mid-way between top-down and bottom-up processing, the thinking process in terms of GR and GA might be named "middle-out" processing (c.f., White, 1993). We would also argue that, although GR has the obvious advantages of being visible, concrete, and manipulable, it cannot replace either top-down or bottom-up processing. Overreliance on GR and GA without integrative thinking across the three levels may result in misconceptions.

Top-down and bottom-up processes in learning and thinking

In cognitive psychology and cognitive science, top-down and bottom-up processes refer to processes that flow from either the top or the bottom of the information processing hierarchy, respectively (Lindsay & Norman, 1972). The top of the hierarchy is assumed to contain high-level, abstract, and encompassing knowledge representations such as concepts, mental models, and schemata. On the other hand, the bottom of the hierarchy is assumed to contain low-level, concrete, and specific knowledge representations such as visual features, lexicons, and propositions (e.g., Bruning, Schraw, & Ronning, 1995; Kintsch, 1998).

Cognitive psychologists and cognitive scientists believe that both top-down and bottom-up processes are indispensable to both human and machine thinking. Bottom-up processing is said to occur when one draws from some particular examples, instances, cases, or events to a generalization, rule, or law to capture the commonality between the examples, instances, cases or events (e.g., Brown, Collins, & Duguid, 1989). Similarly, top-down processing is said to occur when one infers from a generalization, rule or law to conclude something about a particular example, instance, case, or event. Induction is an example of bottom-up processing, and deduction is an example of top-down processing.

In the context of economic questions and problems, one can also go through either a top-down or a bottom-up process, or both. Suppose a teacher wants a student to consider whether or not there is perfect competition in the real world. The teacher may lead the student to examine the criteria for perfect competition (e.g., free entry and exit of suppliers or demanders) one by one, and then come to the conclusion that because these criteria cannot be realized in the empirical world, most of the time perfect competition hardly exists. This way of thinking goes from a theoretical framework to a conclusion about the empirical world. It is a deduction process, which is also a top-down process.

Alternatively, thinking about the same question may go through a bottom-up route. A teacher may lead the student to examine a particular market in the real world where competition is very fierce. The student would be asked to consider whether or not the competition in that market is perfect (e.g., no demander or supplier has the market power to control the price). When the student realizes that the competition in that particular market falls short of perfect competition, the student would be led to consider another fiercely competitive market. After the student has examined several markets and failed to find perfect competition in any of them, the student would gradually come to the conclusion that there is probably no perfect competition in the empirical world. This way of thinking goes from particular cases to a generalization about the empirical world. It is an induction process, which is also a bottom-up process.

This example is reminiscent of some of the decision heuristics identified in the research of Tversky and Kahneman (e.g., 1973, 1982, and 1983), which may also be placed in the framework of top-down and bottom-up processing. People are said to follow the *availability* heuristic if they judge the probability of an event by thinking of similar events they can retrieve from memory. People are said to follow the *representativeness* heuristic if they judge the probability of an event by the degree to which this event is "(i) similar in essential properties to its parent population; and (ii) reflects the salient feature of the process by which it was generated" (Tversky & Kahneman, 1972, pp. 431). In the former, thinking starts with particular examples, whereas in the latter, it starts with something general. The former may be considered bottom-up and the latter top-down process.

Of course, thinking is more dynamic than our simplified description might have suggested. Students may intertwine both top-down and bottom-up processes in their thinking, perhaps in a "spiral" way. The important point is to investigate a theory by examining it against some empirical facts; or to explain an empirical fact by scrutinizing it with one or more theory; or more aggressively, to achieve a generalization or conclusion that is both empirically true and theoretically valid. To do this, it is imperative that a student has knowledge of both economic theories and facts, and is able to see a connection between the two.

Graphical representations and analyses as bridges

Where is the place for GR and GA in this framework of top-down and bottom-up processes? We suggest that graphical representations and analyses could be very useful devices that bridge the gap between top-down and bottom-up processes.

