*Journal of Industrial Organization
Education*

Manuscript 1048

Using Experiments to Illustrate the Role of
Network Externalities in Technology
Adoption and Industry Evolution

W. Parker Wheatley, *College of St. Benedict, St. John's
University*

Using Experiments to Illustrate the Role of Network Externalities in Technology Adoption and Industry Evolution

W. Parker Wheatley

Abstract

This experiment helps students to understand the importance of network externalities in technology adoption and the evolution of industries. Students observe the roles of lock-in and critical mass in technology adoption, understand how pricing affects adoption, and see welfare implications of network externalities. Given examples of network effects in firm and government action (e.g., the advanced television systems committee, antitrust litigation for the credit/debit card industry, and private strategy in newer DVD technologies (HD DVD vs. Blue-Ray)), this experiment fits courses that wish to illustrate these ideas and provides a starting point for a more detailed study of network externalities.

KEYWORDS: classroom experiments, network externalities, technology adoption

Author Notes: The author wishes to acknowledge the observations and participation of his Economics 320 and Economics 359 students at the College of St. Benedict, St. John's University in the years from 2008 to 2011. He also thanks Steve Strand for helpful comments on an earlier manuscript.

Introduction

Ideas related to network externalities are now common in economic language and conversations. Undergraduate texts have added discussions relative to network externalities (e.g., Krugman and Wells (2006), Pindyck and Rubinfeld (2009), and Carlton and Perloff (2005)). Kwoka and White (2009) provide an excellent overview of the concept in the context of recent antitrust cases. These additions to undergraduate texts reflect a growing view that undergraduate students should have a basic understanding of how networks, lock-in, and critical mass affect technology adoption and industrial evolution. There are tangible examples of where network related issues have factored into markets, including coordinated and mandatory technology adoption (e.g., high-definition television), differences in adoption of new technologies in the U.S. relative to other countries (e.g., 2G to 3G to 4G cell phones), the entry/exit dynamics in markets with new and competing technologies (e.g., HD DVD and Blu-Ray), and the evolution of financial exchanges from physical trading spaces to electronic markets. These few examples provide a starting point for conversations with students about the role of network externalities in technology and standards adoption processes.

Notwithstanding the Liebowitz and Margolis (1994) rejoinder that economists avoid the Pigouvian trap of seeing network externalities everywhere, the fact is that real-world examples of industry efforts at coordination, legal cases, and interesting processes of technology adoption call on economic educators to explore the ideas more fully so that students can better understand the phenomena related to network externalities. Part of the challenge of the literature in the field is that it is not particularly accessible to an undergraduate. One need only consider Arthur (1989) and Witt's (1997) argument over the competing forces of "lock-in" and "critical mass" to understand that detailed theories of network externalities and technology adoption would be inappropriate for many undergraduate courses.

This paper describes an experiment that permits students at different levels of economic understanding to appreciate the role of network externalities in technology adoption and explore the extent to which market outcomes can be suboptimal from a social welfare perspective. Ruebeck et al. (2003) provide another interesting approach to the study of network externalities and provide some considerations relative to endogenous sequencing of adoption, switching costs, and noisiness in market signals about adoption. The approach taken here is somewhat different and allows for a more detailed consideration of pricing and social welfare as relevant considerations in adoption and evaluation of market outcomes. This experiment provides students with a sense of the potential importance of network externalities and their effects on technology adoption as

well as illustrating cases of sub-optimal technology adoption (i.e., where individuals choose the “wrong” technology in equilibrium).

This experiment can be run before or after teaching the various concepts related to network externalities; however, it is recommended that students be provided some preliminary explanation about the nature of network externalities prior to this activity. For an introductory course, the experiment would fit well after a review of the concepts such as those found in Krugman and Wells. For the intermediate level industrial organization course, it provides an excellent introduction to such ideas before students read Kwoka and White’s antitrust cases related to network externalities, for example, and for the advanced undergraduate course in industrial organization, one could use it as intuitive starting point to readings of some more advanced literature in the field of network externalities. The structure of the experiment is based on the ideas presented in Katz and Shapiro (1986). In addition to the above mentioned sources, for those seeking some good background material before running this experiment, several papers provide a general overview of the topic, including Besen and Farrell (1994), Katz and Shapiro (1994), and Economides (1996). Depending on the target student audience, greater or lesser detail of the ideas could be included in a discussion of the topic.

