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Undergraduate Research Journal

THE UNIVERSITY OF TEXAS AT AUSTIN

2002

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LAYOUT + DESIGN

BY JUSTIN GLASSON

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FROM THE EDITORS

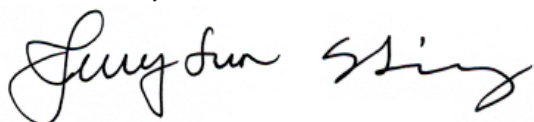
Welcome to the first volume of the University of Texas at Austin Undergraduate Research Journal. The idea for this multidisciplinary journal was born as part of a discussion in the Cabinet of College Councils, the UT Academic Senate, Research and Grants Committee. The purpose of the committee is to find ways to expand interest and access to undergraduate research activity at UT. We immediately became enamored with the idea of an undergraduate research journal because of its ability to be a vehicle for increasing interest in undergraduate research as well as its ability to be a medium for communicating the outstanding work of undergraduate students at the university.

In this first issue, you will find research articles from many disciplines found across our diverse campus. Each article was researched by undergraduate students and written with the purpose of being accessible to the entire university community. We hope that through these articles, you and all the members of the UT community will gain a greater understanding and appreciation of undergraduate work.

If you would like to contribute to future issues of the University of Texas at Austin Undergraduate Research Journal, we invite you to submit an article for our next issue or to become a member of our staff. Please visit our website at www.utexas.edu/research/resources/urj for more information.

We hope that you enjoy the rich and diverse student written and researched articles from across this great university. We now invite you to explore the articles within these pages and to discover new ideas and insights into our world.

Sincerely,



Jerry Sun,
Co-Editor

Sarah Tierney,
Co-Editor

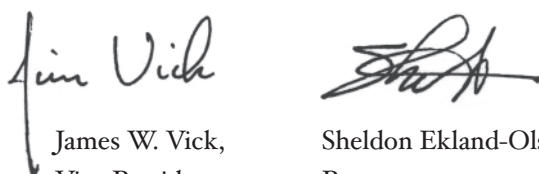
FROM THE VICE PRESIDENT AND PROVOST

Dear Colleagues: We are delighted to introduce the first student publication of undergraduate research at The University of Texas at Austin. This volume represents the broad range of scholarly work being done by our students and the excellent results being produced on our campus and in fieldwork throughout the world. The Cabinet of College Councils has provided a valuable service to our academic community by selecting some of the finest student efforts and publishing the work so that others may benefit from it.

In 1995 the Carnegie Foundation for the Advancement of Teaching created the National Commission on Educating Undergraduates in the Research University, often called the Boyer Commission after its initial presiding member, the late Ernest L. Boyer. Their landmark report proposes ten ways to change undergraduate education. Their first recommendation calls for strengthening student involvement in research, beginning at the earliest levels in the college experience. This publication is a clear indication that our University has already made major strides toward accomplishing the goals of the Commission.

On behalf of our faculty and administration, we congratulate the students who conducted the research reported here and the members of the Cabinet of College Councils whose hard work and dedication have brought this publication from an idea to a finished product. We look forward to expanding opportunities for undergraduate research and continued recognition of the students and their results.

Sincerely,



James W. Vick,
Vice President
of Student Affairs

Sheldon Ekland-Olson,
Provost

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Competition and Pricing Strategies in the Online Marketplace

*The University
of Texas
at Austin*

*Undergraduate
Research
Journal*

*Volume 1
Spring 2002*

Kenny Suttles, *The University of Texas at Austin*

Imperfect information is a large source of friction in the economic markets of today. Imperfectly informed consumers often make decisions that do not maximize their utility. For example, consumers may avoid a new furniture store that they have never been to because they are uncertain of its quality and price. This consumer may choose an inferior-quality or more expensive store that they frequently patronize because they have imperfect information (Bailey 9). The internet is just now becoming a viable alternative to this conventional 'bricks and mortar' medium of commerce. It is now possible for retailers to market and sell their goods online, and for consumers to search and make their purchases online. In the above example if the new furniture retailer were to enter the furniture market through the internet channel, consumers could visit their new store with a simple point and click. The dilemma of imperfect

information would not seem to cause such a problem here in this example furniture market, and in that case, all other online markets.

Is it possible that the internet could lead to better informed consumers and producers who transact at high levels of efficiency in a frictionless online marketplace? Bill Gates, founder of Microsoft, gave his opinion on the matter in his 1995 book, *The Road Ahead*: “Capitalism, demonstrably the greatest of the constructed economic systems, has in the past decade clearly proved its advantages over the alternative systems. The information highway will magnify those advantages. It will allow those who produce goods to see, a lot more efficiently than ever before, what buyers want, and will allow potential consumers to buy those goods more efficiently. Adam Smith would be pleased. More important, consumers everywhere will enjoy the benefits.” (Gates)

Information technology can help consumers find information more easily, thereby reducing the problems of imperfect information that maintains higher prices. Consumers may now be able to make decisions that maximize their utility because information is inexpensive to find and process over the internet. These benefits would result in lower transaction costs in a market exchange (Bailey 10). Furthermore, suppliers may find it more difficult to conceal information from their competitors so that price competition is more likely.

It certainly seems reasonable to assume that the ease of information exchange, which leads to lower search and switching costs online, could provide for a highly efficient, supercharged economy. This paper seeks to find justification for this assumption, and to do this it analyzes the book industry, both its online and conventional channel retailers. In order to analyze online and conventional market efficiency of the book industry, four key efficiency aspects have been identified: price levels, price elasticity, menu costs, and price dispersion.

Four Aspects of Market Efficiency

In a perfectly efficient market the price a consumer pays for a good is exactly equal to the marginal cost of producing and selling that good. Because the costs of selling a good is lower in the internet channel, due to

not operating expensive physical stores, we would expect to see lower prices on the internet versus bricks and mortar prices. Also, the costs to enter the market are much lower in the online channel than in the conventional channel, therefore existing firms can not easily exercise market power by setting prices above marginal costs for fear a challenger may enter with a lower price and steal their market share. This characteristic of internet markets may also lead to lower prices online. Still further downward pressure on internet prices should come from the fact that lower online search and switching costs allow for better price comparison on the internet. There are two studies which have measured price levels in the online and conventional channels for books. The first of these two was done on 1996 book prices. The researcher found prices for books to actually be higher online versus bricks and mortar prices (Bailey 83). This finding runs counter to the efficiency theories outlined above, which predict prices to be lower on the internet. The author attributed his findings primarily to market immaturity. The second study was performed on book prices from 1998-1999. The authors found online prices for books to be 9-16% lower than conventional outlet prices (Smith, Bailey, Brynjolfsson 3). From the data collected by this thesis, shown in Tables 1 and 2 of the Appendix, internet prices for books in 2001 were found to be, on the average, 14% lower than the conventional outlet prices. There are two retailers in this study who operate both an online outlet and a conventional outlet for their books. In both cases these two retailers charge significantly lower prices for the same book in their online outlet versus their conventional stores. This is more evidence that online prices for books are indeed significantly lower than bricks and mortar prices. A downward trend in online prices for books becomes apparent when studying the results of these three studies. Online prices were higher in 1996, then came down in 1998-1999, and were on the order of 14% lower in 2001. These findings would be consistent with an argument stating that the internet has matured and become more efficient as a medium for commerce between the years of 1996 and 2001.

The second efficiency aspect for the book industry

is price elasticity. Price elasticity measures how sensitive consumers are to changes in prices. If a small change in the price of a good leads to a large change in consumer demand for that good, then the consumers are said to be highly price elastic, or price sensitive. If a large change in price triggers a small change in consumer demand, then the consumers are said to have low price sensitivity. Search and switching costs are much lower in internet markets, than in conventional markets, and therefore consumers can easily and efficiently shop around the internet for the best deals on the goods they wish to buy. This fact would be expected to lead to highly price-sensitive online consumers. But the empirical evidence to date does not support this conclusion. A 1998 study on internet price elasticity compared the price sensitivity of groceries sold through conventional and electronic outlets. They found that price sensitivity is lower among online grocery shoppers (Degeratu, Rangaswamy, Wu 10). This finding is contrary to the highly efficiency internet marketplace argument. Another study found that in 1997 internet purchases were highly sensitive to local tax rates. In this study consumers were divided into two groups, high local tax payers and low local tax payers. The consumers in this study that were subject to high local tax rates were much more likely to purchase their goods online, and avoid the high taxes (Goolsbee 4). While this study doesn't directly test price elasticity between internet firms, it does point to a high degree of sensitivity between costs online and costs in conventional outlets. The majority of the empirical evidence on price sensitivity online is mixed so far. Therefore, it is hard to say with any degree of certainty if internet consumers are more or less price sensitive than their conventional counterparts.

The third aspect of market efficiency is menu costs. Menu costs are the costs incurred by the retailer when making price changes. Retailers will only make price changes when the benefit exceeds the cost of the change. Therefore low menu costs allow retailers to change their prices much more often and to stay better in line with changes in supply and demand. It is somewhat intuitive to see that in terms of menu costs an internet retailer is more efficient than a bricks and mortar retailer. For example, if the owner of a conventional grocery store

discovers an imbalance in his supply and demand and he therefore decides to make price changes, he must pay someone to physically re-label all of his shelves. Conversely, if the owner of an online grocery store wanted to make the same price changes all she would have to do is change some numbers in a data base of prices. This would be much cheaper for the online retailer to do, and would allow her to make these price changes more frequently, and in smaller increments, meaning she could follow changes in her supply and demand much better than the conventional grocery retailer. All empirical evidence on menu costs point to the fact that they are indeed lower online. A 1998 study found that internet retailers make significantly more price changes than conventional retailers, and concluded that menu costs on the internet are lower (Bailey 30). A 1999 study found internet retailers make price changes that are up to 100 times smaller than the smallest change observed in conventional outlets. Therefore the cost of these changes must be lower online (Smith, Bailey, Brynjolfsson 6).

It is natural to assume that if search and switching costs are lower on the internet, and if consumers are more informed of prices, then price dispersion on the internet should be lower than in conventional outlets. In other words, we would expect to see a small range in prices for identical goods across different online retailers. But this is actually not supported by empirical evidence. A study done on online price dispersion in 1998-1999 found that online prices for identical books differed by as much as 50%, with an average difference of 33% (Smith, Bailey, Brynjolfsson, 6). Needless to say, these are huge price dispersions. From the data gathered on 2001 prices for books, shown in tables one and two, internet prices for identical books at different retailers differ by as much as 38%, with an average difference of 20%, compared to conventional prices which differed by an average of 2.3%. While the price dispersions of the online market are still high in 2001 when compared to the conventional market, there does appear to be a downward trend. Price dispersions went from an average of 33% in 1998-1999, down to an average of 20% in 2001. These high online price dispersion findings are very surprising. It is difficult to support a

high internet market efficiency argument in the face of these high online price dispersions for identical books across different internet retailers.

Sources for Online Price Dispersion

There are several possible sources for the high degree of price dispersion found in the online outlet for books. The first of these possible sources is price discrimination. Price discrimination occurs when a retailer charges different prices to different categories of consumers based on their willingness to pay. If the online book retailers were able to successfully identify different groups of consumers and to effectively charge them different prices, high degrees of price dispersion could exist. The best form of price discrimination apparent in online commerce today is one in which different convenience levels are matched with different price levels, and time sensitive consumers are discriminated against. This is done through a "price matching" policy, by retailers like buy.com and books.com (who was recently bought out by BarnesandNoble.com). For example, if a customer were to be in the closing stages of purchasing a book through buy.com, she would be given the opportunity to have buy.com's central computers query a group of competitors prices for that same book. If a better price were to be found at a competitors web site, she would be allowed to purchase the book at the competitors lower price, on buy.com's web site. On the surface it may seem that buy.com is providing a valuable service for its customers, but in reality this is a form of price discrimination, which is stealing away consumer surplus and turning it into producer surplus. What makes this a form of price discrimination is that this price matching function is difficult to find and takes a significant amount of time and effort to complete. The consumers who place high values on their time will not engage in the price matching, and will opt to pay the higher price. In their minds it is not worth the 10% discount to waste ten minutes of their time on price matching. These time sensitive consumers are being discriminated against through higher prices. Another possible way for online retailers to price discriminate against their consumers is for them to identify which consumers are likely to

pay more for a particular product. For example, if a consumer had been repeatedly purchasing mystery novels from Amazon.com and wished to buy another one from Amazon.com, they may be charged a higher price for the book than other consumers because Amazon knows how highly this consumer values mystery novels, based on his purchase history. In fact, Amazon.com recently got into some hot water with their customers for doing exactly this. A study done by Computerworld discovered that Amazon.com was charging different prices to different consumers for identical DVDs. For example, on a September Tuesday at 2:40 p.m. a search for the *Planet of the Apes* DVD on the Amazon site that Computerworld conducted using a Netscape Web browser turned up a quoted price of \$64.99. But several seconds later, a similar search performed with Microsoft's Internet Explorer browser resulted in a price of \$74.99 for the same product. Amazon responded to the situation by saying, "We've learned that certain aspects of our site resonate with customers in different ways, and we are continually fine-tuning our site presentation to see how these variables affect customers' purchasing decisions....Amazon is testing the prices on select merchandise in its DVD store for a limited time, so different shoppers could indeed be charged different prices for the same product" (Rosencrance).

The more information online retailers are able to gather on their consumers, the better they will be able to identify their propensity to pay. There are actually retail software packages out today that allow the online retailer to gather and sort a large amount of information on their customers, and then to charge different prices to different customers based on this information. An example of a software package like this is Broadvision's Retail Commerce Suite. BroadVision describes this software package as "Enabling retailers to unlock vital data that helps identify their best customers, BroadVision's retail solution analyzes consumer buying behavior, and presents personalized, dynamic content tailored to individual customer preferences." Software packages like this may make it possible for online retailers to price discriminate with very high degrees of success in the future, which could possibly provide for

even higher levels of online price dispersion.

High online price dispersion may also arise from lock-in. Lock-in occurs when a retailer has found a way to successfully convince his first time customers to become repeat customers, and not to switch to other retailers. The retailer may charge a price premium once the customers are “locked in” to his web page. Lock-in is accomplished by increasing the customer switching costs. Customer switching costs can be increased in several ways. First of all, the online retailer can create loyalty programs, in which repeat purchases are rewarded with higher levels of discounts. This creates utility for the customer if he stays with the same retailer, and a switching cost if he decides to change retailers. Another way is to store customer billing and shipping information in order to make it more convenient for the customer to continue using the same retailer. If the customer wanted to switch over to a different retailer she would have to re-enter all of her billing and shipping information, which is a time consuming process, and a source of switching costs. Also, the online retailer can use the customers purchasing history to make personal recommendations. In the example used before about the customer who had been repeatedly buying mystery novels from Amazon.com, Amazon could use that information to personally recommend the most popular mystery novels to him every time he logs on to the Amazon.com home page. This is a source of utility for this consumer in that he benefits from being notified of the new, popular mystery novels. If he decides to switch to a different online book retailer, he has a switching cost equal to the amount of utility derived from Amazon.com’s personal mystery novel recommendations. Once the switching costs are leveraged against the consumers, the retailer can then begin to charge price premiums. These price premiums could be a source for the high levels of price dispersion seen in the online marketplace.