In the context of science education, and physics education in particular, White (1993) has argued that the top-down approach may not work by itself because the semantic distance between the theories and the real-world phenomena to which the theories apply is too great. She also argued that the bottom-up approach may not work by itself, either, because the process of gradual generalizations from exposure to many real-world instances is slow and inefficient. These comments seem equally applicable to economic education.

GR are not as abstract as theories or concepts. GR are neither as real as empirical facts or events. Yet, if they could portray the important features of abstract theoretical concepts in a concrete form, or if they could delineate theoretical explanations in a sequence of discrete steps, then they could serve the useful function of bridging theories and facts, and provides a basis for making predictions about outcomes (Larkin, 1985).

In the following, we describe two applications in which GR and GA take the role of a mediator between theories and facts. In the first example, GR and GA are indispensable because the theories are too difficult. The second example shows that GR and GA may be misleading if we cease to consider the essential pre-conditions before interpreting the graphs.

An example of positive effects of graphical analysis

From time to time, there are discussions, among policymakers or the public, on the issue such as, "Should the government collect a sales tax?" or "What is the burden on the suppliers, when consumption tax is imposed on their products?"[1] To address this type of issues, we may, on the one hand, look at the experiences of some economies of a similar type (i.e., the bottom-up approach); or, on the other hand, derive from some highly-theoretical models the implications of a sales tax (i.e., the top-down approach). However, the former may not be available whereas the latter may be too difficult. In this case, GR can bring out the implication of theories to illuminate the facts that could possibly be found. The latter, if found, could either confirm or falsify a theory.

Refer to Figure 1A below, which presents the impacts of a sales tax[2] on the quantity transacted and the equilibrium prices. A graph of this type can be found in many college or pre-college economics textbooks but our focus of interest deviates a bit

Figure 1A Impacts of a sales tax on the short-run market supply (SRS)

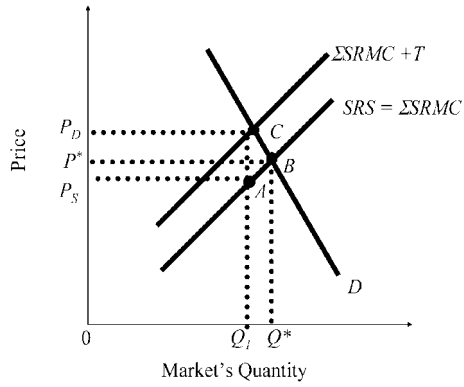
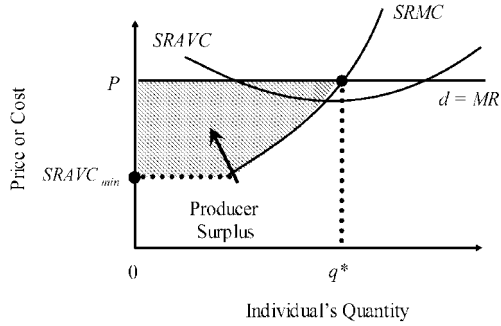


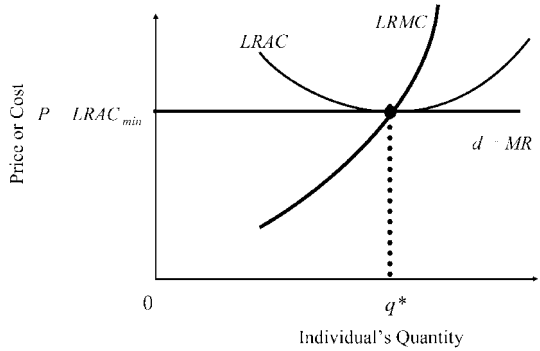
Figure 1B Short-run individual margin cost (SRMC) at short-run competitive equilibrium



from the usual textbooks. In most, if not all, of the textbooks, the authors proceed with the claim that the decrease in consumer surplus equals the area of the trapezium P_DP^*BC, while the decrease in *producer surplus* equals that of the trapezium P^*P_SAB, and the deadweight loss or the excess burden is the area of the triangle *ABC*.