Description of the Experiment and Debriefing

Following is a general outline of an experiment which the author has used in several courses. More or less analysis of experimental results would be merited depending on the level of the course. To illustrate the process of technology adoption in an environment of network externalities, this experiment has two hypothetical sellers (seller of technology A and seller of technology B). There are two periods over which consumers can adopt a particular technology, but each individual consumer is assigned to be either a period 1 adopter or a period 2 adopter. This exogenous determination is intended to induce certain behavior according to available price information presented at the beginning of the experiment. The experiment should be repeated at least five times under different pricing conditions and given different numbers of period 1 and period 2 adopters. Some carefully constructed prices and numbers of first and second period buyers are provided in Appendix Tables 1-3 to assist instructors in preparing the experiment.

The value of either technology to a consumer exhibits direct network externalities that are linearly related to the total number of adopters of the technology that a consumer chooses. Depending on class sizes of ten, twenty, or thirty, the example assumes a network benefit of $V(N) = a \cdot N_x$ where a is the linear benefit parameter and N_x is the number of adopters of technology x (either

A or B as the case may be). In Appendix Tables 1-3, network benefits for classes of ten, twenty, and thirty were found by assuming that the linear parameter takes a value of 10, 7.5, and 5, respectively. The different assumed parameters allow for pricing that is within the realm of plausibility in terms of dollar cost. One could easily modify the network externality into a nonlinear form, but this linear parameter is likely the most accessible to students in such a setting.

There are two pricing scenarios that could be used (non-strategic and strategic), but a non-strategic approach has been found easier to demonstrate in a single class and allows students to focus more on the buyers' side of the adoption process. In the post-experiment debriefing, it is then possible to discuss how pricing strategy would work from the perspective of strategic sellers. The non-strategic approach is consistent with the "unsponsored technologies" discussed by Katz and Shapiro (1986).

In the non-strategic setting, firms are compelled to price their products at marginal cost in each period, and the prices in both periods of both technologies are revealed to all consumers at the beginning of period 1 of the experiment. Once these prices are listed, first period adopters are asked to make their private adoption decisions. Since the idea is to have students make adoption choices without full knowledge as to what their current peers are doing, students provide these adoption decisions on a chit of paper to the experimenter and are asked not to engage in conversation, and the experimenter then records the aggregate adoption of each technology on the computer with total adoption of each technology projected on a screen. It is assumed that firms must sell their product to all consumers who desire their product at the same price in a given period. After the first period of adoption decisions have been made and recorded, second period adopters are then permitted to make their adoption decisions, again without conversation.

This experiment is generally run with different permutations of period 1 and period 2 consumers and with different underlying cost/price structures. In this way, students can begin to see two ideas: (1) that relatively larger numbers of first period adopters can lock-in second period adopters to choose the technology that first period adopters choose and conversely that relatively larger numbers of second period adopters can create a critical mass such that first period adopters choose the technology preferred most by second period adopters; and (2) that pricing dynamics (or expected pricing dynamics) can also impact adoption behavior. In order to narrow the scope of possible outcomes both in terms of predicted equilibrium market outcomes and social welfare, all experiments discussed here assume that technology A is the less expensive technology in period 1, and technology B is the less expensive technology in period 2. The level of cost asymmetries are intended to induce various outcomes such as all

parties adopting technology A based on individual choices and sequential decisions when social welfare is maximized by everyone adopting technology B.

Before class, students are provided instruction sheets and tables for calculating individual net welfare from technology adoption and are assigned a particular buyer number. Students should also be provided with a table that indicates whether they are a period 1 or period 2 consumers in each experiment. In order to maintain full engagement of students in the activity, all consumers are permitted the opportunity to make a technology choice in one period. Students should also know how many buyers are scheduled to buy concurrently with them and how many will buy before or after them. This approach can feel a bit artificial, but when conducting the experiments, this approach helps reduce the number of variables that must be considered by a student when making the adoption decision as compared with allowing endogenous adoption sequencing. If this question of when to adopt is of more interest to teachers, then the Ruebeck et al. (2003) paper provides an appropriate approach.