The most probable source for online price dispersion is differences in consumer trust for, and awareness of, online retailers. The retailers with the highest levels of awareness and trust may be able to sustain large price premiums. This is due to two facts: one, that consumers will only buy from retailers that they are aware exist,

and two, that consumers will pay higher prices to retailers they trust and feel comfortable with. Therefore it is hypothesized that prices will be highest in the online retailers that have the highest levels of trust and awareness, and prices will be lowest in the online retailers that have the lowest levels of trust and awareness. In order to quantify retailer trust and awareness levels, survey data was gathered. It was further hypothesized that the correlations between trust, awareness, and price would be strongest in groups of people who are not as computer literate. People who do not know how to use the internet efficiently for shopping and comparing prices online, may get stuck at the larger expensive more well known retailers. People who have a lot of experience with computers and the internet may have a better understanding of how to successfully compare prices online, giving them the ability to locate the smaller, more inexpensive retailers. To test these hypotheses survey data on trust and awareness was gathered from two different groups of people, college students and non-college students. The college student group will act as a proxy for the computer savvy group, and the non-college student group will proxy for the less computer literate group. A summary of the survey used, and its results can be seen in tables three and four.

In order to see how awareness correlated to price, the retailers in this study were ranked based on the results. For example, the retailer with the highest level of consumer awareness was assigned a rank of 1, and the retailer with the lowest level of consumer awareness was assigned a rank of 7. The retailers were then assigned a price ranking. The most expensive retailer was assigned a price ranking of 1, and the cheapest retailer was assigned a price ranking of 7. The retailers were ranked on their trust levels in the same way, a 1 signifies the most trusted retailer, while a 7 signifies the least trusted retailer. The retailers were also ranked on their size. Quarterly revenue was used as a proxy for size, and the company with the highest quarterly revenue was assigned a rank of 1, while the lowest quarterly revenue company received a rank of 7. The results of these rankings can be seen in tables five and six. A rank correlation coefficient was used to calculate the correlation between trust

and price, awareness and price, and quarterly revenue and price, for both groups of people. For the college student group, trust correlated to price with a coefficient of .643; awareness correlated to price with a coefficient of .607; and quarterly revenue correlated to price with a coefficient of .429. While these correlations are not quite statistically significant, they do still suggest some sort of relationship between these variables. The same rank correlation coefficients were calculated for the non-college student group as well, and the results were much stronger. Trust correlated to price with a coefficient of .857; and awareness correlated to price with a coefficient of .893. Both of these results are strong enough to be significant at the 95% confidence level. The fact that the correlations were much stronger with the non-college student group suggests that the less computer savvy online shoppers do indeed get stuck at the more pricey internet retailers. The correlation between quarterly revenue and price also suggests that it is the larger companies that are charging the highest prices. The small retailers have low levels of trust and awareness, and therefore must charge low prices in order to try and attract consumers. It is now easy to see how different prices for the same product may arise, due to differences in consumer trust and awareness, and how this may contribute to large levels of online price dispersions.

Conclusion

This thesis began by analyzing the hypothesis that the ease of information exchange on the internet will allow it to become a highly efficient medium for commerce. In highly efficient markets we find a small range in prices, which are only slightly above marginal costs. To explore the efficiency of online commerce, four key aspects of market efficiency were identified, price levels, price elasticity, menu costs, and price dispersion. These four efficiency dimensions were then applied to the book industry in order to prove or disprove that the internet is a more efficient medium for commerce than the physical bricks and mortar outlets. Through the

book pricing data that was collected, prices were found to be lower on the internet, when compared to the conventional retailers, and falling since 1996. A review of the relevant literature showed that price elasticity is neither higher nor lower on the internet. The literature also showed that menu costs are without a doubt lower on the internet. But the pricing data gathered showed that price dispersions are much higher in the internet channel versus the conventional channel. The fact that prices are much more disperse on the internet is a significant finding, and this thesis spent its remaining time explaining where the high online price dispersion may arise from. It was shown that one significant source is price discrimination. Internet retailers may have a high ability to price discriminate, due to both the vast amount of information they are able to gather on their consumers, and to software packages like Broadvision's Retail Commerce Suite, which allow them to deliver personalized content to different consumers based on certain individual characteristics like purchase history and web browser. Lock-in and shopping convenience may play bigger roles in sustainable price premiums online than they do in the physical markets, leading to higher levels of price dispersion. But the most significant source of price dispersion arises from differences in consumer trust and awareness. It was shown that the prices retailers charge correlate very strongly with their levels of consumer trust and awareness.

The evidence is mixed on the current state of internet commerce. It is difficult to say if it is currently more efficient or not. Prices and menu costs may be lower online, but price dispersions are higher. But it does seem possible to speculate about the future of online commerce. Prices are continuing to fall lower, and to gravitate to smaller and smaller ranges. Perhaps as more and more consumers gain access to the internet along with the ability to successfully shop and compare prices online, the internet will surpass the conventional channel in efficiency, and through near Bertrand competition come close to resembling the theoretical model of perfect competition.

Appendix: Tables and Data Analysis

Table 1 PRICES CHARGED FOR TEN RANDOM TITLES BY ONLINE RETAILERS

Retailer	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
Amazon.com	\$27.95	\$20.00	\$9.90	\$11.65	\$13.50	\$17.10	\$11.65	\$6.29	\$13.50	\$24.00
BarnesandNoble.com	\$22.00	\$20.00	\$9.90	\$11.65	\$13.50	\$15.20	\$12.95	\$6.29	\$13.50	\$24.00
iBookStreet.com	\$33.54	\$17.00	\$9.90	\$11.66	\$13.50	\$16.15	\$11.66	\$6.29	\$13.50	\$25.50
Buy.com	\$27.95	\$20.00	\$10.23	\$10.23	\$11.85	\$13.49	\$10.23	\$5.52	\$11.85	\$20.40
Borders.com	\$20.96	\$15.00	\$11.01	\$11.01	\$12.75	\$14.25	\$11.65	\$5.94	\$12.75	\$22.50
BooksaMillion.com	\$27.95	\$14.00	\$10.36	\$10.36	\$12.00	\$13.30	\$10.36	\$5.59	\$12.00	\$21.00
Ecampus.com	\$22.29	\$17.67	\$8.77	\$10.32	\$11.96	\$15.15	\$10.32	\$6.29	\$13.50	\$23.92
% Price Difference=	37.5%	30%	20%	12%	12%	22%	21%	12%	12%	20%

Avg. % Price Difference= 20.0%

Table 2 PRICES CHARGED FOR TEN RANDOM TITLES BY BRICKS AND MORTAR RETAILERS

Retailer	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
Barnes and Noble	\$27.50	\$20.00	\$11.00	\$12.95	\$15.00	\$19.00	\$12.95	\$6.99	\$15.00	\$30.00
Borders	\$27.95	\$20.00	\$11.00	\$12.95	\$15.00	\$19.00	\$12.95	\$6.99	\$14.00	\$30.00
Book People	\$27.65	\$20.00	\$11.00	\$12.95	\$14.00	\$19.00	\$12.95	\$6.99	\$15.00	\$27.50
B Dalton Booksellers	\$27.50	\$20.00	\$11.00	\$12.95	\$15.00	\$19.00	\$12.95	\$6.99	\$15.00	\$30.00
% Price Difference=	2%	0%	0%	0%	7%	0%	0%	0%	7%	8%

Avg. % Price Difference= 2.33%

Table 3 COLLEGE STUDENT GROUP RESULTS

	Amazon	BN	Borders	iBookstreet	Buy	BAM	Ecampus
Heard of It?	56	54	30	4	43	5	19
Visited It?	49	33	7	1	23	0	5
Bought Anything?	34	10	1	0	11	0	2
Purchase Rate=	69.4%	30.3%	14.3%	0.0%	47.8%	0.0%	40.0%

	1	2	3	4	Average Trust Level
Amazon	0	3	19	34	3.55
BN	1	3	23	29	3.43
Borders	13	12	22	9	2.48
iBookstreet	29	18	8	1	1.66
Buy	12	11	21	12	2.59
BAM	27	21	6	12	2.41
Ecampus	21	23	8	4	1.91

Table 4 | NON-COLLEGE STUDENT GROUP RESULTS

	Amazon	BN	Borders	iBookstreet	Buy	BAM	Ecampus
Heard of It?	23	20	12	3	16	2	0
Visited It?	21	11	0	0	6	0	0
Bought Anything?	15	3	0	0	3	0	0
Purchase Rate=	71.4%	27.3%	0.0%	0.0%	50.0%	0.0%	0.0%

	1	2	3	4	Average Trust Level
Amazon	0	0	6	17	3.74
BN	0	0	10	13	3.57
Borders	3	3	11	6	2.87
iBookstreet	7	6	10	0	2.13
Buy	2	5	12	4	2.78
BAM	10	4	9	0	1.96
Ecampus	11	4	8	0	1.87

Table 5 | RANKINGS FOR THE COLLEGE STUDENT GROUP

	Trust Ranking	Awareness Ranking	Quarterly Revenue	Price Ranking
Amazon	1	1	3	1
BN	2	2	1	2
Borders	4	4	2	5
iBookstreet	7	7	7	3
Buy	3	3	4	4
BAM	5	6	5	6
Ecampus	6	5	6	7

Trust to Price Rank Correlation Coefficient = .643	p=.114
Awareness to Price Rank Correlation Coefficient = .607	p=.136
Quarterly Sales to Price Rank Correlation Coefficient = .429	p=.294

Table 6 | RANKINGS FOR THE NON-COLLEGE STUDENT GROUP

	Trust Ranking	Awareness Ranking	Quarterly Revenue	Price Ranking
Amazon	1	1	3	1
BN	2	2	1	2
Borders	3	4	2	5
iBookstreet	5	5	7	3
Buy	4	3	4	4
BAM	6	6	5	6
Ecampus	7	7	6	7

Trust to Price Rank Correlation Coefficient = .857	p=.036
Awareness to Price Rank Correlation Coefficient = .893	p=.029
Quarterly Sales to Price Rank Correlation Coefficient = .429	p=.294

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Perceptions, Attitudes, and American Public Opinion toward Skilled Asian Immigrants

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Guest labor programs are one of the most complex issues confronting United States immigration policy. The aim of guest labor programs is to add workers to the labor force at times of labor shortage without adding permanent residents to the population (Martin 1). Previous guest labor programs have left behind complex, unresolved issues that continue to plague existing programs (e.g. the permanent stay of temporary workers, economic competition with native workers, and racial resentment). The H-1B program is a guest labor program to allow skilled foreign workers to temporarily work in the U.S. for up to six years. Since the early 1990s, computer industry CEOs have claimed a shortage of workers with technical skills and lobbied Congress to increase the number of H-1B visas.

Nevertheless, the longevity of any guest labor program is dependent upon the American sentiment toward foreign workers

and their views of the economic and social contributions made by these immigrants. Americans who view the influx of foreign workers as a threat to the jobs of native workers or the welfare of American society will intensify their campaign to reduce or abolish the H-1B visa quota. The U.S. government's ideology of "government by the people" guarantees that the attitudes of the majority will transpire in legislation. However, the government is concerned that if domestic access to skilled workers is limited or denied, high technology firms in the U.S. may relocate to other countries where there is an abundance of skilled and cheap labor. Thus, it is important to assess the current American public opinion toward skilled foreign immigrants.

Background

Immigration policies are historically affected by racial context. From the 1840s to 1870s, Chinese laborers migrated to the U.S. to fill the labor shortage in mines and railroad construction (Kitano and Daniels 4). After their initial welcome, their race became an issue that perpetuated a series of legal and illegal actions including lynching, murders, and race riots. Anti-Chinese sentiment culminated in The Chinese Exclusion Act of 1882 in which Congress enacted immigration legislation excluding "idiots," "lunatics," and "Chinese laborers" (Hing 1). In time, other immigration policies were enacted to forbid the immigration of every Asian group.

At the time, U.S. immigration law defined one's national-origin as the criterion for entry. These discriminatory policies coupled with anti-Asian sentiment in the U.S. resulted in the dramatic decline in the number of immigrants from China, India, and other Asian countries. Exclusion of Asians, rather than restriction, became the law of the land (Kitano and Daniels 14). Driven by World War II politics and the desire to form alliances in Asia, exclusion policies toward Asians began to relax in 1943, starting with the repeal of The Chinese Exclusion Act (Kitano and Daniels 16). U.S. immigration policy was dramatically revised in 1965. Though designed to encourage European immigration, The Immigration Act of 1965 allowed the Asian immigration population to jump from one million in 1965 to seven million in 1990 (Hing 40).

Since the late 1980s, a large percentage of Asian laborers have been re-invited into the U.S. in order to fill another labor shortage. Instead of filling the labor-intensive jobs of the old economy, these technically savvy Asian laborers have been invited to fill the shortage of computer programmers, scientists, and engineers in the new economy. The U.S. Immigration and Naturalization Service reported that India and China held 56.8% of the H-1B visas (Wayne 1). Refer to Table 1 for the number of H-1B visas granted by country.*

The H-1B visa program had its roots in the temporary visa programs begun in the 1950s, but it took off in the 1980s and again in the late 1990s as high-technology industries blossomed (Wayne 1). The issuance of H-1B visas has steadily increased to 195,000 yearly visas in 2001 as high-technology companies lobbied Congress to demand more skilled foreign workers.

Theory

A conglomerate of influences shape Americans' perception toward Asian immigrants. Respondents with personal or familial immigration experiences are often able to identify with the push or pull factors that propel emigration from one's motherland. Thus, these respondents are more likely to support guest labor programs that afford immigrants the same opportunities as they had received. Respondents who have contact with Asians are influenced by their subjective experiences. In general, those with positive experiences are more likely to support Asian immigration, while those with negative experiences are less likely to agree.

Conversely, common stereotypes of Asian Americans in the media, based on accurate, yet infrequent cases, lead to negative attitudes toward Asian immigrants. Respondents who are detached from the immigration experience or have less contact with the Asian American population are more likely to be primarily influenced by the media's negative stereotypes. In the 1960s, the media began to promote the model minority theory through statistic-laden articles depicting Asian Americans as an exceptionally accomplished and industrious minority group (Chang, Kong, Shih, and Wu 1).

*See Appendix for Tables and Figures, pp. 16-21

Since the late 1960s, the media has continued to selectively report success stories of a few Asian immigrants attaining the “American Dream,” rather than the political, economic, social, and educational challenges faced by a large part of the Asian American population. This inaccurate portrayal has resulted in a stereotype among Americans, predominately White, that Asian Americans are doing better than other minority groups and enjoy a status comparable to the wealthy White population. A similarly misleading stereotype portrays Asian immigrants as those who are ill-equipped to compete in American society and pose to be a drag on the American economy (Hing 10). Television shows and Hollywood movies often associate Asian immigrants with sweatshops, ethnic ghettos, illegal activities, and other unflattering images.

Both stereotypes of the Asian population not only aggravate existing racial tension but also influence American public opinion toward arriving Asian immigrants. On the one hand, skilled Asian immigrants may be perceived as “super beings” whose aim is to compete for skilled positions in the high-technology industry. This image raises a fear of unfair competition from these “super beings” that is reminiscent of what led to the desire to control their immigration numbers in the past (Hing 11). Native workers, especially those working in the high-technology industry, may believe in a direct displacement of jobs—one more job taken by a foreign worker is equated with one less job for a native worker. On the other hand, Americans may view Asian immigrants as an economic and social burden on American society. Both views of the Asian American population in the U.S. foster negative perceptions toward Asian immigrants. Refer to Figure 1 for a diagram of the theory described above.