Given the analysis about Figure 1A, it is tempting for a student to conclude that in *reality*, the suppliers will suffer from a decrease in producer surplus, should a sales tax be imposed. We are going to argue that this is, at most, the case in the *short-run*, but not the case in the *long-run*. This conclusion can be most easily illustrated with a graph.

Figure 1C Long-run individual marginal cost (LRMC) at long-run competitive equilibrium

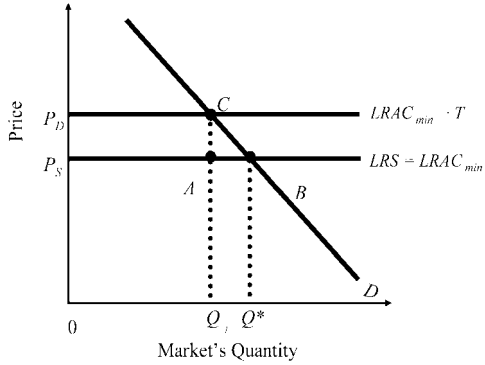


The "standard" analysis hinges on the upward-sloping *market* supply curve (such as S in the figure), which is the horizontal summation of the upward-sloping (short-run) *individual* marginal cost curves (the one depicted in Figure 1B). Economics professionals or even some senior economics students are aware of the more theoretical fundamentals for an upward-sloping marginal cost curve, but those fundamentals are beyond the scope of this paper. As one can see in Figure 1B, correspondingly, an individual firm can enjoy the producer surplus in the short-run, and this producer surplus is sometimes called *abnormal profit*. However, it is well-documented that in the long-run, the abnormal profit/producer surplus dissipates, due to the entry of new firms which drives down the equilibrium (suppliers') price. In the long-run, as depicted in Figure 1C, an individual firm that survives in the market will produce at the minimum of the long-run average cost curve ($LRAC_{min}$), despite the fact that the long-run *individual* marginal cost curve is arguably upward-sloping too. All in all, in the long-run, the *market* supply curve (see *S* in Figure 1D) is horizontal and unlike the case in the short-run (see Figure 1A) there is *no* abnormal profit/producer surplus in the long-run, no matter there is a sales tax or not.[3]

What can we learn from these GR and GA? If the producers in a market protest against a levy of sales tax, there are two possibilities. (1) The market is not competitive in the sense that even in the long-run, entry of new firms cannot drive away the producer surplus; (2) The producers need time to adapt to the introduction of sales tax, some of the less efficient producers may even shut down in the long-run.

In view of (1), for sake of efficiency, the market needs some kind of regulations or taxations anyway. Whether a levy of sales tax is the optimal policy is another issue.

Figure 1D Impacts of a sales tax on the long-run market supply (LRS)



For (2), the policymakers are reminded to spare some time for consultation of the *implementation* of the sales tax on the one hand, and they are reminded to announce in advance the imposition of the tax on the other hand. How long *in advance* definitely varies with the institutional factors in different economies, which in turn govern the speed of adjustments from a short-run supply curve to a long-run supply curve.

An example of negative effects of graphical analysis

Employment and poverty are two major topics in economics, and policy making. From time to time, labor organizations urge for passing the act of minimum wage (and maximum working hours). Rapid developments in new information economy and globalization result in an ever-rising income inequality or an increase in poverty, regardless of how one quantifies these two concepts. No wonder the debate on the merits and demerits of minimum wage has been heated over the past ten years. See, for instance, Card and Krueger (2000) and the references therein.

Opponents of minimum wage law often make their arguments with a *top-down approach*. Minimum wage means a price floor imposed on the labor market. Whenever it is effective, the prevailing wage exceeds the wage that clears the market. As a result, minimum wage causes unemployment (or an increase in the number of unemployed). Alternatively put, some of the opponents may proceed and claim that minimum wage law even does harm to the workers, apart from claiming that a wage distortion in the labor market causes inefficiency.