At the conclusion of both rounds of adoption, students should be asked to calculate their individual payoffs given the network benefit function provided and the costs of the unit they bought. Be careful to remind students that the network benefit of a particular technology is a function of total adoption (both period 1 and period 2) of a specific technology. Detailed instructions for this experiment appear in Appendix 1.

After completing the experiment at least five times under different costs and ratios of period 1 and period 2 adopters, a debriefing or discussion should be conducted. Following is a reasonable way to conduct this debriefing. First, discuss the role of prices in different individuals' adoption choices. Second, discuss the role of expectations about peer and future individuals' adoption choices in the decisions of each individual. Third, review on the computer, overhead, or chalkboard the payoffs of the individuals in each experiment. Fourth, compare these payoffs with what players could have earned had social welfare maximizing adoption been achieved. This last component can be accompanied by a figure such as that shown in Figure 1 below that shows the example under different pricing scenarios given equal numbers of adopters in each period as shown in Table 1. This figure shows the adoption behavior, optimal welfare, and actual welfare achieved. While necessary information to arrange a spreadsheet to automatically construct this figure is available in Appendix 2, interested parties can obtain a spreadsheet at the following URL: <http://employees.csbsju.edu/pwheatley/>.

If one were reviewing information for Experiment 1 in Table 1 and Figure 1, an instructor could note that technology B has a significant cost disadvantage in Period 1 and a modest cost advantage in Period 2. The instructor could then observe that when all consumers choose to adopt technology A, actual social

welfare would equal the maximum possible social welfare. Moreover, Period 2 consumers are locked-in to technology A because of earlier adoption even though it is “inferior” in terms of cost in Period 2. Alternatively, in Experiment 2, when a technology’s cost advantage was slightly larger in Period 2, it was possible for technology B to attract consumers to it in both Period 2 when it had the cost advantage and in Period 1 even when it was disadvantaged. This adoption process would reveal that actual welfare achieved was less than optimal in terms of possible aggregate welfare as shown in Figure 2. This example would illustrate how future adoption expectations can drive earlier Period 1 consumers to adopt what appears to be an inferior technology (technology B) in that period in terms of cost.

For purposes of comparison, Appendix Tables 1-3 provide calculated welfares under scenarios when all consumers adopt technology A, all consumers adopt technology B, and when all first period consumers adopt technology A with all second period consumers adopting technology B. Given the assumed cost gradients, it should never be the case that all first period consumers adopt technology B while all second period consumers adopt technology A. In conclusion, given these comparisons, students can see how pricing affects adoption and lock-in. In cases where numbers of first period or second period adopters are asymmetric, these effects as well as critical mass effects can be explored.

Table 1. Sample Experiment Pricing and Adoption Assuming 5 Period 1 and 5 Period 2 Adopters

		Price of A for current period	Total Number Sold by A	Price of B for current period	Total Number Sold by B
Experiment 1	Period 1	25	5	100	0
	Period 2	40	5	25	0
Experiment 2	Period 1	25	3	100	2
	Period 2	100	0	50	5
Experiment 3	Period 1	25	1	50	4
	Period 2	100	0	25	5
Experiment 4	Period 1	25	3	100	2
	Period 2	100	0	10	5
Experiment 5	Period 1	5	5	120	0
	Period 2	120	0	5	5

Figure 1. Comparing Adoption and Welfare Under Different Experiments

Possible Extensions

Imperfect Information on Future Prices

For simplicity and to allow consumers to think strategically about future expectations of consumption, the above experiment assumed that consumers knew the posted prices for all future periods. One could constrain the pricing information such that first period consumers only know first period prices and then only reveal second period prices after first period consumers have made their adoption choices. Such increased complexity more closely mimics real-world pricing and thus could be more appealing and lead to greater variability in technology adoption; however, it also adds another variable that would make subsequent interpretation more challenging.