Methods

To evaluate the American public opinion toward skilled Asian immigrants, I utilized survey data collected between May and August 2001. Two hundred forty-one U.S. citizens participated by responding to a series of written questions concerning their views toward skilled immigrants and inquiries of demographic information. The survey questionnaire utilized the indirect method

to identify attitudes toward skilled Asian immigrants.

Survey data was collected in Austin, Texas, often referred to as the “Silicon Hills.” Austin is the hub of major technology based companies, such as Motorola and IBM, who employ skilled Asian immigrants. According to The Department of Labor data, technology companies across the country received permission to hire 9,404 foreign workers for jobs based in Austin and nearby suburb, Round Rock (Bahadur 1). Surveys were distributed at Zilker and Barton Springs public parks, where a diverse population gathers for recreational sports and other special events.

The sample aimed to depict a cross section of American society with participants from different occupations, gender, races, age groups, education levels, and backgrounds. However, due to the limitation of the study population, the sample was not heavily weighted on high technology workers. Thus, the sample of high technology workers is more susceptible to sampling errors. Further study is needed to target high-technology workers. Refer to Table 2 for the number of participants in each demographic category.

The dependent variable of the study was the extent to which the subject agreed or disagreed with each of the statements made on the survey (i.e. U.S. high-technology firms should import skilled foreign workers to fill skilled labor positions). The response was categorized on a 5-point scale, with “strongly disagree” scored as 1, “disagree” as 2, “neutral” as 3, “agree” as 4, and “strongly agree” as 5. The “don’t know” response was an option outside of the 5-point scale; it was coded as 0. However, for purposes of data analysis, only three categories, “disagree,” “neutral,” and “agree,” were created. “Don’t know” responses were not included in the data analysis, and the “strongly agree/disagree” responses were combined with the “agree/disagree” categories.

Demographic variables incorporated into the study included the respondent’s occupation, gender, race, age, education, and whether or not a respondent was born in the U.S. The impact of these predictors on the respondents’ opinions toward skilled foreign workers was examined using the Pearson chi-square test. This statistical tool was used to evaluate the statistical signifi

cance of the relationship between the independent and dependent variables.

Results

The results indicated the following: (1) High-technology workers born outside of the U.S. held more favorable attitudes toward importing foreign workers. (2) Asian Americans held more favorable attitudes toward importing foreign workers and less concerns on the adverse effects of immigration. (3) Hispanic Americans perceived skilled Asian workers to have made more technical and economic contributions than European workers. (4) Highly educated Americans had more concerns of the economic effects of immigration.

High Technology Workers

There is a significant relationship between respondents' country of birth and their attitude toward importing skilled foreign workers. The difference in the responses of high technology workers born in the U.S. and those born outside of the U.S. is too large to be a consequence of sampling error alone. The differences are statistically significant at the 95% confidence interval. Although previous studies are inconclusive regarding a real shortage in the high-technology industry, the difference in opinion between these two groups is interesting in itself (Matloff 4). Seventy-one percent of high-technology workers born outside of U.S. believed there was a labor shortage in the high-technology industry, while 41% of high-technology workers born in the U.S. believed in the same statement. Furthermore, 64% of high-technology workers born outside of the U.S. supported the importation of skilled foreign workers to fill skilled labor positions, while 26% of workers born in the U.S. supported the same statement. Thus, high technology workers born outside of the U.S. borders are more likely to believe in the existence of a labor shortage of skilled workers and support the importation of skilled foreign workers.

Asian Americans

The race of the respondents impacted their attitude toward skilled Asian immigrants. Asian Americans are more likely than Whites to agree that the economic

contributions made by Asian immigrants have contributed to the economic expansion (see Table 5). The difference in responses between Asian Americans and Whites is statistically significant at the 90% confidence interval. Ninety-one percent of Asian Americans responded favorably concerning the contributions of skilled Asian immigrants, while 71% of Whites affirmed the same statement. While Asian Americans favored training U.S. citizens to fill skilled high-technology positions, the group also held more favorable opinions of importing skilled foreign workers to fill the shortage of skilled labor than Whites (see Table 3). Furthermore, Asian Americans were less likely to be concerned that increasing the number of skilled foreign workers in the U.S. may negatively affect national security (see Table 7).

Hispanic Americans

The Hispanic population perceived Asian immigrants to have made more contributions to the development of advanced technology and the economic expansion than skilled European immigrants (see Table 4 and Table 5). Thirty-eight percent of Hispanic respondents, compared to 59% of the White respondents, agreed that Europe immigrants have contributed to the development of more advanced technology. The difference is statistically significant at the 95% confidence interval. Forty-three percent of Hispanic respondents, compared with 79% of the White respondents, agreed that European immigrants have contributed to the economic expansion. The difference is statistically significant at the 99% confidence interval.

Americans with Higher Education

Americans with post-graduate degrees are more likely than those with a 2-4 year college degree to view skilled foreign workers as a direct displacement of U.S. workers. 46% of the respondents with post-graduate degrees believed that one more job filled by a skilled foreign worker is one less job for a skilled American worker, while 34% of the respondents with 2-4 year college education agreed with the same statement (see Table 6). The difference in the responses is statistically significant at the 95% confidence interval.

Discussion

This study identified demographic variables that affected Americans' perceptions of skilled Asian immigrants. The following are possible explanations of the above results. Future research examining each of the demographic variables will assess the validity of these explanations.

High Technology Workers

The saturation of skilled foreign workers, especially those of Asian descent, in the high-technology industry has led to differing views concerning the importation of skilled foreign labor. A large percentage of existing high-technology workers were either previous holders of the H-1B visa or have immigrated to the U.S. (Donnelly 6). Respondents with such experiences may identify with the immigration experience and may be familiar with the push and pull factors that propel emigration. Thus, their own experience as a H-1B visa worker or immigrant might have influenced the disparity of attitudes between skilled workers born in and outside of the U.S.

The first area of disparity is identifying the existence of a labor shortage in the high technology industry. The native-born high technology respondents believed there is little shortage, while the foreign born high-technology respondents believed a shortage of skilled labor exists in the U.S. These different opinions are crucial for understanding the complexity of the H-1B visa issue. If no shortage exists, the aim of the H-1B visa program to import more skilled labor is nullified. Secondly, these two groups differ on whether skilled foreign workers ought to be imported. Using the previous question as a point of reference, it is not surprising that native-born workers disagreed at a greater extent when compared with foreign-born workers. If native-born workers did not realize the existence of a shortage of skilled workers, there is no reasonable explanation for importing skilled foreign labor.

Asian Americans

Asian Americans, like other minority groups, broadcast the outstanding accomplishments of individuals from the ethnic group to their community. Ethnic enclaves print and circulate ethnic newspapers, often her-

alding the accomplishments of Asian workers. Access to positive news reports may have affected the responses of Asian Americans. Furthermore, the extensive kinship and family networks among Asian Americans is conducive for the spread of positive information about the successes of family members in their respective fields. Therefore, it is not surprising that Asian Americans responded favorably concerning the contributions of skilled Asian immigrants and were more likely to agree with the importation of foreign workers.

Since the majority of Asian Americans immigrated to the U.S. as a result of The Immigration Act of 1965, many still recollect their personal or familial immigration experience. Recollections of their own experience may have caused them to be more sympathetic toward skilled Asian workers. Asian Americans are less likely than Whites to believe that immigration poses a threat to U.S. national security. It may be difficult for Asian communities with their close kin-networks to view anyone in their community as a threat to the societal welfare of the U.S. After scientist Wen Ho Lee was vindicated of 59 charges of Communist espionage in 2000, Asian Americans may even view the use of national security to legitimize tighter immigration policies as racial discrimination.

Hispanic Americans

Hispanic Americans held less favorable views toward skilled European immigrants than Asian immigrants. No evidence suggests that skilled Asian immigrants have made more technical or economic contributions than European workers. The racial background of European immigrants might explain these disparities. Among the Hispanic population, racial discrimination toward Whites may exist. This might be a sign of racial tension caused by a history of racial conflicts between the two groups. Furthermore, ethnic enclaves tend to centralize in the same areas; the proximity of Hispanic ethnic enclaves to Asian enclaves may attribute to more interaction between the two groups and, thus, result in more favorable perceptions of Asian workers than Europeans.

Americans with Higher Education

In general, respondents with higher education are inclined to view foreign workers as taking away the jobs of native workers. Respondents with higher education are often employed in skilled positions that are directly affected by the importation of skilled foreign workers. The group is most prone to face competition from H-1B holders and more likely to hold negative views of the economic effects of guest labor programs.

Future Research

This study identified segments of the U.S. population in which attitudes toward skilled Asian immigrants were significantly different from other demographic groups. Attitude differences among the demographic variables may be related to a conglomerate of influences, such as each group's immigration experience, interaction with Asians, media influences, economic opportunities, and many others.

Further investigations will seek to understand the complexity of influences that shape each demographic group's perceptions toward skilled Asian immigrants. Future research methods will include in-depth interviews, survey, and historical analysis with each of the demographic groups identified in this study.

Author's Note

The terrorist attack on September 11, 2001, in which at least one of the terrorists involved held a student visa, may have dramatically changed the perceptions of Americans toward immigrants. Future research is necessary to assess the magnitude of the event's impact on future U.S. immigration policies.

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Appendix: Tables and Figures

Table 1 | H-1B PETITIONS APPROVED BY COUNTRY OF BIRTH IN FEB. 2000

Country of Birth	Estimate	Total
All countries	100	"134,400"
India	47.5	"63,900"
China	9.3	"12,400"
United Kingdom	3.2	"4,400"
Canada	3	"4,000"
Philippines	2.7	"3,700"
Korea	2.3	"3,100"
Taiwan	2.1	"2,800"
Japan	2	"2,700"
Other Countries	27.8	"37,400"

Source: U.S. Immigration and Naturalization Service

Figure 1 | INFLUENCES ON PERCEPTIONS OF ASIAN IMMIGRANTS

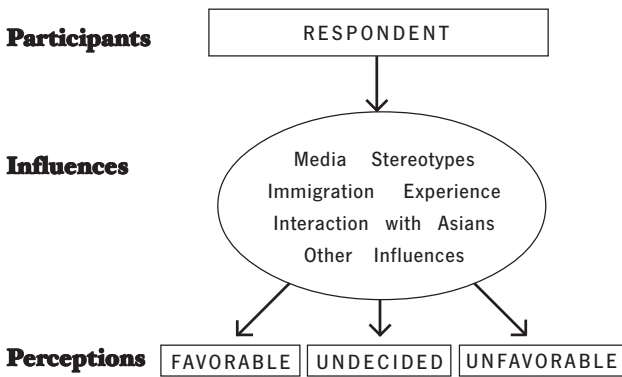


Table 2 | DEMOGRAPHIC DATA¹

Demographic Variables	Number in Category (n)
Occupation:	
High-Tech Workers	52
Non-High-Tech Workers	188
Gender:	
Men	120
Women	120
Race:	
White	158
African American	9
Asian American	20
Hispanic	40
Other	11
Age:	
Aged 20 or under	16
Aged 20 to 29	83
Aged 30 to 39	67
Aged 40 to 49	43
Aged 50 to 59	15
Aged 60 to 69	13
Aged 70 or over	3
Education:	
High School Graduate	48
College Graduate	130
Post Graduate Degree	61
Place of Birth:	
Born in the U.S.	210
Born outside of the U.S.	29

¹ The number of total participants in the study was 241. However, some participants may not have disclosed certain demographic information.

Table 3

AMERICAN PUBLIC OPINION: IMPORT OR TRAIN SKILLED LABOR¹
 (percentage responding by occupation, gender, race, age, education, and place of birth, 2001)

	Import Foreign Skilled Labor				Train U.S. Citizens			
	Agree ²	Neutral	Disagree	Significance ³	Agree	Neutral	Disagree	Significance
Total⁴	30%	25%	43%		83%	9%	4%	
Occupation:				ns ⁵				p<.10
High-Tech Workers	34	29	34		75	17	6	
Non-High-Tech Workers	33	26	40		88	7	3	
Gender:				ns				ns
Men	36	23	40		83	12	5	
Women	27	26	46		90	6	3	
Race:				p<.10				ns
White	27	23	47		87	7	5	
Asian American	45	35	20		80	15	5	
Race:				ns				ns
White	27	23	47		87	7	5	
Hispanic	33	22	45		88	10	0	
Age:				ns				ns
Aged 29 or under	31	31	36		84	8	6	
Aged 30 to 49	28	19	50		87	11	2	
Aged 50 to 70 or over	35	19	38		94	6	0	
Education:⁶				ns				ns
College Graduate	36	27	36		82	12	5	
Post Graduate Degree	30	18	48		93	3	3	
Place of Birth:				p<.01				ns
Born in the U.S.	27	24	47		88	8	3	
Born outside of the U.S.	56	24	17		83	10	7	

1 Survey questions: "U.S. high-tech firms should import foreign skilled workers to fill skilled labor positions."
 "U.S. high-tech firms should cultivate and train U.S. citizens to fill skilled labor positions."

2 Responses in the categories of "strongly agree" and "somewhat agree" were combined and included in the "agree" category. The same is true for the "disagree" category.

3 Significance refers to the Pearson chi-square test (one-tailed).

4 The numbers may not add to 100% because "don't know" responses were not included in the calculations.

5 p value >.10

6 Number of high school graduates was insufficient for effective chi-square analysis.

Table 4 | AMERICAN PUBLIC OPINION: TECHNICAL CONTRIBUTIONS OF ASIAN AND EUROPEAN SKILLED WORKERS¹
(percentage responding by occupation, gender, race, age, education, and place of birth, 2001)

	Asian Workers				European Workers			
	Agree ²	Neutral	Disagree	Significance ³	Agree	Neutral	Disagree	Significance
Total⁴	71%	18%	4%		56%	24%	7%	
Occupation:				ns ⁵				ns
High-Tech Workers	69	21	4		56	27	8	
Non-High-Tech Workers	67	19	1		57	24	8	
Gender:				ns				p < .01
Men	73	17	3		61	24	7	
Women	67	19	3		53	25	6	
Race:				ns				ns
White	70	16	4		59	22	6	
Asian American	85	10	0		70	25	0	
Race:				ns				p < .05
White	70	16	4		59	22	6	
Hispanic	65	25	5		38	38	10	
Age:				ns				ns
Aged 29 or under	70	15	2		54	24	5	
Aged 30 to 49	67	27	5		53	29	7	
Aged 50 to 70 or over	84	10	0		77	10	6	
Education:⁶				ns				ns
College Graduate	74	18	2		59	22	8	
Post Graduate Degree	72	13	6		62	20	5	
Place of Birth:				ns				ns
Born in the U.S.	76	10	3		55	26	7	
Born outside of the U.S.	70	19	3		66	17	3	

1 Survey questions: “Skilled workers from Asia have contributed to the development of more advanced technology in the U.S.” “Skilled workers from Europe have contributed to the development of more advanced technology in the U.S.”

2 Responses in the categories of “strongly agree” and “somewhat agree” were combined and included in the “agree” category. The same is true for the “disagree” category.