Figure 2A Impact of a minimum wage on employment (the usual case in most textbooks)

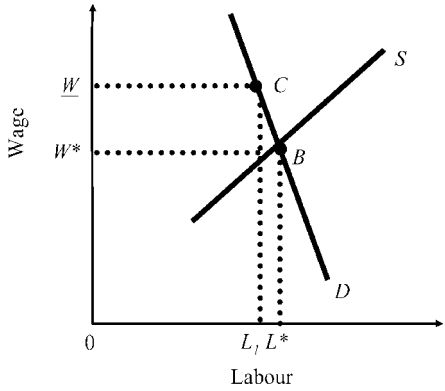
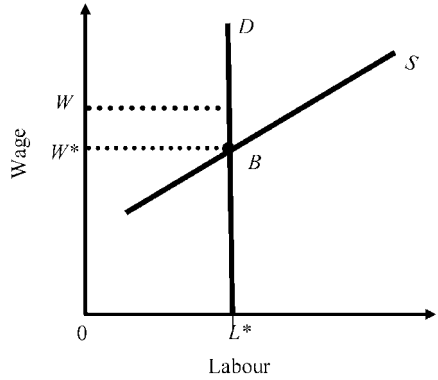


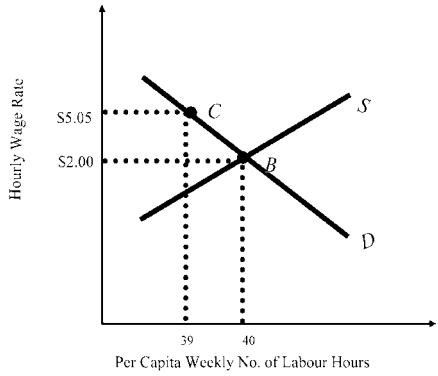
Figure 2B Impact of a minimum wage on employment (with perfectly inelastic labour demand)



This reasoning can easily be represented in a graph. Refer to Figure 2A. Minimum wage ($\underline{W}$) exceeds the wage (W^*) that clears the market. As a result, minimum wage causes unemployment.

Despite the beauty and simplicity of the GA with Figure 2A, the increase in unemployment hinges on the fact that labor demand is *not* perfectly inelastic, that is, the labor demand curve is *not* vertical. As one can see in Figure 2B, where the demand curve is vertical, the number of employed is unchanged. The

Figure 2C Tradeoff between employment and wage rate: Scenario (1)



unemployment in Figure 2A results partially from the fact that the labor force grows when the wage rate increases from W^* to $\underline{W}$.

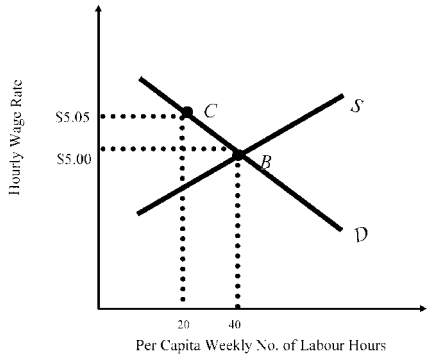
Figure 2B may be an extreme case in which the labor demand is totally insensitive to wage rate. Nevertheless, it is arguable that in the case of service industry, the labor demand is inelastic. More importantly, apart from employment, workers also care about the wage rate, as one may conclude from the analysis of Figures 2C and 2D.[5]

Figures 2C and 2D are elaborated versions of Figure 2A. Figure 2C refers to the case that the hourly wage increases from $2.00 (which is hardly above the *subsistence level*) to $5.05 while the per capita weekly number of working hours decreases *marginally* from 40 to 39. Definitely under this scenario, the workers welcome the minimum wage law. Either the workers share their jobs (and each of them gets a higher monthly pay) or the employed pay more tax with their higher pay and feed the unemployed.

In contrast, Figure 2D refers to the case that the hourly wage increases *marginally* from $5.00 to $5.05 but the per capita weekly number of working hours decreases *substantially* from 40 to 20. Evidently under this scenario, a minimum wage law does harm to the workers.

Whether Figure 2C or 2D is a better description of the empirical world requires some *bottom-up analyses*. Recently, prominent economists have attempted some elaborate empirical analyses. Some (such as Gregg, 2000) finds diverse results, while some find even controversial results (see Card and Krueger, 1994, Neumark and Wascher, 2000 and Card and Krueger, 2000).