Strategic Interactions

While presenting some challenges in practice due to the more complex strategic thinking required, it is also possible to conduct this experiment where either one or both firms (Firm A and Firm B) is permitted to price strategically. In such a scenario, one or both firms would be represented by students who are provided

with private cost information. In one version with strategic interaction, students would only need to reveal first period prices in the first period and second period prices in the second period, thus mimicking the extension suggested above. Alternatively, for a simpler strategic setting, one could require firms to reveal both periods' prices at the beginning of Period 1. In either case, careful instructions would need to be prepared for sellers in order to give them a clear idea of how to price strategically in some effective way.

Coordination

As a final extension, it would also be quite easy to allow each period's consumers to coordinate their adoption of a technology in order to allow them to jointly maximize a given period's welfare from adoption.

Conclusions

This paper discusses a classroom experiment where students gain experience with ideas of technology adoption and network externalities. Students should appreciate the roles of lock-in and critical mass in adoption as well as begin to understand the important role of pricing in technology adoption. They should also have a clearer idea as to why coordinated technology adoption through government or private sector consortia can help to improve social welfare, with appropriate real-world references to the coordination of digital standards, for example. The activity would fit well into a variety of levels in the undergraduate curriculum and can act as a starting point to more in depth discussions of the theory and policy related implications. While network externalities remain a relatively peripheral concept in many texts, this activity provides an appropriate way to illustrate the ideas without too much of the technical and theoretical background required for more advanced study. Past experience with students reveals that they gain some interesting insights and find this approach to be accessible.

Appendix 1. Instructions

For the purposes of replication, following is an explanation of the process for conducting this experiment. Instructions are based closely on general instructions developed in Davis and Holt (1993).

Read Instructions at Beginning of Class

Instructions for Buyers in a Market with Network Benefits

This is the market with buyers and two hypothetical sellers. There are two periods in this market, and consumers are determined as being first period buyers or second period buyers. The number of buyers in period 1 is N_1 , and the number of buyers in period 2 is N_2 . Buyers either want 1 unit of the good or nothing. The two sellers sell their products in both period 1 and period 2. Consumers benefit from their consumption of a good, and their value of a product increases as more consumers buy that product. We will discuss this relationship in more detail below. Following is an outline of how we will conduct this experiment.

Before each experiment, buyers will be assigned as period 1 or period 2 buyers. You are permitted but not required to buy one unit of the good in the period to which you are assigned.

Period 1.

1. Seller A and seller B prices for both periods are announced and posted to the computer display.
2. Without discussion, Period 1 buyers write on a piece of paper whether they will buy a unit from seller A or seller B at the posted price or not at all.
3. The experiment leader posts Period 1 buyer decisions on the computer display.

Period 2

1. Period 2 consumers write on a piece of paper whether they will buy a unit from seller A or seller B or not at all.
2. The experiment leader posts decisions of Period 2 consumers.

Experiment Completion

1. Period 1 consumers and Period 2 consumers calculate their net surpluses given the final adoption of their respective products.

Method of Calculating Surpluses

Buyers

1. Buyer earnings = value for good as a function of the total numbers purchasing that good minus the price paid.

Value = [**Linear Network Parameter (as set by experimenter or suggested in Appendix Tables 1, 2, and 3)**] multiplied by the number of individuals who adopt the same technology as you. For example, if there are 3 individuals in Period 1 that adopt Technology A and 5 individuals in Period 2 that adopt Technology A, then your value (not including cost) would be $8 \times [\text{Linear Network Parameter}]$.

Once you know your earnings from adopting a technology, you must subtract your payment. For example, if you were one of the Period 1 adopters of Technology A in the above example and the cost of Technology A is 75, then your net benefit or surplus would be the Value calculated above minus 75.

2. If a buyer does not make a purchase, the buyer earns 0.

Sellers

We will not have actual individuals setting prices in order to simplify the experiment, but in the real world, any seller would behave so as to maximize profits over time.

Any questions?