3 Significance refers to the Pearson chi-square test (one-tailed).

4 The numbers may not add to 100% because “don’t know” responses were not included in the calculations.

5 p value > .10

6 Number of high school graduates was insufficient for effective chi-square analysis.

Table 5**AMERICAN PUBLIC OPINION: ECONOMIC CONTRIBUTIONS OF ASIAN AND EUROPEAN SKILLED WORKERS¹***(percentage responding by occupation, gender, race, age, education, and place of birth, 2001)*

	Asian Workers				European Workers			
	Agree ²	Neutral	Disagree	Significance ³	Agree	Neutral	Disagree	Significance
Total⁴	71%	18%	4%		56%	24%	7%	
Occupation:				ns ⁵				ns
High-Tech Workers	75	17	4		65	25	4	
Non-High-Tech Workers	72	17	5		58	22	9	
Gender:				ns				ns
Men	71	21	5		60	25	8	
Women	68	17	7		52	21	8	
Race:				p < .10				ns
White	71	19	3		79	8	0	
Asian American	95	5	0		65	25	0	
Race:				ns				p < .0001
White	71	19	3		79	8	0	
Hispanic	63	23	13		43	28	18	
Age:				ns				ns
Aged 29 or under	78	20	2		65	28	7	
Aged 30 to 49	69	21	10		59	30	11	
Aged 50 to 70 or over	86	10	3		11	11	78	
Education:⁶				ns				p < .05
College Graduate	72	17	7		58	18	12	
Post Graduate Degree	66	20	2		56	28	6	
Place of Birth:				p < .0001				p < .0001
Born in the U.S.	67	20	7		53	24	10	
Born outside of the U.S.	86	7	0		76	14	0	

1 Survey questions: "Skilled workers from Asia have contributed to the U.S. economic expansion." "Skilled workers from Europe have contributed to the U.S. economic expansion."

2 Responses in the categories of "strongly agree" and "somewhat agree" were combined and included in the "agree" category. The same is true for the "disagree" category.

3 Significance refers to the Pearson chi-square test (one-tailed).

4 The numbers may not add to 100% because "don't know" responses were not included in the calculations.

5 p value > .10

6 Number of high school graduates was insufficient for effective chi-square analysis.

Table 6 | AMERICAN PUBLIC OPINION: EFFECTS OF IMMIGRATION¹
 (percentage responding by occupation, gender, race, age, education, and place of birth, 2001)

	Skilled Labor Shortage				Direct Displacement of Jobs			
	Agree ²	Neutral	Disagree	Significance ³	Agree	Neutral	Disagree	Significance
Total⁴	47%	12%	33%		42%	16%	40%	
Occupation:				p < .10 ⁵				ns
High-Tech Workers	48	6	44		33	15	52	
Non-High-Tech Workers	46	18	34		41	15	42	
Gender:				ns				ns
Men	48	17	33		41	17	42	
Women	46	15	34		43	16	39	
Race:				ns				ns
White	44	14	34		44	14	41	
Asian American	55	20	25		30	30	40	
Race:				ns				ns
White	44	14	34		44	14	41	
Hispanic	33	23	38		45	13	40	
Age:								ns
Aged 29 or under	43	15	39	ns	33	20	45	
Aged 30 to 49	46	19	28		45	15	39	
Aged 50 to 70 or over	61	6	26		42	16	39	
Education:⁶				p < .10				p < .05
College Graduate	42	15	38		34	14	45	
Post Graduate Degree	62	11	25		46	10	41	
Place of Birth:				ns				ns
Born in the U.S.	45	16	35		38	16	38	
Born outside of the U.S.	62	17	17		28	14	55	

¹ Survey questions: “There is a shortage of skilled workers in the U.S. high-tech market.” “One more job filled by a foreign skilled worker is one less job for an American skilled worker.”

² Responses in the categories of “strongly agree” and “somewhat agree” were combined and included in the “agree” category. The same is true for the “disagree” category.

³ Significance refers to the Pearson chi-square test (one-tailed).

⁴ The numbers may not add to 100% because “don’t know” responses were not included in the calculations.

⁵ p value > .10

⁶ Number of high school graduates was insufficient for effective chi-square analysis.

Table 7

AMERICAN PUBLIC OPINION: EFFECTS OF IMMIGRATION¹
(percentage responding by occupation, gender, race, age, education, and place of birth, 2001)

	Economic Burden				Threat to National Security			
	Agree ²	Neutral	Disagree	Significance ³	Agree	Neutral	Disagree	Significance
Total⁴	28%	20%	51%		22%	13%	59%	
Occupation:				ns ⁵				ns
High-Tech Workers	21	21	54		13	19	63	
Non-High-Tech Workers	28	20	51		20	14	60	
Gender:				ns				ns
Men	26	17	56		21	13	60	
Women	31	23	45		23	18	57	
Race:				ns				p<.05
White	27	17	54		22	12	60	
Asian American	20	25	50		5	30	60	
Race:				p<.10				ns
White	27	17	54		22	12	60	
Hispanic	38	28	33		33	15	50	
Age:				ns				ns
Aged 29 or under	26	22	48		16	19	58	
Aged 30 to 49	30	18	52		25	9	59	
Aged 50 to 70 or over	26	19	52		58	10	26	
Education:⁶				ns				ns
College Graduate	23	22	52		19	15	60	
Post Graduate Degree	28	16	54		18	8	67	
Place of Birth:				ns				ns
Born in the U.S.	25	20	50		23	12	58	
Born outside of the U.S.	28	14	56		10	21	59	

1 Survey questions: "Foreign skilled workers place an economic burden on the U.S." "Increasing foreign skilled workers in the U.S. may negatively affect U.S. national security."

2 Responses in the categories of "strongly agree" and "somewhat agree" were combined and included in the "agree" category. The same is true for the "disagree" category.

3 Significance refers to the Pearson chi-square test (one-tailed).

4 The numbers may not add to 100% because "don't know" responses were not included in the calculations.

5 p value >.10

6 Number of high school graduates was insufficient for effective chi-square analysis.

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Wolf's Great Sensitivity Integrating the Poetic Structure and Meaning into Music:

A Musical Analysis of His Lied, An eine Äeolsharfe

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Most music historians and scholars agree that Hugo Wolf contributed significantly to the development of the art song in the second half of the nineteenth century. Eric Sams and Graham Johnson describe this famous and prolific art song composer as “a representative of the opposite end of the spectrum of lied composition [from Schubert]” (677), and indeed, Wolf’s historical status in the lied could be compared to that of Brahms in the genre of symphony. Especially, as a Wagnerian advocate, Wolf achieved a new standard in art song composition in which both the poem and music are treated equally as an inseparable entity. In this model, all the musical devices unmistakably support and reinforce the meanings and connotations of the poem. To this point, Sams and Johnson state: “As an originator rather than a traditionalist, he had to create his own models by assimilating the wide variety of

vocal and keyboard techniques and devices needed to express the deep emotive content of verse” (677). Lawrence Kramer wrote similarly about Wolf’s interest in poetic setting: “[Wolf] understood [poetry] preternaturally well, and ‘expressed’ them to perfection by repeating their sound and meaning in the form of music...Wolf was more intent on perfect declamation than most lied composers, and he made a point of demanding high-quality poetry” (186).

Thus, as these and other music scholars have pointed out, there is no doubt that Wolf deals carefully with the poet’s structure and declamation in his music. The close synthesis of poetry and music interested Wolf to such an extent that he wanted the poem declaimed on stage prior to the performance of his songs. With such a close interaction of poetry and music, it can be insightful to first analyze each of these components independently.

In this regard, I will focus on two main tasks in this paper. First, I will analyze Wolf’s technique of integrating poetic and musical structures into his song, and then discuss the aesthetic impact of his technique. Second, I will analyze Wolf’s extensive use of musical devices to incorporate poetic meaning into his songs. The use of

radical harmonic progressions which deviate from the traditional harmonic idiom, irregular voice leadings, and interesting rhetorical gestures will be emphasized in my discussion with regard to text painting.

Wolf’s collection, *Gedichte von Eduard Mörike*,¹ has many songs that represent his distinctive compositional features. Wolf loved Mörike’s poems more than that of any others because Mörike’s poems contain the psychological depths and avoidance of overt subjectivity, which are Wolf’s concern. The set of Mörike’s Fifty-three songs was composed in one year, between 16 February 1888 and 26 November 1888, and these belong to Wolf’s third stylistic period (Sams and Youens 491-493).² I will analyze his eleventh song, *An eine Äeolsharfe*, which was composed on 15 April 1888. This poem consists of two stanzas. The first stanza has eighteen lines, and the second stanza contains seven. To illustrate how the composer creates a musical structure by integrating its poetic structure in the art song, a careful examination of

¹ This is the song collection published in 1889, which consists of 53 Wolf’s songs using Mörike’s poem.

² Eric Sams and Susan Youens divide Wolf’s stylistic periods into four: the first period is labeled ‘formative year’ (1860 – 1883); the second period ‘years of uncertainty’ (1883 – 1887); the third period as ‘mastery and fame’ (1888-1897); and the fourth ‘breakdown and terminal illness’ (1897 – 1903) (463).

Table 1 THE POETIC STRUCTURE

Stanza	Division by Grammar	Division by Meaning
I (1st-18th)	First: 1st-7th line	First: 1st-7th line – address to the harp
	Second: 8th-11th line	Second: 8th-18th line – description of the harp’s sound played by winds which came from far away
	Third: 12th-18th line	
II (19th-25th)	Fourth: 19th-23rd line	Third: 19th-25th line – connects harp, wind and poet’s soul
	Fifth: 24th-25th line	

Table 2 THE MUSICAL STRUCTURE OF THE LIED, AN EINE ÄEOLSHARFE

Division by Meaning	Musical Structure by Wolf
First: 1st-7th line	A Section – Mm. 1-12: recitative like section
Second: 8th-18th line	B Section – Mm. 13-69: aria like section (An interlude between the second and third of poem)
Third: 19th-25th line	

the poem should precede the musical analysis.

Two ways of considering the poetic structure are possible. First, if one observes this poem from a grammatical and syntactical point of view, he would divide the stanzas into three and two parts, respectively. On the other hand, a consideration of the division by meaning of the poem leads us to divide the poem into three parts. The first part consists of the first to seventh lines in which the poet addresses the harp. The second part is the eighth to eighteenth lines, which describe the harp's sound played by winds that came from far away. The third and final part is the nineteenth to twenty-sixth lines, which draw a connection between the harp, the wind, and the poet's soul. Thus, the first and second parts correspond to the first stanza of this poem, and the third part corresponds to the second stanza of this poem. The poetic structure is summarized in Table 1.

Hugo Wolf must have first carefully observed the poetic structure of this poem, and then attempted to integrate it into the musical structure in a distinctive manner. He takes the poetic meaning as his starting point for designing the large-level musical structure. The music is split into two sections: the first section (mm. 1-12) corresponds to the first part of the poem, and the second section the second and third parts of the poem. In this second section, Wolf continues the same pattern of the music throughout the second and third parts of this poem only once with a four-measure piano interlude between them. [SEE TABLE 2]

The musical structure of this piece resembles a recitative and aria pair of the 18th-century Neapolitan opera. A series of chords in the first section of this lied is reminiscent of a simple accompaniment by the basso continuo, which is used to give a harmonic background for the recitative. The recitative section, where Wolf uses some radical harmonic excursions, is more complex than the following aria in terms of harmony. For example, the recitative section of the piece starts not on a tonic, but on a ii in E major. Also, there are sudden shifts of successive dominant-7th chords at mm. 4-8. [SEE EXAMPLE 1]

On the other hand, the aria section starts with an arpeggio figuration on a clear harmonic background, and offers more lyrical melodies than the first section.

Numbers in George Frideric Handel's operas and oratorios, as exemplars of the 18th-century Neapolitan opera, have a similar musical structure as seen in this lied. The pairing of a recitative, with more chromatic harmonic progression and declamatory rhythm, and an aria, with more predictable harmonic progression and lyrical melody, characterize these genres. In Handel's opera, *Serses*, the famous aria "Ombra mai fu" and a preceding recitative, for example, represent such a stylistic association. The recitative section, "Frondi tenere," does not give any sense of establishing a single tonal center overall, but harmonic progressions are broken up into blocks which are connected by some radical voice-leading. Finally, a stable key F major is established together with the initiation of the lyrical and tuneful aria. [SEE EXAMPLE 2]

Example 1

RADICAL HARMONIC EXCURSION:

Non-functional use of dominant 7th chords (the harmonic synopsis at mm. 4-7).

m.4 m.6 m.7

B_7^{\sharp} (=V $\frac{7}{4}$ in E) ——— C_6^{\flat} ——— A_7 (=Ger.+6 in C#)

A question arises regarding why Wolf adopted a musical structure typical of the 18th-century opera. The reason seems related to the composer's choice to integrate poetic meaning and the musical structure. The speech-like mood for the first section corresponds to the recitative, whereas the second section expresses an elegant playing, which sounds like a modern harp with its arpeggio-figure. Another reason might be that, as Eric Sams and Susan Youens report, Wolf had already started considering a relationship between musical characteristics and atmospheric expression and had planned to compose an opera since his early career (472). Thus, his prior interest in opera might be another explanation for his adopting an operatic genre.

The grammatical and syntactical division governs the local level of the musical structure, while the division by the poetic contents affects the large-level musical struc-

ture. Following a pattern of punctuation for clause and sentence, the aria section has been divided into four parts. Wolf accents these units by creating some important pauses between parts using an interlude, many cadences, predictable harmonic progressions, sudden changes of harmony, and short rests. Also, each of the four units is distinctive in its treatment of harmony. [SEE TABLE 3]

In part (1) of the aria section, the harmonic progression becomes more predictable than it was in the recitative; it even threatens to become monotonous because of the repetition of a single harmonic progression and immediate resolutions of any chromatic chords. At the beginning of part (2), Wolf builds up more tension through chromatic and embellished harmonic vocabularies, although these progressions can still be readily heard in terms of a traditional harmonic idiom. A cadence is delayed by prolonging the dominant pedal with an inter-

Example 2

**THE HARMONIC SYNOPSIS OF THE RECITATIVE SECTION
"FRONDI TENERE" FROM HANDEL'S SERSES**

m.1 2 3 4 5 7 9

Bb c₂ F⁶ Bb e⁰⁶ F g₅ C F A⁶ c^{#06} d d⁶ d E a

Table 3

SUBLEVELS OF THE MUSICAL STRUCTURE IN THE ARIA

Division by Grammar	Musical Setting	
First: 1st-7th line	First part: Recitative section	
Second: 8th-11th line	Second part: Aria section	(1) Mm. 13-20: At the end, there are authentic cadence and one measure rest in the voice.
Third: 12th-18th line		(2) Mm. 21-39: Four-measure interlude follows this section.
Fourth: 19th-23rd line		(3) Mm. 44-51: At the end, the piano continues chromatic harmonies; voice rests one measure.
Fifth: 24th-25th line		(4) Mm. 52-57: Authentic Cadence, followed by piano postlude (mm. 58-69)

changeable repetition of Ger.⁶ and V⁷. Unlike the earlier ones, the last two parts of the aria section are closely connected in Wolf's setting even though the texts are grammatically separated. The background harmonic structure of these two parts, (3) and (4), outlines ii – V – I (F[#] – B – E) in E. Interestingly, the recitative section is also framed by the same progression with a long stretch of the F[#] in mm.1-10. A similar prolongation of F[#] is embedded in part (3) and (4); it covers mm.43-56 as part of the same fourth, F[#] – B. Therefore, one could argue that the fourth characterizes the large structure that the bass motion articulates. Both fourths are part of ii – V – I progressions that connect to the opening recitative and the second half of the aria to the postlude, respectively. Hence, both contribute to the tonal unity of the entire piece. [SEE EXAMPLE 3]

In addition, the large-level fourth motive appears at local levels of both harmony and melody. For example, the bass line moves directly from B[#] to E[#] at mm.26-28, and again from B to E in the cadence of mm.30-31. In mm.47-51, the bass line alternates between F[#] and C[#] inside the F[#] prolongation. Moreover, the fourth often appears in the melody of the recitative. This and other instances of the fourth promote a sense of openness and emptiness in the sound, and might have been deliberately adopted for the purpose of reflecting the Aeolian harp's sonority. According to Stephen Bonner, the

Aeolian harp historically was believed to have symbolic meanings, and such claims began to appear in the literature from the 1740s on (175). Thus, the poet often describes less of the Aeolian harp as the man-made medium through which Nature speaks to man than as the tragic reflection of his own life-experience, an 'Actor, perfect in all tragic sound!' (Bonner 175).