Figure 2D Tradeoff between employment and wage rate: Scenario (2)



Pedagogical considerations of GR and GA

Educational psychologists have pointed out that GR can be very helpful in learning quantitative or scientific concepts because GR can express the features of the concept explicitly (Larkin and Simon, 1987; Pinker, 1990).

As illustrated in our examples, GR and GA are most useful when theories are very difficult. GR can depict a reasoning model (e.g., constraint maximization) by showing the constraints imposed by several factors in the model (e.g., the long-run marginal cost *LRMC* and the long-run supply *LRS* in Example 1) simultaneously so that the implications of the interaction of these factors can be recognized easily. GR can also depict a causal model (e.g., a sequence of steps in which a process evolves) by showing the sequence of events leading to an outcome. Although it is the former that is most common in economics, both of them are concrete representations of abstract theories.

The second example above also shows that GR and GA may be inadequate by themselves. Some students of economics might have the misconception that conclusions derived from GR and GA must be true empirically. For instance, students who have studied Figure 2A tend to believe that minimum wage causes unemployment. However, the truth is that GR and GA suggest possibilities implicated by theories only (Figures 2A-D); which of these possibilities is in fact the case in the empirical world is a question to be verified. In this minimum wage example, students may want to collect information about the empirical situation they are interested in to determine which demand curve most *closely* represents that situation.

Another misconception that students often develop as a result of learning with GR and GA is that they tend to believe that concepts represented by the same shaped GR element must have identical properties. In Figures 1B and 1C, both short-run marginal cost (*SRMC*) and long-run marginal cost (*LRMC*) of an *individual* firm are represented by an upward sloping curve. In the short-run, the *market* supply is upward sloping as it is the horizontal summation of the individual *SRMC*. In contrast, the long-run *market* supply coincides with the $LRAC_{min}$. Ignoring the time frame that we consider will give us an incorrect conclusion on the economic burden of a consumption tax on the suppliers.

All in all, the challenge for educators and students of economics is to connect GR and GA upwardly with theories and downwardly with the empirical world. Regarding the former, it is necessary to determine, firstly, the mapping between the elements of a GR and the concepts being represented (i.e., which concept is being quantified); and secondly, the mapping between the visual features of a GR element (e.g., a *curve* line) and the semantic features of the concept (e.g., diminishing marginal return) (Pinker, 1990).

Regarding the connection between GR and the empirical world, it is necessary to determine which empirical situation is being depicted by a GR (Novick & Hmelo, 1994), that is, the referents of the concepts.

To accomplish these two objectives, students should be encouraged to construct different GRs (e.g., labor demand curves with different slopes) in order to explore the implications that can possibly be derived from a theory. Students should also be encouraged to collect information about the empirical world so that they can identify which of these possible GRs best matches the empirical situation. Only with a thinking process that bridges theories and the empirical world can thorough understanding of economics be achieved.

Conclusion

About two decades ago, Kayaalp (1983) wrote that "Economic topics are patently abstract and highly technical. To compensate for this, economic prose has become more and more self-contained. This resulted in introductory texts that are but a catalogue of broad concepts which fail to impart a sense of immediate application of economic knowledge to problems actually affecting the readers' lives" (pp. 295). Added to this problem is proliferation of mathematics in economics textbooks in the past twenty years. As a result, economics appears to be a subject full of "dangling theories" and "tedious mathematics." We have argued in this paper that by quantifying the qualitative concepts and conceptualizing the quantities with GR, students will be able to integrate economic theories with the empirical situations to which they apply.

References

Brown, J., Collins, A. & Duguid, P. (1989) Situated cognition and the culture of learning. *Educational Researcher*, Vol. 18, pp. 32-42.

Bruning, R.H., Schraw, G.J. & Ronning, R.R. (1995) *Cognitive psychology and instruction*. Englewood, NJ: Merrill.

Card, D. & Krueger, A.B. (1994) Minimum wages and employment: a case study of the fast-food industry in New Jersey and Pennsylvania. *American Economic Review*, Vol. 84, pp. 772-793.