General Directions/Reminders

1. You can only buy in the period you are assigned to be a buyer, and if you buy, you must buy at the price corresponding with the period you are a buyer.
2. Your value received depends not only on the number of individuals adopting a particular technology in the same period as you but also those adopting that same technology in the period preceding or following you, as the case may be.
3. You should not engage in discussion with other buyers during the process of these experiments.

NOT TO BE RECITED

For Experimenter - Steps of Implementation

- Step 1. Post prices for both products in both periods.
- Step 2. Allow buyers to write down their preferred product on chits of paper and hand them to you.
- Step 3. Post adoption information.
- Step 4. After posting information from period 1, permit second period buyers to indicate their preferred product.
- Step 5. Post adoption information.
- Step 6. Permit buyers to calculate their payoffs from experiment.

Preparation Details

- 1. Before class, prepare instructions and record tables for buyers.
- 2. Prepare the record table on the blackboard or computer. Supporting materials to help with tabulations and calculation are available in an Excel file at the following URL: <http://employees.csbsju.edu/pwheatley/>.
- 4. Distribute instructions to buyers.
- 5. Read the common text aloud and answer procedural questions.
- 6. Decide on Experiment Price/Cost Parameters
 - P_{A1} = Period 1 Price/Cost Per Unit from Firm A
 - P_{A2} = Period 2 Price/Cost Per Unit from Firm A
 - P_{B1} = Period 1 Price/Cost Per Unit from Firm B
 - P_{B2} = Period 2 Price/Cost Per Unit from Firm B

Buyer Number _____

Instructions for Buyers

This is the market with buyers and sellers. There are two sellers (A and B), and buyers are limited to buying in either Period 1 or Period 2, but not both. For each experiment, you will be assigned to be either a period 1 or a period 2 buyer. Sellers are allowed to sell in both periods. We will then give buyers the chance to purchase one unit from either of the sellers. If you are a period 1 buyer, you are allowed to buy one unit of the product in period 1 of the game, but you are not allowed to buy anything in period 2. If you are a period 2 buyer, you are allowed to buy one unit of the product in period 2, but you are not allowed to buy anything in period 1. Your value of a product is increasing in the total number of buyers of the product you buy (i.e., either the total number of buyers of A or the total number of buyers of B). Earnings are determined according to the table below:

1. Buyer earnings = value for good as a function of the total numbers purchasing minus the price paid.

Value = [**Linear Network Parameter (as set by experimenter or suggested in Appendix Tables 1, 2, and 3)**] multiplied by the number of individuals who adopt the same technology as you. For example, if there are 3 individuals in Period 1 that adopt Technology A and 5 individuals in Period 2 that adopt Technology A, then your value (not including cost) would be $8 \times [\text{Linear Network Parameter}]$.

Once you know your earnings from adopting a technology, you must subtract your payment. For example if you were one of the Period 1 adopters of Technology A in the above example and the cost of Technology A is 75, then your net benefit or surplus would be the Value calculated above minus 75.

2. If a buyer does not make a purchase, the buyer earns 0.

N.B. You cannot know the total value until after the end of both periods. For example, if you are a period 1 consumer, and you choose product A along with three other period 1 consumers, you must wait until you know how many period 2 consumers also choose that product before determining your value of consuming product A. However, once you know the total number of period 2 consumers adopting technology A is five, for example, then you can ascertain that the total

number of buyers of technology A is nine, the four adopters in period 1 (you plus three others) added to the five second period consumers of technology A.

In summary, when sellers' prices are posted and buyers in a period have determined whether they will buy or not, we collect those sheets and record the prices of each good under the seller letter, and we then indicate the total number of buyers of each good. You can use the table below to calculate (hypothetical) earnings.

Please note your buyer number and be aware when the experimenter indicates who can buy in a given period.