Thus, Wolf, who was probably familiar with the poetic connotation, attempts to reflect such a mood in the music by using the fourth appropriate for the expression of the poetic contents. In addition to this reflection, he tries to directly borrow the characteristic sound of the harp. The accompaniment imitates ways of performing the modern harp by providing the figuration of broken chords in the recitative section and of arpeggios in the left hand in the aria section. The aria section is unified by a single pattern of arpeggios. In order to reflect the subtle sound effect of the Aeolian harp in which the winds generate the sound and then its gradual echoing away, the left-hand part of the accompaniment also moves from the lower to the higher register in every single measure. This is especially apparent in the postlude, in which the same accompaniment figuration is combined continuously with softer dynamics and higher register.

I have thus far examined how the poetic structure has been integrated into the music. Wolf established the

Example 3

THE BASS OUTLINE OF THE RECITATIVE AND THE ARIA SECTION

The Recitative Section

m.1 m.11

Outline of the 4th

E: ii V

The Aria Section

m.13 m.38 m.43 m.57 m.59

Outline of the 4th

I V (ii) V I

The Interlude which shows the prolongation of B

poetic structure, considering the meaning and syntax of the poem into this music on several different layers. Also, he used an accompaniment figuration to evoke the sound of a harp. As seen in Wolf's lieder, the most remarkable characteristic lies in the melody. The musical elements of this melody such as high and low pitches and long and short rhythmic values are integrated toward a correct declamation of the words. Gorrell reports the close relationship between poet and music as seen in Wolf's lied, "Because of Richard Wagner's influence, both Wolf and Debussy wrote with a heightened sensitivity to poetic and musical synthesis" (284). In this song, Wolf uses many ways to set the melody considering the poetic declamation. The eleventh line of the poem "Wie süß bedrängt ihr dies Herz" is repeated twice. The repetition highlights the fact that this line has poetic importance as a first expression of the poet's own mood: "how sweetly you oppress my heart" (Miller 68). This is a dramatic moment in that the poet's own subjective feeling is synthesized with the description of the harp's sound.

Wolf considers the poetic declamatory and text painting as an important aspect of expression. First, in order to describe expressive word such as "du," "ach," or "und hier," Wolf assigns long notes to those words at m. 4, 17, and 52. Second, melodic contour, such as ascending, descending, or leaping, is related to the poetic meaning. For example, at mm.5-6, the ascending melodic line represents the poetic words of "Muse, born of the air!" (Phillips 245). Also, at mm.32-33, the downward melodic line expresses the motion of the wind on "and gently sigh in the string" (Miller 68). In addition, the leap of A to F# at mm. 24-25 is the expression of a sense of overflowing, reaching the strong fragrance on "and touching

the spring flowers along the way, satiated with fragrance" (68). For these two lines, the music accumulates much dissonance: D in the bass of the piano against E in the voice at m.22 and A# of Ger.¹⁶ in the piano against A in the voice at m.24. These dissonances seem a deliberate choice to prepare the most important line "Wie süß bedrängt ihr dies Herz." The most intriguing passage of text painting is mm.4-8, which has already been illuminated in Example 1. This example shows non-functional harmonic progressions: a succession of unresolved dominant seventh chords, which symbolize the mysterious state of the text, "mysterious strings-playing" (Phillips 246). This colorful harmonic vocabulary might be understood as an influence from Wagner's chromaticism.

Consideration of the poetic effects also involves rhythmic aspects. Gorrell discusses the rhythm in Wolf's songs in general: "The rhythms of accompaniment are so independent from both text and meter of the song" (286). In the aria section, the rhythmic motion of the voice and piano were quite complex. As he invites the triplet in the accompaniment, Wolf achieves this rhythmic complexity by two-against-three in which the piano-part rhythm becomes more independent from the voice. Also, using a mixture of duple and triplet in the vocal part, he pursued freer and more declamatory treatment of the melody, which makes more independent vocal line from the accompaniment.

This song illustrates Wolf's great sensitivity to the poetic structure, and his skill in integrating the poetic meaning into the song. He achieved this poetic and musical integration by means of text painting, sudden shifts of harmony, declamatory melody, and accompaniment which evokes and creates the appropriate poetic mood.

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Indo-Americans' Lifestyle Assimilation As a Function of Community Size

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Ethnologists have studied cross-cultural differences in values, behavior, and perceptions. An unsettled question concerns factors that diminish these differences. One potential cause is cultural assimilation, the process by which immigrants and their progeny adapt the culture of their host country in lieu of preserving the culture of their homeland. This cause is controversial because ethnologists disagree on how to measure cultural assimilation and what the variables are that may expedite or mitigate it.

Social science researchers have measured cultural assimilation in various ways. Ethnolinguists commonly focus on the role of language when measuring cultural assimilation. For example, Gramman, Saenz, and Shaul used Spanish-speaking ability as a sole measure of cultural assimilation in a study on California Hispanics. On the other hand, Lichter and Qian chose intercultural marriage as their measure

of assimilation. Still other researchers look to family structure as a measure of assimilation (Lambeth).

A result of these different research traditions is that it is not clear whether certain variables encourage or discourage assimilation. The level of the immigrant group's education is one such variable. An ethnolinguist might find that higher education hastens assimilation, because immigrants who work in high-education fields have fewer opportunities to converse in their native languages (Mackey and Siguan 30). In contrast, a researcher focusing on food may conclude that higher education prevents assimilation because jobs that require more education may provide more disposable income, which can be spent on preparing an ethnicity's traditional cuisine (Bunle 113).

Researchers continue to grapple with one unresolved issue: what is the effect of population density of a particular ethnic group on that ethnic group's assimilation to the mass U.S. culture? Some sociologists claim that ethnic enclaves prevent their residents from assimilating to the mass U.S. culture. This conclusion stems from the researchers' focus on language as well as consideration of such factors as music, dress, and food. For example, Chiswick's research shows that immigrants who live in areas with fewer fellow immigrants replace their native language with English faster than those who live in ethnic enclaves (Krikorian). Still, the effect of population density on lifestyle choices and religious adherence is unknown.

Indo-Americans and Moral Values

Indo-Americans are Asian-Indian immigrants and their progeny in America, and they provide a dynamic modern-day example of assimilation. Our knowledge about American-raised Indos' lifestyle comes largely from secondary sources, including essays on Indo-Americans. Fenton reports that second generation Indo-Americans are clearly exhibiting assimilation (200). The immigrant parent generation and the American-raised second generation clash on ways to deal with this process.

Indian parents consider "moral issues" to be worthy of cultural preservation. According to a nationwide, random survey of Indian parents conducted by *Little India* magazine, the decline in moral values is the most

important concern of Indian parents about the second generation: "Nearly four in 10 Indians identify moral values of the second generation as their single most important concern" when immigrating to the U.S. (Deshpande and Mehra). "Moral values" include such aspects as marriage, dating, dietary restrictions, alcohol use, and drug use (Fenton 202). For Indo-Americans, whose parents are fluent in English and who speak divergent mother tongues, language usage is considered only one of many variables in cultural preservation (Gawlick).

Indo-Americans provide a valuable example in understanding the effect of ethnic enclaves on assimilation, because many Indo-Americans are so concerned with preserving traditional moral values. Research has been conducted on preservation of cultural, moral values of "The Old Country" in America. However, few studies have identified variables that promote the preservation of traditional moral values. The present study addresses this empirical gap. Research regarding the effect of ethnic concentration on preservation of that ethnicity's moral values has been neglected. Thus, there is a profound need for such research.

The Present Study

It is widely believed that a larger population of Indo-Americans in a community would positively affect the preservation of Indian values in that community. Essays by Indo-American writers and interviews of Indo-Americans indicate this popular opinion (Dasgupta 61; Gawlick; Rangaswamy 74). However, it is hypothesized that there is a positive association between small Indo-American communities and preservation of traditional Indian culture. This hypothesis was tested by conducting a survey and analyzing the results.

The present study examined the effect of 'Indo-density' on Indo-American college students' behavior and views. 'Indo-density' is a term coined in the present study to refer to the population density of Indo-Americans in a local community. Indo-Americans were surveyed on their behavior, their views, and the Indo-density in their upbringing. For the participants of the study, the number of Indo-Americans attending the participants' high schools provided the basis for Indo-density

as it could be used to derive the proportion of Indos in the respondents' neighborhoods.

Respondents of the survey were classified into groups based on the Indo-density in their upbringing. These groups were then analyzed in terms of their assimilationist versus preservationist tendencies. "Assimilationist tendency" is a term coined in the present study to refer to behaviors and views aligned with mass American culture. Here "mass American culture" is defined by the average tendencies of American youth. "Preservationist tendency" is a term coined in the present study to refer to behaviors and views aligned with traditional Indian culture. The cultural questions focused on behaviors and views commonly associated with moral values, such as marriage, dating, dietary restrictions, alcohol and drug use. While no empirical data exist on which specific behaviors are considered culturally relevant, essays and personal interviews (Fenton 202-8; Dasgupta 118-30; Pandit 106-14) point to the behaviors examined in this study.

Six questions identified assimilationist versus preservationist tendencies. An example of an assimilationist tendency would be to support the practice of romantic partners living together before marriage. A preservationist tendency would be to oppose the practice of living together before marriage. In traditional Indian culture, living together before marriage is unheard of, while in modern American society cohabitation is much more common and more widely accepted (Fenton 202; Cohen).

The general hypothesis, that there is a positive association between small Indo-American communities and preservation of traditional Indian culture, can be separated into three sub hypotheses:

- H1: The percentage answering assimilationist responses will be higher for high Indo-density respondents than for low Indo-density respondents.
- H2: The percentage answering assimilationist responses will be higher for medium Indo-density respondents than for low Indo-density respondents.
- H3: The percentage answering assimilationist responses will be higher for high Indo-density respondents than for medium Indo-density respondents.

Method

Participants

One hundred and fifty-nine Indo-American undergraduate and graduate students (56 percent male, 44 percent female) at The University of Texas at Austin were respondents to the survey. In exchange for their participation, respondents received free pizza funded by the Undergraduate Research Fellowship received by the researcher. Eligibility for answering the survey was based on ethnic background (all respondents had to be of full South Asian background) and place of upbringing (all respondents had to be primarily raised in North America). Since all participants met these criteria and followed the instructions of the survey, no data were excluded from analysis.

Materials — survey design

The survey included two categories of questions to test the primary hypothesis: (a) questions on behavior or views and (b) questions on Indo-density. The survey also included several other questions related to such issues as arranged marriage, sub-culture ancestry, religious and caste background, and marriage criteria. An analysis of these issues is not described because they are unrelated to the hypothesis addressed in this paper, though the data are available from the author. Explanation of the two primary question types is as follows.

BEHAVIOR/VIEWS. The survey included six questions on behavior and views. These questions (numbers 23 – 28) addressed the issues of dating/marriage, dietary restrictions, alcohol use, and drug use [SEE APPENDIX]. Each question had five answer choices, thereby providing respondents with a continuum of answer choices ranging from extremely preservationist to extremely assimilationist. For example, in the question concerning the respondent's perception of pre-marital intimacy, the extremely preservationist answer choice stated that pre-marital physical intimacy of any kind is inappropriate, and the extremely assimilationist answer choice stated that all forms of intimacy—including the biological definition of intercourse—are appropriate.

INDO-DENSITY QUESTIONS. The survey included 2 questions on the participants' high school's overall popu-

lation and the high school's Indo population.

In addition, I chose to identify other possible determinants of the Indo-American students' behavior and views. The following variables were alternative explanations for behavior and views:

- The participants' travel to India
- The participants' parents' educational level
- The participants' ability to speak Indian languages
- The participants' penetration of relatives in North America

Data analysis methods

An analysis was conducted comparing the percentage exhibiting assimilationist versus preservationist tendencies among three different respondent groups: low Indo-density respondents (under 50 Indos in their high schools), medium Indo-density respondents (between 50 and 150 Indos in their high schools), and high Indo-density respondents (over 150 Indos in their high schools). The cutoff numbers (50 and 150) were picked not only for their roundedness, but also because there were few respondents who had Indo-density on the border of these groups (such as respondents with 55 or 155 Indos in their high school).

Forty-nine percent of the sample attended high schools with fewer than 50 Indos. Among those with fewer than 50 Indos in their high school, 64 percent had high schools with fewer than 20 Indos. Those between 20 and 50 Indos tended to have very large high schools, so functionally their Indo-density was low.

Twenty-four percent of the respondents had between 50 and 150 Indos in their high schools, and 27 percent of the respondents had over 150 Indos in their high schools. The comparison of these groups was accomplished through a test of proportions.

For each question, the four or five answer choices were collapsed into two broad categories—assimilationist and preservationist. This collapse varied from question to question, however in each question the collapse was based on how far the answer choices deviated from traditional Indian culture. No authoritative cultural text exists on which answer choices could be labeled “preservationist.” The answer choices were interpreted by applying the standards indicated by interviews and writings of Indian parents and cultural leaders (Gandhi 102-7, 137-48, 308, 415-9; Gangulay 117-35; Fenton 202-8; Pandit 106-14; Pravananda 12-17, 131, 191-6). The breakdown of which answer choices were considered “preservationist” and which were considered “assimilationist” is provided in Table 1, and answer choices are provided in the survey.

Results

A test of proportions supports the thesis of this research project that there is a positive association between low Indo-density and preservation of traditional Indian culture. On all six questions that concerned assimilation versus preservation of cultural values, Indos from low Indo-density communities had a smaller percentage answering assimilationist responses than did the Indos from

Table 1 | COLLAPSE OF ANSWER CHOICES*

Q # Issue	Assimilationist Answer Choices	Preservationist Answer Choices
23) Pre-marital sex	D & E	A, B, & C
24) Cohabitation	A, B, & C	D & E
25) Dietary restrictions	A & B	C & D
26) General drinking behavior	A	B, C, D, & E
27) Inebriation frequency	A & B	C, D, & E
28) Drug use	A, B, & C	D

*See appendix for corresponding questions and answer choices

high Indo-density communities. Thus, the primary findings were the differences between these two groups, which imply that Indos from low Indo-density communities exhibit more preservationist tendencies than do their peers raised in high-Indo density communities.

The low Indo-density respondents answered a smaller percentage of the assimilationist choices than did the high Indo-density respondents on all six questions. Of the differences in percentage on these questions, three out of six were statistically significant. Here statistical significance implies that the differences in the two groups' percentages would occur by chance alone no more than 1 out of 20 times. For the six questions, Table 2 shows the differences between the two groups. The "assimilationist percentage" is the proportion of each group — low and high Indo-density — that exhibited assimilationist tendencies in the issue questioned. The *p*-value in Table 2 is the percent likelihood such a large difference between the two groups would occur by chance alone. *P* values less than .05 are generally considered to reflect statistically significant differences between groups. Thus the questions on general drinking behavior, inebriation frequency, and drug use produced significant differences between the low and high Indo-density groups. The largest difference was found on the two alcohol related questions. Questions on pre-marital sex, cohabitation, and dietary restrictions were not associated with statistically significant differences, though the results are in the direction predicted.