Card, D. & Krueger, A.B. (2000) Minimum wages and employment: a case study of the fast-food industry in New Jersey and Pennsylvania: reply. *American Economic Review*, Vol. 90, pp. 1397-1420.

Dickinson, D.L. (2003) Illustrated examples of the effects of risk preferences and expectations on bargaining outcomes. *Journal of Economic Education*, Vol. 34, pp. 169-180.

Gregg, P. (2000) The use of wage floors as policy tools. *OECD Economic Studies* No.31, pp. 133-146.

Kayaalp, O. (1993) Economic text and acquisition of economic literacy: There is a cognitive remedy. *Journal of Socio-Economics*, Vol. 22, pp. 295-301.

Kintsch, W. (1998) *Comprehension: A paradigm for cognition*. New York: Cambridge University Press.

Krueger, A.B. (2001) Teaching the minimum wage in econ 101 in light of the new economics of the minimum wage. *Journal of Economic Education*, Vol. 32, pp. 243-258.

Lai, C.C., Chang, J.J. & Kao, M.R. (2004) The money-creation model: Graphic illustration. *Journal of Economic Education*, Vol. 35, pp. 79-88.

Larkin, J.H. (1985) Understanding, problem representations, and skill in physics. In: Chipman, S. F., Segal J. W. & Glaser R. (Eds) *Thinking and learning skills, Vol. 2: Research on open questions*. Hillsdale, NJ: Erlbaum.

Larkin, J.H. & Simon, H.A. (1987) Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science*, Vol. 11, pp. 65–99.

Lindsay, P. & Norman, D.A. (1972) *Human information processing; an introduction to psychology*. New York: Academic Press.

MacDonald-Ross, M. (1977) Graphics in texts. *Review of Research in Education*, Vol. 5, pp. 49–85.

Neumark, D. & Wascher, W. (2000) Minimum wages and employment: a case study of the fast-food industry in New Jersey and Pennsylvania: comment. *American Economic Review*, Vol. 90, pp. 1362-1396.

Novick, L.R. & Hmelo, C.E. (1994) Transferring symbolic representations across nonisomorphic problems. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, Vol. 20, pp. 1296-1321.

Pinker, S. (1990) A theory of graph comprehension. In: Freedle R. (Ed) *Artificial intelligence and the future of testing*. Hillsdale, N.J. Erlbaum.

Stern, E., Aprea, C. & Ebner, H.G. (2003) Improving cross-content transfer in text processing by means of active graphical representation. *Learning and Instruction*, Vol. 13, pp. 191-203.

Trandel, G.A. (2003) Demonstrating the equivalence between two methods of measuring excess burden. *Journal of Economic Education*, Vol. 34, pp. 54-59.

Tversky, A. & Kahneman, D. (1972) Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, Vol. 5, pp. 207-232.

Tversky, A. & Kahneman, D. (1982) Evidential impact of base rates. In: Kahneman, D., Slovic, P. & Tversky, A. (Eds) *Judgment under uncertainty: Heuristics and biase*. New York: Cambridge University Press

Tversky, A. & Kahneman, D. (1983) Extensional versus intuitive reasoning: The conjunction fallacy in probability judgment. *Psychological Review*, Vol. 90, pp. 293-315.

White, B.Y. (1993) Intermediate causal models: A missing link for successful science education? In: R. Glaser (Ed) *Advances in instructional psychology*, Vol. 4. Hillsdale, NJ: Erlbaum.

Yanchus, D. & de Vanssay, X. (2003) The myth of fair prices: A graphical analysis. *Journal of Economic Education*, Vol. 34, pp. 235-40.

Notes

1 As one can see below, only for illustrative purposes, we focus on the suppliers. That does not mean that the impacts on the demanders are not important.

2 More precisely, we consider a per-unit tax. Nevertheless, our subsequent analysis should not be affected if we consider an ad valorem tax instead.

3 Having said that, as long as the demand curve is downward-sloping, in the long-run there is still deadweight loss, which equals the area of the triangle ABC in Figure 1D.

5 We are indebted to Chun-wah Liu for prompting us to this point.

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