Buyer Activity Sheet					
	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5
1) Product Bought (A or B)					
2) Buyer Value					
3) Price Paid					
4) Value – Price					
	Experiment 6	Experiment 7	Experiment 8	Experiment 9	Experiment 10
1) Product Bought (A or B)					
2) Buyer Value					
3) Price Paid					
4) Value – Price					
	Experiment 11	Experiment 12	Experiment 13	Experiment 14	Experiment 15
1) Product Bought (A or B)					
2) Buyer Value					
3) Price Paid					
4) Value – Price					

Appendix 2. Calculating Total Welfare

While a spreadsheet with embedded formulae is provided at URL: <http://employees.csbsju.edu/pwheatley/>, this appendix shows the formulae for calculating total welfare in this experiment. Let N_{1A} be the number of first period consumers that adopt technology A, N_{1B} be the number of first period consumers that adopt technology B, N_{2A} be the number of second period consumers that adopt technology A, and N_{2B} be the number of second period consumers that adopt technology B. This experiment assumed that prices were set equal to marginal cost, and we recall that P_{A1} = Period 1 Cost Per Unit to Firm A; P_{A2} = Period 2 Cost Per Unit to Firm A; P_{B1} = Period 1 Cost Per Unit to Firm B; P_{B2} = Period 2 Cost Per Unit to Firm B.

The value of a technology to a consumer is $a \cdot N_x$, where a represents the linear network parameter and N_x is the total number of adopters of a particular technology x (where $x = A$ or B). The total welfare from a given experiment may be calculated as follows:

$$\begin{aligned}\text{Welfare from A} = W_A &= a \cdot (N_{1A} + N_{2A})^2 - P_{A1}N_{1A} - P_{A2}N_{2A} \\ \text{Welfare from B} = W_B &= a \cdot (N_{1B} + N_{2B})^2 - P_{B1}N_{1B} - P_{B2}N_{2B} \\ \text{Total Welfare} &= W_A + W_B\end{aligned}$$

One can use these formulae to calculate actual welfare given the adoption choices of the experiment participants. Moreover, the experimenter can calculate the maximum possible welfare by considering what would happen if all consumers adopted technology A, all consumers adopted technology B, or consumers exactly split between A and B with all first period consumers adopting technology A and all second period consumers adopting technology B. The experimenter could then simply compare the actual welfare achieved with the maximum from these latter three calculations.

Appendix Table 1. Experiment Parameters, Predictions, and Welfare Possible Welfare Achieved When There Are 10 Consumers (With a Value of 10 for the Linear Network Externality Parameter)								
Number of Buyers in Period 1 (N1)	Number of Buyers in Period 2 (N2)	Price of Technology A in Period 1 (PA1)	Price of Technology B in Period 1 (PB1)	Price of Technology A in Period 2 (PA2)	Price of Technology B in Period 2 (PB2)	Welfare From Both Groups Adopting A	Welfare From Both Groups Adopting B	Welfare from Period 1 Consumers Adopting A and Period 2 Consumers Adopting B
5	5	25	100	40	25	675	375	250
5	5	25	100	100	50	375	250	125
5	5	25	50	100	25	375	625	250
5	5	25	50	50	10	625	700	325
5	5	5	120	120	5	375	375	450
2	8	25	100	100	25	150	600	430
2	8	10	100	100	25	180	600	460
2	8	10	100	100	80	180	160	20
2	8	25	100	100	90	150	80	-90
2	8	10	180	100	50	180	240	260
8	2	25	100	40	10	720	180	460
8	2	25	100	100	10	600	180	460
8	2	25	35	100	10	600	700	460
8	2	25	50	130	10	540	580	460
8	2	25	100	180	10	440	180	460

Appendix Table 2. Experiment Parameters, Predictions, and Welfare Possible Welfare Achieved When There Are 20 Consumers (With a Value of 7.5 for the Linear Network Externality Parameter)								
Number of Buyers in Period 1 (N1)	Number of Buyers in Period 2 (N2)	Price of Technology A in Period 1 (PA1)	Price of Technology B in Period 1 (PB1)	Price of Technology A in Period 2 (PA2)	Price of Technology B in Period 2 (PB2)	Welfare From Both Groups Adopting A	Welfare From Both Groups Adopting B	Welfare from Period 1 Consumers Adopting A and Period 2 Consumers Adopting B
10	10	25	100	40	25	2350	1750	1000
10	10	25	120	110	35	1650	1450	900
10	10	25	50	100	25	1750	2250	1000
10	10	25	50	50	10	2250	2400	1150
10	10	5	120	120	5	1750	1750	1400
4	16	25	100	100	25	1300	2200	1540
4	16	10	140	100	25	1360	2040	1600
4	16	10	160	100	70	1360	1240	880
4	16	25	100	100	90	1300	1160	500
4	16	10	275	125	50	960	1100	1200
16	4	25	100	40	10	2440	1360	1600
16	4	25	100	150	10	2000	1360	1600
16	4	25	35	150	10	2000	2400	1600
16	4	25	55	150	10	2000	2080	1600
16	4	25	100	275	10	1500	1360	1600