Those with medium Indo-density showed a medium level of assimilationist tendencies on five of the six ques-

tions. That is, medium Indo-density respondents had a higher percentage exhibiting assimilationist tendencies than low Indo-density respondents, but a lower percentage exhibiting assimilationist tendencies than high Indo-density respondents. The exception was question 23 concerning pre-marital sex, in which low Indo-density respondents had a slightly higher share answering assimilationist choices than did medium Indo-density respondents (68 percent vs. 66 percent). The differences between medium-level and low or high-level Indo-density respondents were not statistically significant.

Discussion

The data support the general thesis by suggesting that greater density of Indos is associated with assimilation to mass U.S. culture in terms of moralistic behavior (dating/marriage, dietary restrictions, alcohol use, and drug use). Three of the six questions showed differences between low and high Indo-density respondents that were statistically significant. The three non-significant differences showed the same pattern — a smaller percentage of the low Indo-density respondents exhibited assimilationist tendencies compared with the high Indo-density respondents.

Since medium level Indo-density respondents did not have statistically significant differences from the other two groups, the data do not suggest that Hypothesis 2 (comparing medium and low Indo-density respondents) and Hypothesis 3 (comparing high and medium Indo-density respondents) are valid. However, in evaluating the effect of the Indo-density variable, it is more

Table 2 | DIFFERENCES IN ASSIMILATIONIST TENDENCIES*

Q#	Issue	(Low-Indo) Assimilationist %	(High-Indo) Preservationist %	<i>P</i> -Value
23)	Pre-marital sex	68%	83%	.0628
24)	Cohabitation	64%	75%	.1836
25)	Dietary restrictions	46%	55%	.303
26)	General drinking behavior	28%	58%	< .001
27)	Inebriation frequency	29%	58%	< .001
28)	Drug use	56%	77%	.008

*See appendix for corresponding questions and answer choices

important to focus on the differences between the two extreme groups to see if any effect is present; that is, Hypothesis 1 (comparing low and high Indo-density respondents) was more important than Hypothesis 2 or Hypothesis 3 concerning the medium Indo-density respondents. Medium level Indo-density respondents would likely not display the differences so profoundly, because in reality their upbringings are not very different from either of the other two groups. In contrast, low Indo-density respondents have true differences in upbringing compared with the high Indo-density respondents. That the medium Indo-density respondents had medium proportions exhibiting assimilationist tendencies is consistent with the general hypothesis that there is a positive association between small Indo-American communities and preservation of traditional Indian culture.

The conclusion that greater Indo-density is associated with more assimilationist tendencies does not necessarily mean that greater Indo-density causes more assimilation. The association could instead be the result of reverse causation or endogenous third variables. First, it could be that the causation works in the opposite direction; that is, assimilationist tendencies caused the respondents to move to higher Indo-density areas. Here, however, reverse causation is unlikely because the assimilationist respondents could not have forced their families to move to high Indo-density areas before they entered high school. Second, the data do not support the existence of endogenous third variables that might explain the relationship observed here between Indo-density and assimilation. For example, some possible explanations would be that parents' "educational levels" or "penetration of relatives in North America" (the proportion of the respondents' extended family residing in North America) tend to determine both place of residence and how committed these parents are to instilling moral values. In fact, the data show that there were no differences in penetration of relatives in North America or parents' educational level between the assimilationist respondents and preservationist respondents. Also, "frequency and duration of vacations in India" "family's educational level," "penetration of relatives in North America" and

"language-speaking abilities" were not predictive of the respondents' behavior in general. Analyses of the alternate variables are available from the author.

Sociological Implications of Findings

Why would greater Indo-density be predictive of more assimilationist moral values? Based on personal observations of Indo-Americans, two explanations are offered. First, Indo enclaves may give parents a false sense of security with their children's adherence to traditional culture. This false sense of security belies the true nature of assimilation and may prevent the parents from taking positive actions to rectify the situation. Some Indian parents fallaciously believe that when their children associate with other Indo-American children the parents need not supervise their children's behavior. Second, Indo-Americans living in neighborhoods with few Indos may feel more representative of their cultural heritage. When an Indo-American is surrounded by few Indo peers, he may feel as though he should symbolize his community by adhering to the cultural moral norms of India. In contrast, Indo-Americans surrounded by many other Indo-Americans might not feel the same burden.

This paper does not posit that Indo-density is the primary factor determining assimilationist versus preservationist tendencies. Personalities and natural talents of the respondents matter as well. For example, someone with a rebellious personality might be more likely to go against the cultural norms of his parents. There may also be effects associated with how parents raise their children. Performing religious rituals, establishing good parent-child relationships, and overseeing children's behavior may affect preservation of cultural morals.

This paper also does not suggest that the variables measured in this study (dating/marriage, dietary restrictions, alcohol and drug use) or the interpretations of answer choices in this study are the only true measures of Indian culture. Indian culture varies considerably, and people may apply varied interpretations of what tendencies would be considered "assimilationist." This study focuses only on what Indian immigrant parents would consider as important variables and "assimilationist" tendencies.

Future Research on This Subject

Future investigations should attempt to explain why greater Indo-density is associated with cultural assimilation. There may be endogenous variables that affect both Indo-density and cultural assimilation. I recommend studying the personality types of parents who choose to live in ethnic enclaves. Perhaps people of certain personalities desire to live among people of their own ethnicity, but these people do not wish to instill traditional culture in their children.

Future research should also consider what is it about living in Indo enclaves that might reduce adherence to traditional culture. It is unlikely that the non-Indos in these communities are somehow different from the non-Indos in other parts of the country. There is likely something about parental and peer relationships for enclaved

Indo youth that differ from such relationships for non-enclaved Indo youth. Future research should study the dynamics of Indo enclaves.

Finally, ethnologists should study enclaves of various cultural groups to see if the findings of the present study would be replicated in other cultural groups. The association discovered in the present study may be idiosyncratic to the Indo-American community, so a study of other cultures may lead to a better understanding of assimilation. As they conduct such studies, researchers should consider measures of assimilation other than language. Ethnic enclaves naturally support traditional language, dance, music, food, etc. because of the greater opportunity to share such items in the community. However ethnic enclaves may not help preserve traditional values, lifestyle choices, and viewpoints.

Appendix

SURVEY EXCERPT

23) What level of pre-marital physical intimacy do you think you would consider pursuing? (NOTE: the question asks not what you have done, but what behaviors you would consider)

- A) Pre-marital physical intimacy of any kind is inappropriate
- B) Kissing, holding hands, and hugging only
- C) In addition to 'B,' everything except any intimacy involving the primary sexual organs
- D) Any level of intimacy after 'B' except for the biological definition of intercourse
- E) The biological definition of intercourse

24) Please circle the letter that best exemplifies your views on living with a mate before marriage.

- A) It is ok with me, and I strongly hope to do so.
- B) It is ok with me, and I will certainly consider it in the future.
- C) It is ok with me, but I will try to avoid doing so.
- D) I do not like the idea, but I might consider it in the future.
- E) I do not like the idea at all for me.

25) If some of your grandparents practiced religious-based dietary restrictions, (vegetarianism, Ramadan fasting, etc.) please select the statement that exemplifies your and your family's dietary behavior:

- A) I do not follow any religious-based dietary restrictions whatsoever, and neither do my parents.
- B) I do not follow any religious-based dietary restrictions whatsoever, but at least one of my parents does.
- C) I follow only some dietary restrictions or I limit the consumption of restricted foods.
- D) I completely follow all dietary restrictions.

26) Indicate which statement best exemplifies your behavior as pertains to alcohol consumption.

- A) When I drink alcohol, I do so to become inebriated.
- B) When I drink alcohol, it is only to get a light buzz.
- C) I drink alcohol because I like the taste, but not to experience other effects.
- D) I will only consume alcohol under extreme peer pressure, and even then I drink very little.
- E) I have not consumed alcohol.

27) If you have become inebriated, please select the statement that best exemplifies your frequency of inebriation.

- A) I become inebriated very often — on many weekdays and almost every weekend.
- B) I become inebriated on many weekends and on most special occasions.
- C) When I become inebriated it is only on special occasions or a few weekends each semester.
- D) I become inebriated no more than once or twice each semester.
- E) I have only been inebriated once.

28) How do you feel about your use of drugs that are illegal in the U.S. (not including alcohol)? (select one letter)

- A) I have no problem with possibly experimenting with all types of drugs (even less popular ones such as acid), and I have no problem with using other more popular drugs recreationally (example: marijuana)
- B) I do not like the idea of experimenting with "harmful" drugs such as acid or cocaine, but I have no problem with using less harmful drugs recreationally (example: marijuana)
- C) I am fine with experimenting with less harmful drugs (example: marijuana), but not using them regularly.
- D) I am completely against the regular use or experimentation of all illegal drugs.

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An Introduction to the Computation of American Option

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In 1997 Robert Merton and Myron Scholes received the Nobel Prize in Economics for their discovery of “a new method to determine the value of derivatives.” Almost 25 years earlier, Scholes had worked with Fischer Black to come up with equations to describe option pricing (Ferreira). Options are traded on the stock market similarly to how stocks are traded, but options are actually contracts. We studied the Black-Scholes inequality and developed numerical schemes to find its solution. The first half of this paper shows how to derive the Black-Scholes differential inequality we studied, and the second half is about the techniques we used to find numerical solutions.

Lots of people in the stock market want to make a quick buck; they want to get in and out quickly with a large profit. Their strategy is

“buy low, sell high,” or sell shares at the optimal time. To make money with options, you need to exercise (explained below) at the most optimal time. The ultimate goal of our project was to find the optimal time to exercise an option; if you know differential equations, you may recognize our problem as a free boundary problem. Options are widely traded on the stock market, and they have the potential for great gains or great losses.

Background Concepts

An option is a contract to buy or sell an underlying asset, such as stocks, at a specified time, called the expiry, for a specified price, sometimes called the strike price. Two types of options are American and European. European options can only be exercised at the expiry, but American options can be exercised at any time up until expiry. Solutions for values of European options can be found in closed form, meaning there exists an explicit formula (Wilmott 49). Because American options can be exercised prior to their expiry, the solutions are much more complex and cannot be found in closed form: the values must be found numerically.

The two types of options are calls and puts. A call is an option to buy an asset. For example, if you bought an American call, you would have the right to exercise that call anytime until its expiry. If you exercise the call, you will buy a specified amount of stock for a specified price from the person who sold you the contract.

A put is an option to sell an asset. If you bought an American put, you would have the right to exercise it until its expiry. If you exercise the put, you would be selling a specified number of shares of stock at a specified price to the person who sold you the contract.

One way to think about potential profit from an option is to look at a payoff function. Payoff functions describe the amount profited at expiry given different values of the asset or stock price, S . The exercise price is denoted by E . Consider the American call: if the current market price, S , is greater than the exercise price, E , it makes sense to exercise the option. You can buy shares for E dollars and sell them for S dollars, clearing a profit of $S-E$. If $S < E$, however, exercising the option would mean paying more than the current market price for the

shares of stock. Therefore, if $S > E$, the profit is $S-E$. If $S < E$, the profit is 0. Combining this into one equation gives the payoff function for an American call: $\max(S-E, 0)$.

Similarly, the payoff function for an American put is $\max(E-S, 0)$. If the market price S is less than the price specified in the option, you would gain a profit by exercising the option. Upon exercising the option, you would have to buy the stock at S dollars per share and sell it at E dollars. This yields a profit of $E - S$ dollars. If, however, $S > E$, you would not want to sell the stock by exercising the option.

To find a way to model option prices, it is necessary to find a way to describe the change in a stock price. Let dS denote the change in the stock price, S , of a particular stock over a very short period of time. Let dt denote this short time interval.

We will assume the stock has some average growth rate,

$$\mu = \frac{\text{change in } S \text{ over unit time}}{S * (\text{unit time})},$$

so the stock price will change by $\mu S dt$. This unit time could be measured in hours, days, weeks, etc. When we found solutions, we measured μ in terms of days.

A stock price will not change solely based on its average growth rate, so there is some volatility of the price. Let σ be the measurement of this volatility, which is the standard deviation of returns. A stock's return is

$$\frac{\Delta \text{ price}}{\text{original value}}.$$

It is not possible to know where the stock market is going tomorrow, so a random variable is also used to describe these unknown changes. Let X be a random variable with mean 0 and standard deviation 1. Because X is a random variable, it is used to model random events. If a new president were elected or there were some sort of national disaster, the stock market would probably be affected; X accounts for these events. The contribution to the change in a stock's price from its volatility and the random variable X is $\sigma S dX$.

The equation showing the total change in an asset price is

$$dS = \mu S dt + \sigma S dX \quad (2.1)$$

The value of an option is dependent on the time to expiry and the value of the underlying asset. Let V denote the value of an option, either a call or a put. V is a function of S and t (that means it depends on both S and t). As before, it is helpful to consider how V is going to change over a small time interval dt . dV denotes the change in V . A Taylor Series expansion will be used to model dV . A Taylor expansion is a way to write a function as an infinite sum; they are useful in making approximations. Although the Taylor expansion is an infinite sum, only the first few terms are kept. It may seem a little surprising that only the first few terms of an infinite series are being used as an approximation. The terms not being kept are much smaller than the ones being kept. By simplifying the Taylor expansion, it is easier to arrive at solutions. Here is the expansion for dV .

$$dV = \frac{\partial V}{\partial S} dS + \frac{\partial V}{\partial t} dt + \frac{1}{2} \frac{\partial^2 V}{\partial S^2} dS^2 + \dots \quad (2.2)$$

Substituting 2.1 into 2.2 and rearranging terms leads to

$$dV = \alpha S \frac{\partial V}{\partial S} dX + \left(\mu S \frac{\partial V}{\partial S} + \frac{\sigma^2 S^2}{2} \frac{\partial^2 V}{\partial S^2} + \frac{\partial V}{\partial t} \right) dt \quad (2.3)$$

Now that we have equations for the change in the asset price and the change in the option value, this information can be combined to describe the change in value of a portfolio. A portfolio is a collection of assets; in this case, we will consider a portfolio consisting of an option and shares of stock. Let $\Pi = V - \Delta S$, where Π is the value of the portfolio, V is the value of the option, Δ is the number of shares owned of the underlying asset, and $-\Delta$ may be fractional. The value of A will be determined later. The change in the value of the portfolio is given by

$$d\Pi = dV - \Delta dS - \delta_0 \Delta S dt \quad (2.4)$$

where δ_0 is the dividend rate. Dividends are paid to stock holders, and their amount is dependent on the asset price and the number of shares the owner holds. For computational purposes, we assume that the dividend rate is constant and does not change over time. This is not always the case for real dividend rates, but it is an OK assumption to make.