Appendix Table 3. Experiment Parameters, Predictions, and Welfare Possible Welfare Achieved When There Are 30 Consumers (With a Value of 5 for the Linear Network Externality Parameter)								
Number of Buyers in Period 1 (N1)	Number of Buyers in Period 2 (N2)	Price of Technology A in Period 1 (PA1)	Price of Technology B in Period 1 (PB1)	Price of Technology A in Period 2 (PA2)	Price of Technology B in Period 2 (PB2)	Welfare From Both Groups Adopting A	Welfare From Both Groups Adopting B	Welfare from Period 1 Consumers Adopting A and Period 2 Consumers Adopting B
15	15	25	100	40	25	3525	2625	1500
15	15	25	120	110	35	2475	2175	1350
15	15	25	50	100	25	2625	3375	1500
15	15	25	50	50	10	3375	3600	1725
15	15	5	120	120	5	2625	2625	2100
5	25	25	100	100	25	1875	3375	2500
5	25	10	140	100	25	1950	3175	2575
5	25	10	160	100	70	1950	1950	1450
5	25	25	100	100	90	1875	1750	875
5	25	10	275	125	50	1325	1875	1950
25	5	25	100	40	10	3675	1950	2575
25	5	25	100	150	10	3125	1950	2575
25	5	25	35	150	10	3125	3575	2575
25	5	25	50	150	10	3125	3200	2575
25	5	25	100	275	10	2500	1950	2575

REFERENCES

- Arthur, W.B. 1989. Competing technologies, increasing returns, and lock-in by historical Events. *The Economic Journal* 99 (394): 116-34.
- Besen, S.M. and J. Farrell. 1994. Choosing how to compete: strategies and tactics in standardization. *The Journal of Economic Perspectives* 8(2): 117-131.
- Carlton, D.W. and J.M. Perloff. 2005. *Modern Industrial Organization*. Pearson Addison Wesley.
- Davis, D. and C.A. Holt. 1993. *Experimental Economics*. Princeton: Princeton University Press.
- Economides, N. 1996. The economics of networks. *International Journal of Industrial Organization* 14(6): 673-699.
- Katz, M.L. and C. Shapiro. 1986. Technology adoption in the presence of network externalities. *Journal of Political Economy* 94(4): 822-841.
- Katz, M.L. and C. Shapiro. 1994. Systems competition and network effects. *The Journal of Economic Perspectives* 8(2): 93-115.
- Krugman, P. and R. Wells. 2006. *Economics*. New York: Worth Publishers.
- Kwoka, J.E. and L.J. White. 2009. *The Antitrust Revolution: Economics, Competition, and Policy*. New York: Oxford University Press.
- Liebowitz, S. J. and S.E. Margolis. 1994. Network externality: an uncommon tragedy. *The Journal of Economic Perspectives* 8(2): 133-150.
- Pindyck, R.S. and D.L. Rubinfeld. 2009. *Microeconomics*. Upper Saddle River: Pearson Prentice Hall.
- Witt, U. 1997. 'Lock-in' vs. 'critical masses' – industrial change under network externalities. *International Journal of Industrial Organization* 15(6): 753-773.
- Ruebeck, C., S. Stafford, N. Tynan, W. Alpert, G. Ball, and B. Butkevich. 2003. Network externalities and standardization: A classroom demonstration. *Southern Economic Journal* 69(4) 1000-1008.