Substituting 2.1 and 2.3 into 2.4 leads to

$$d\Pi = \alpha S \left(\frac{\partial V}{\partial S} - \Delta \right) dX + \left(\mu S \left(\frac{\partial V}{\partial S} - \Delta \right) + \frac{\sigma^2 S^2}{2} \frac{\partial^2 V}{\partial S^2} + \frac{\partial V}{\partial t} - \delta_0 \Delta S \right) dt \quad (2.5)$$

Notice that if $\Delta = \partial V / \partial S$, the first term is 0. This is the only term that has dX in it, so removing this term is essentially removing the randomness from the formula for dV . Removing the randomness means $d\Pi$ is completely deterministic (knowing the value at one time means knowing the value at all future times). To remove this random term, Δ will have the value $\partial V / \partial S$. This value of Δ will also make the only term involving μ disappear from the formula for $d\Pi$ also. Thus, $d\Pi$ simplifies to

$$d\Pi = \left(\frac{\sigma^2 S^2}{2} \frac{\partial^2 V}{\partial S^2} + \frac{\partial V}{\partial t} - \delta_0 \Delta S \right) dt \quad (2.6)$$

By constantly holding Δ shares of the asset in your portfolio, you would be guaranteed a risk-free return. Realistically, you would lose a lot of money because you would have to constantly readjust your portfolio and pay brokerage fees for every transaction.

Ignoring brokerage costs, this seems like a great way to make money. There is no risk associated with the portfolio, so it might seem that picking the right stocks would ensure a huge profit. But, this is not the case. The arbitrage principle states that the best return you could get in a risk free portfolio is the rate of return you would get by putting your money into a bank. Interest from a bank is determined from the amount of money in the bank account and the interest rate, r . So, the change in the portfolio value has to be $r\Pi dt$. Recall $\Pi = V - \Delta S = V - (\partial V / \partial S) S$, so

$$r\Pi dt = \left(\frac{\sigma^2 S^2}{2} \frac{\partial^2 V}{\partial S^2} + \frac{\partial V}{\partial t} - \delta_0 S \frac{\partial V}{\partial S} \right) dt \quad (2.7)$$

Rearranging equation 2.7 leads to the following.

$$0 = \frac{\sigma^2 S^2}{2} \frac{\partial^2 V}{\partial S^2} + (r - \delta_0) S \frac{\partial V}{\partial S} + \frac{\partial V}{\partial t} - rV \quad (2.8)$$

Equation 2.8 is the Black-Scholes equation for a European option.

Because the American option can be exercised

early, the Black-Scholes equation is an inequality for an American option.

$$0 \geq \frac{\sigma^2 S^2}{2} \frac{\partial^2 V}{\partial S^2} + (r - \delta_0) S \frac{\partial V}{\partial S} + \frac{\partial V}{\partial t} - rV \quad (2.9)$$

Equation 2.9 is in its final form and finding its solutions is the focus of the rest of this paper. For the rest of this paper, only American puts are considered. For information on how to find the formulas for solutions, see our complete paper online (Bold, Chen, and Dutzmann).

Finding a solution to the above inequality would mean finding the optimal time to exercise the option. While knowing the optimal time to exercise the option will not necessarily make you a lot of money, it may help you avoid losing money.

Solutions to the Black-Scholes Inequality for an American Put

As was mentioned before, solving the Black-Scholes Inequality would lead to the solution of the optimal time to buy. Equation 2.8 does have a relatively easy solution, but there is not an easy solution to Equation 2.9. Because we could not get closed form solutions (closed form solutions are functions in which you can relatively easily plug in variables to get an answer) for the Black-Scholes inequality, we had to approximate solutions. Recall that V , the option value, is a function of S and t . We could not find solutions of V for all S and t , but we were able to find solutions at discrete values of S and t . The possible values of S are the realistic values a stock price will have over time. For a stock currently priced at \$90, we could expect it to stay within the range from \$0 to \$200 for the length of the option (usually several months). We will call the endpoints of this interval ϵ and d . ϵ cannot be chosen to equal zero because this would result in division by 0. Thus, ϵ is chosen to be some small number close to 0. For our calculations, we chose $\epsilon = 0.1$. When looking at a stock priced at \$90, we chose $d = 200$. The possible values of t are from 0 (meaning right now) to T (the expiry time).

To approximate the value of the option over these intervals, we made a mesh of points in these intervals. Each mesh point corresponds to a particular S value (K)

at a particular time (t). A fine mesh of at least several hundred points, meaning several hundred possible S values and several hundred possible t values, is necessary for accurate solutions.

Values of an option are denoted by $\alpha_K^{(n,t)}$ where K denotes the asset price and t denotes the time. Solutions are found through an iterative process (meaning the same process repeats many times), and n denotes which iteration is being considered.

After using techniques from differential equations (a variational inequality), we reduced the Black-Scholes Inequality to a different problem. The values of $\alpha_K^{(n,t)}$ in the following equation are the solutions to the Black-Scholes Inequality.

$$(y - \alpha_K^{(n,t)}) (\alpha_j^{(n,t)} b_0 + \alpha_K^{(n,t)} b_1 + \alpha_L^{(n-1,t)} b_2 - b_3) \geq 0 \quad (3.1)$$

where $y \geq \max(E - K, 0)$.

The solution for $\alpha_K^{(n,t)}$ is

$$\alpha_K^{(n,t)} = \max\left(\frac{b_3 - \alpha_j^{(n,t)} b_0 - \alpha_L^{(n-1,t)} b_2}{b_1}, \max(E - K, 0)\right) \quad (3.2)$$

While this is the formula for a put, the solution for a call is very similar.

Now, the hardest part of the work is done. We spent a lot of time getting to this point and understanding how to come up with that equation as the solution. The one equation for $\alpha_K^{(n,t)}$ will be used over and over again to find the solution to the Black-Scholes inequality. To use it over and over again, we designed a computer program in C++ to do the repetitive work.

Finite Iterative Schemes

In implementing the formulas for solutions, we made two different schemes (two different ways for the computer to find solutions). Although these schemes are used a lot in numerical analysis, we arrived at them on our own after some direction from our professors. The first scheme we used was Domain Decomposition. That this scheme gives correct solutions has been proved. The second scheme we used was the Full Multigrid. There is no proof that this scheme finds the correct solutions, but it appears to. The Full Multigrid scheme is much faster than the Domain Decomposition scheme.

4.1. Domain Decomposition. As was described earlier, the finite scheme iterates through a mesh of points ranging from some ϵ to some d , where ϵ and d are chosen to be fixed to the payoff function (the payoff function for a put is $\max(E - S, 0)$). The iteration continues for each time step until the values at the mesh point have converged, at which point the method moves on to the next time step. In this section, it will be demonstrated how this scheme is implemented. At least under certain circumstances, this finite scheme does indeed converge, although the accuracy of the scheme's approximation to the true Black-Scholes solution has not yet been tested (Bold, Chen, and Dutzmann). Values of the solution are found at successive time steps by iterating through all of the points until they are changing by less than some specified amount (such as 10^{-9}). The first few iterations will go as follows:

Step 0: $\alpha_K^{(0,t_0)}$ given values of $\max(E - S, 0)$, the payoff function

Step 1: $\alpha_K^{(1,t_0)}$ all mesh points get a new value based on the formula for α_K ; the points are evaluated from left to right

Step 2: $\alpha_K^{(2,t_0)}$ all mesh points get a new, more accurate value; they are again evaluated from left to right

Step n: $\alpha_K^{(n,t_0)}$ after n iterations, the points will change by less than some specified amount, and they will be considered fully converged

Step n+1: $\alpha_K^{(0,t_1)}$ given values from $\alpha_K^{(n,t_0)}$

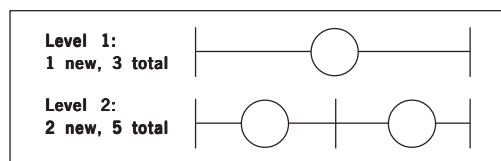
... the process continues for all time steps, and the values at each time step are fully converged before the next time step is started

This process continues through the specified number of time steps. If it ever takes more than a specified number of iterations (several tens of thousands) to converge, the computer program will stop and say the values are not converging. This is typically not a problem with our code, and we have gotten realistic option values.

4.2. Full Multigrid. We also developed a more efficient (fewer iterations needed for full convergence) numerical scheme, the full multigrid, for our calculations, but we have no proof this scheme converges. Values from the full multigrid method agree with values from the domain decomposition method, of which

we have proof of convergence.

The full multigrid scheme uses sequentially finer meshes to approximate solutions. The first mesh contains only three points: the two endpoints midpoint (ϵ , d) and the midpoint ($(\epsilon + d)/2$). The midpoint's initial value is the average of its two neighboring points. Only one iteration is needed to get a fully converged value of the midpoint. In the second interval, two new mesh points are added, as shown in the following diagram.



Vertical lines denote original values from previous iterations, and circles denote new points with original values being the average of the two neighboring points.

When new points are added, the mesh is iterated until fully converged values are found. This iteration is in the same manner as for domain decomposition; solutions are found using the formula for α_K from left to right. When fully converged values are found, new mesh points are introduced (one new point in between every pair of old points). This is continued to any desired number of mesh points. At any one level there are $2^n + 1$ points, so n does not need to be very large for an ultimately fine mesh. The full multigrid method took about $2/3$ as many iterations as the domain decomposition method.

Conclusion

The goal of our project was to find the value of an option at any point up to expiry, and from that information to find the optimal time to exercise the option. We used a variational inequality to formulate a solution and designed two computer programming schemes to find numerical solutions. For us, the appeal of the project was not in finding out which stocks to buy, but rather the mathematical and computational aspects. We would not advise you to pick your options and exercise them based on numerical data.

Future work on this project includes finding more efficient programming schemes and alternative ways to solve the problem theoretically.

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Perception and Societal Response to Hazard Mitigation:

An Example of Arsenic Contamination of Drinking Water in Bangladesh

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Despite being among the most well watered countries on earth, Bangladesh suffers from major shortages of pure drinking water. As a result, over 40% of the nation's 133 million people must rely on arsenic-contaminated, hand-pumped, tube-well water for drinking and cooking. Drinking and ingestion of arsenic-contaminated water by such a large populace may be the largest mass poisoning in human history. Arsenic is very hazardous to humans and immediate efforts must be made in order to mitigate its impact. Existing studies on arsenic-contaminated drinking water in Bangladesh deal with sources of the arsenic, its impacts, and options for addressing the contamination. Both geo-chemical and human-induced sources release arsenic into the drinking water of Bangladesh. When oxidized, naturally occurring pyrite minerals release arsenic into underground water (Das et al. 7). Oxidation of

pyrite occurs as human-induced depletion of the ground water table (by crop irrigation, and the diversion of the Ganges River water by India) allows oxygen to rise to the pyrite layer of the bedrock (Nickson et al. 405).

The health effects of arsenic ingestion appear in about 5 to 10 years, initially as skin lesions. Its dose-dependent hazardous impacts include internal cancer, interference in DNA replication, chromosomal aberrations, and death (Smith). While its hazardous impacts are still being discovered, various methods of mitigation of arsenic contamination in drinking water are also being tried. These methods of arsenic mitigation include the following: pond-sand-filter (PSF) using pond water, low-pressure nano-filtration, and conventional co-precipitation method using ferric chloride, lime softening, activated alumina as well as membrane filtration.

While there is extensive research on arsenic mitigation techniques, the socio-economic dimensions of the arsenic hazard mitigation are yet to be examined. Arsenic mitigation involves coping with the hazard and requires increased public awareness, community participation, and intervention by the government and non-governmental organizations (NGOs) (Paul). As these interventions are external forces to these rural societies, community participation and societal response to the hazard emerge as the most important internal components of the mitigation process, which involves monetary expense to purchase technology needed to reduce the Arsenic. Awareness and perception of the hazardous impacts of arsenic contamination in drinking water on public health play a very important role in increasing community participation in the mitigation process so that Bangladeshi citizens will be willing to bear the cost of the mitigation technology. However, public awareness of the arsenic contamination hazard and the level of community participation vary across Bangladesh as well as across socio-economic cross-sections of the rural community. Therefore, this forms an important topic for geographic research, which has not yet been undertaken in Bangladesh.

The objective of this study is three-fold. First, it aims to assess the Bangladeshi people's knowledge and perception of the arsenic hazard and its mitigation options, and thus explores the extent of public awareness of the

hazard. Second, it analyzes the socio-economic conditions of the affected people and their level of awareness of the health hazard by arsenic contamination. Finally, it explores the different levels of community participation by analyzing the household response to the cost of the mitigation options and willingness to pay for the cost.

Study Area, Data, and Method

The present study was conducted in five villages selected from five districts in western and southwestern Bangladesh. Earlier studies done by the British Geological Survey revealed that large numbers of hand pump tube wells in each village were contaminated with toxic levels (>0.05 mg/l) of naturally released underground arsenic and that there are growing numbers of patients showing the symptoms of arsenic poisoning. The villages (Rajarampur in Nawabganj, Samta in Jessore, Fingri in Satkhira, Kanchanpur in Khulna, and Taltala-Lakshipasha in Narail) vary from each other in terms of the amount of arsenic present in drinking water, numbers of tube-wells contaminated, number of arsenic victims per 1000 people, and socio-economic conditions of their residents, thus forming unique conditions to study arsenic hazards and its mitigations (Table 1).*

Data was collected through detailed fieldwork conducted during the summer of 2001. A total of 243 sample households were selected and surveyed from five villages by a group of five research assistants over a period of two months. A detailed questionnaire was used to conduct the interview with the head of each household. The questionnaire contained questions regarding the sources of drinking water, socio-economic conditions of the household, perception of arsenic contamination of drinking water, and willingness to participate in the mitigation process. The sample households were selected randomly by giving the questionnaire to every third household (i.e., 33%) from a major central point in the village. All the questions were asked in Bengali since most villagers did not speak nor understand English. Data was cross-tabulated and interpreted to explore the respondents' knowledge and perception of the arsenic hazard, its mitigation process, and its variation among various socio-economic groups.

*See Appendix for Tables and Figures, pp. 48-51

Results:

Risk of Arsenic Hazard

The five villages studied are located in different ecosystems where, due to increased irrigation and diversion of the Ganges River water by India, variable rates of depletion of the underground water tables resulted in a variable level of arsenic release in tube well water. In all five villages residents rely on tube-well water supply for drinking and cooking purposes and use pond and well water for washing and bathing. Drinking water contaminated with <0.05 mg/l of arsenic may not be hazardous to humans. Alarming, tube-wells in four out of five villages under study were found to be contaminated with >0.05 mg/l, which is a great concern for their residents.

Each of the five villages had some degree of risk of the arsenic hazard, as indicated by the amount of arsenic present in the drinking water supply, the number of tube wells contaminated, and the number of victims per 1000 people (Table 1). Virtually all sample residents are knowledgeable about the problem of arsenic contamination of drinking water and about their risk or exposure to the arsenic hazard. However, despite their willingness to participate in any arsenic mitigation efforts, poor illiterate farming and wage laborer households with few resources and limited access to alternate water purification technology are at greater risk than the literate middle-to high-income business and servicemen households for exposure to arsenic.

The northwestern village of Rajarampur shows very high risk of arsenic hazard as almost one-half of its tube-wells are contaminated with very high level of arsenic (831 mg/l) that affected 37 people per 1000 residents. In this village, mostly the poor and illiterate farmers and wage laborers are at greater risk of arsenic hazard as revealed from the fact that large number of arsenic victims belong this socio-economic class (Table 1). Another high-risk village is Samta, in which one-third of the village tube wells are contaminated with high quantities of arsenic (0.35 mg/l) that affected a staggeringly large number of people (95 people per 1000 residents). This is a poor village where the majority of the residents earn less than Taka 5000 per month from farming and as wage laborers. Unfortunately, the numbers of arsenic victims

are greater among the poor and illiterate farmers.

The village of Kanchanpur in Khulna district has somewhat moderate risk of arsenic hazard. Despite the fact that most of the tube wells ($>85\%$) were contaminated with moderate levels of arsenic (0.066mg/l), only 10 people per 1000 residents were infected by arsenic-borne skin lesions. Most of the residents in this village are literate and engaged in small business and service to earn a very low monthly income ($<$ Taka 5000).

Low risk of arsenic hazard was found in the village Fingri where almost one-half of the tube wells were contaminated with very low levels of arsenic (0.04mg/l). However, there were no reported cases of arsenic poisoning in this village. The residents of this village are comparatively wealthier than the other villages described above. Most sampled respondents are literate and engaged in business and service and earn over Taka 5000 per month.

Very low risk of arsenic hazard was found in the village Taltala, where only 14% of the village tube-wells are contaminated with low quantities of arsenic. No victims had yet been reported. This village is comparatively prosperous as majority of the sampled households are literate and have high monthly income from business and service. From the village level risk assessment of arsenic hazard, it appears that all the five villages under study have risk of arsenic hazard and the poor illiterate residents are at greater risk of the hazard. Literate and wealthier residents have better access to the information on the arsenic hazard and resource to obtain arsenic free drinking water which may have put them at low risk to the hazard. While various geo-chemical and human-induced factors are responsible for the regional variability of arsenic contamination of tube-wells, variable socio-economic conditions of the village residents have influenced their knowledge, awareness, and perception of arsenic hazard, as well as their ability and willingness to cope with it through mitigation processes.

Knowledge and Perception of Arsenic Hazard

The incidence of arsenic contamination of drinking water has been a widespread problem in recent years in Bangladesh in general and in the areas studied in particular. Most of the residents in the five sampled vil-

lages possess fair knowledge of arsenic contamination of tube-well water on which they must rely for drinking and cooking. However, their view of the chemistry of arsenic and its impact on humans differed significantly. About one-half of the sampled respondent viewed it as a poison, the remaining people identified it as a disease, and virtually all of them recognized it as a cause of skin lesions because that is the most common symptom shown by the arsenic victims.

The knowledge of arsenic hazard and its impact on human health depended on the village risk levels, types of impacts experienced, and socio-economic conditions of the respondents (Table 2 and 3). For example, in Rajarampur village, where the risk level is very high, and most of the victims suffer from skin lesions, 95% of the respondents identified arsenic as a poison that causes skin lesions. In Samta, where the risk level is also very high and the victims commonly suffer from both skin lesion and cancer, the knowledge of arsenic hazard is mixed: 34% respondents referred to it as a poison and 56% identified it as a type of disease; and both groups recognized it as a cause of skin lesions and cancer. Also, somewhat mixed knowledge was found among the three low risk villages of Fingri, Taltala, and Kanchanpur where there are either no victims or few victims reported. Respondents from these three villages viewed arsenic as a poison and is found in drinking water from tube-well; drinking arsenic contaminated water is harmful and may cause white spots on human skin. Absence of victims in these villages actually blurred its residents' perceptual knowledge of the hazard.

The sampled respondents also differed in terms of known years of the arsenic problem and a media to acquire the knowledge. From the sample data, it was revealed that the majority of the respondents knew about the arsenic contamination of drinking water for the last 2 years as more and more people get affected by the poisoning. Most people in the study villages learned about the hazard through mass media such as radio, television, and government and NGO sponsored publicities. Regardless of their socio-economic conditions, most respondents perceived the arsenic contamination of drinking water as a natural hazard that causes too much suffer-

ing and death in their village (Table 2 and 3). Their knowledge and perception of the arsenic hazard forced the village residents to search for its mitigation procedure.

Societal Response to Arsenic Mitigation

A very high percentage of sampled respondents in all five villages had knowledge about water purification and various arsenic mitigation procedures and options (Table 4). Some of the common options known to respondents were water filtering, use of deep tube well water, collection and use of rainwater, and the uses of ponds and well water. Over 80% of the respondents in all five villages knew that water filtering and the use of deep tube wells are safe methods of arsenic mitigation. Less than 10% knew that open surface water such as pond, well, and rainwater should be arsenic free; regardless, they resisted using these sources for drinking and cooking because of the possibility of some other type of contamination.

Only a few active government and non-government organization (NGO) supported arsenic mitigation projects were found in all five villages and most sampled respondents reported that no body is making any attempt to mitigate arsenic contamination (Table 4). Virtually all respondents, regardless of their socio-economic conditions, preferred to receive more government and NGO support to address the arsenic contamination. They were willing to participate in the mitigation projects despite the possibility of their monetary involvement in such projects. Some would prefer to pay the cost of arsenic mitigation as per their financial ability: about 20% of respondents were willing to pay up to Taka 200 per month to receive arsenic-free water and a few rich service and businessmen households were willing to spend as much as Taka 500 or more per month for the safer drinking water supply. Poor, less-educated, and farming and laborer respondents preferred not to pay and insisted that the government and NGO should take more responsibility to assure the supply of arsenic-free water for the country.

Conclusion

The study is significant in two ways. First, it has collected a data set containing information on socio-economic conditions of the users and victims of the

arsenic-contaminated drinking water from variable geographic conditions. It has also collected information on people's awareness of risk, mitigation processes (which involves monetary cost) and variations in willingness to participate depending on socio-economic conditions. The results of the study suggest that the incidence of arsenic contamination of drinking water has been perceived by most of the respondents as a hazard to human health. While most of the respondents were motivated to participate in the water purification and arsenic mitigation projects, they were most in favor of more government-and NGO-sponsored projects in which they would participate and pay as per their financial ability. Socio-economic conditions in general and literacy and income in particular play a role in determining the level of people's awareness of the arsenic hazard and its mitiga-

tion. The results of the study are important for future research and planning the large-scale mitigation process, as they will contribute to our understanding of the importance of socio-economic conditions on the level of awareness of natural hazards and human adjustments to those hazards.

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Appendix: Tables

Table 1 | CHARACTERISTICS OF THE VILLAGES AND THEIR RESIDENTS UNDER STUDY

Village district	Amt. of arsenic in water (mg/l)	No. of tube well contaminated	No. of arsenic victims / 1000 people	Occupational classes				Years of schooling			Monthly income in Taka ¹		
				Farming	Service	Business	Wage Labor	<5	5-10	>10	<5000	5000-9999	>10000
Rajarampur Nawabganj	0.83	17 (39.5%)	37	10 (24%)	13 (32%)	10 (24%)	8 (20%)	18 (44%)	10 (24%)	13 (32%)	23 (56%)	16 (39%)	2 (5%)
Samta Jessore	0.35	17 (34%)	95	12 (24%)	8 (16%)	17 (34%)	13 (26%)	12 (24%)	24 (48%)	14 (28%)	42 (84%)	6 (12%)	2 (4%)
Kanchanpur Khulna	0.066	43 (86%)	10	22 (50%)	8 (16%)	14 (29%)	5 (10%)	9 (18%)	30 (60%)	11 (22%)	34 (68%)	13 (26%)	2 (4%)
Fingri Satkhira	0.055	26 (53%)	0	16 (36%)	15 (34%)	10 (23%)	3 (6.8%)	2 (4.5%)	20 (46%)	22 (50%)	21 (48%)	19 (43%)	4 (9%)
Taltala Narail	0.04	7 (14%)	0	4 (10%)	18 (45%)	13 (33%)	5 (13%)	5 (13%)	12 (30%)	23 (58%)	15 (38%)	20 (50%)	5 (13%)

1. Taka 50 is equivalent to US\$1.00.

Table 2 PERCEPTION AND KNOWLEDGE OF ARSENIC HAZARD BY VILLAGE

Indicators of Perception of Arsenic Hazard and Expected Responses		Rajarampur	Samta	Fingri	Taltala	Kanchanpur	5 Village Total
Do you know about arsenic contamination of drinking water in your village?	Yes	39 (95%)	45 (90%)	44 (100%)	37 (92.5%)	41 (83.7%)	206 (92%)
	No	2 (5%)	5 (10%)	0 (0%)	3 (7.5%)	8 (16.3%)	18 (8%)
What is arsenic?	Poison	39 (95%)	17 (34%)	35 (79.5%)	18 (45%)	11 (22.5%)	120 (53.6%)
	Type of disease	0 (0%)	28 (56%)	9 (20.5%)	20 (50%)	33 (67.3%)	90 (40.2%)
	No knowledge	2 (5%)	5 (10%)	0 (0%)	2 (5%)	5 (10.2%)	14 (6.3%)
Do you know the effects of Arsenic poisoning on humans?	No knowledge	2 (5%)	5 (10%)	0 (0%)	2 (5%)	5 (10.2%)	14 (6.3%)
	Skin lesions	36 (87.8%)	42 (84%)	44 (100%)	38 (95%)	44 (89.8%)	204 (91%)
	Skin Cancer	3 (7.2%)	3 (6%)	0 (0%)	0 (0%)	0 (0%)	6 (2.7%)
How many years you have known about the Arsenic problem?	1-2 years	26 (63.4%)	23 (46%)	26 (59%)	27 (67.5%)	21 (42.9%)	123 (55%)
	3-4 years	13 (31.7%)	22 (44%)	17 (38.6%)	13 (32.5%)	28 (57.1%)	101 (45%)
How did you learn about the Arsenic problem?	Health worker	14 (34%)	17 (34%)	21 (47.7%)	14 (35%)	16 (32.7%)	82 (36.7%)
	Neighbors & Radio/TV/newspaper	25 (61%)	33 (66%)	23 (52.3%)	26 (65%)	33 (67.3%)	142 (63.4%)
What are the major problems in this village?	Arsenic Hazard	38 (93%)	28 (56%)	20 (45.5%)	31 (77.5%)	33 (67.4%)	150 (67%)
	Water contamination	1 (2.4%)	12 (24%)	15 (34.1%)	5 (12.5%)	4 (8.2%)	37 (16.5%)
	Poverty, Unemployment	2 (5%)	10 (20%)	14 (31.8%)	4 (10%)	12 (24.5%)	42 (18.8%)
Do you think that Arsenic problem in your village is hazardous to human life?	Yes	39 (95%)	42 (84%)	35 (79.5%)	31 (77.5%)	37 (75.6%)	184 (82.1%)
	No	2 (5%)	8 (16%)	9 (20.5%)	9 (22.5%)	12 (24.5%)	40 (17.9%)

Table 3 PERCEPTION AND KNOWLEDGE OF ARSENIC HAZARD BY SOCIO-ECONOMIC CONDITIONS OF THE RESPONDENTS

Indicators of perception of arsenic hazard	Expected response	Occupational class				Years of schooling			Monthly income in Taka ¹		
		Farming	Service	Business	Wage Labor	<5	5-10	>10	<5000	5000-9999	>10000
Do you know about arsenic contamination of drinking water in your village?	Yes	74 (98%)	61 (98%)	61 (95%)	32 (97%)	21 (100%)	113 (99%)	57 (97%)	14 (98%)	280 (96%)	6 (100%)
	No	1 (2%)	1 (2%)	3 (5%)	1 (3%)	0 (0%)	2 (1%)	2 (3%)	3 (2%)	3 (4%)	0 (0%)
What is arsenic?	Poison	31 (42%)	37 (60%)	30 (47%)	16 (48%)	6 (29%)	39 (34%)	34 (58%)	61 (42%)	47 (51%)	4 (66%)
	Type of disease	37 (51%)	23 (37%)	29 (46%)	13 (40%)	13 (62%)	66 (57%)	24 (41%)	72 (50%)	32 (39%)	1 (17%)
	No knowledge	5 (7%)	2 (3%)	5 (7%)	4 (12%)	2 (9%)	10 (9%)	1 (1%)	12 (8%)	4 (10%)	1 (17%)
How many years have you known about the arsenic problem?	1-2 years	73 (97%)	59 (95%)	61 (95%)	27 (82%)	18 (86%)	107 (93%)	56 (95%)	134 (92%)	81 (98%)	6 (100%)
	3-4 years	2 (3%)	3 (5%)	3 (5%)	6 (18%)	3 (14%)	8 (7%)	3 (5%)	11 (8%)	2 (2%) (2%)	0 0%
How did you learn about the arsenic problem?	Health worker	25 (34%)	20 (32%)	22 (34%)	12 (41%)	11 (52%)	45 (39%)	19 (32%)	61 (42%)	21 (25%)	2 (33%)
	Neighbors & radio or TV	49 (66%)	42 (67%)	42 (66%)	17 (59%)	10 (48%)	70 (61%)	40 (68%)	84 (58%)	62 (75%)	4 (66%)
What are the major problems in this village?	Arsenic Hazard	70 (93%)	59 (82%)	54 (84%)	28 (97%)	18 (86%)	93 (89%)	54 (92%)	138 (96%)	73 (92%)	4 (100%)
	Water Contamination	0 (0%)	1 (1%)	2 (3%)	0 (0%)	1 (5%)	1 (1%)	2 (3%)	0 (0%)	4 (5%)	0 (0%)
	Poverty/ Unemployment	5 (7%)	12 (17%)	8 (13%)	1 (3%)	2 (9%)	11 (10%)	3 (5%)	6 (4%)	2 (3%)	0 (0%)
Do you have an arsenic patient in your family?	Yes	6 (8%)	9 (15%)	15 (23%)	8 (30%)	3 (14%)	23 (20%)	2 (3%)	27 (19%)	8 (9%)	2 (33%)
	No	69 (92%)	53 (85%)	49 (77%)	19 (70%)	18 (86%)	92 (80%)	57 (97%)	118 (81%)	83 (91%)	4 (67%)
Do you use arsenic-contaminated water?	Yes	38 (51%)	28 (45%)	40 (63%)	13 (41%)	12 (60%)	57 (49%)	29 (49%)	71 (49%)	42 (51%)	2 (33%)
	No	37 (49%)	34 (55%)	24 (37%)	19 (59%)	8 (40%)	58 (51%)	30 (51%)	73 (51%)	41 (49%)	4 (67%)
If yes, why?	No alternative	23 (31%)	12 (19%)	21 (32%)	5 (16%)	6 (29%)	39 (34%)	13 (22%)	44 (30%)	14 (17%)	1 (17%)
	Believe no harm	2 (2%)	2 (4%)	5 (9%)	1 (3%)	1 (4%)	5 (4%)	2 (3%)	4 (3%)	5 (6%)	0 (0%)
	Water not tested	50 (67%)	48 (77%)	38 (59%)	26 (81%)	14 (67%)	71 (62%)	44 (75%)	96 (67%)	64 (77%)	5 (83%)

1. Taka 50 is equivalent to US\$1.00.

Table 4**MITIGATION OPTIONS AND PEOPLE'S PARTICIPATION IN MITIGATION PROCESS**

Mitigation options	Expected response	Occupational class				Years of schooling			Monthly income in Taka ¹		
		Farming	Service	Business	Wage Labor	<5	5-10	>10	<5000	5000-9999	>10000
Do you know about water purification?	Yes	63 (82%)	46 (74%)	50 (78%)	24 (72%)	17 (81%)	92 (80%)	46 (78%)	110 (76%)	73 (88%)	4 (67%)
	No	14 (18%)	16 (26%)	14 (22%)	9 (28%)	4 (19%)	23 (20%)	13 (24%)	35 (24%)	10 (12%)	2 (33%)
What are the arsenic mitigation methods you know or heard of?	Filtering	33 (44%)	22 (35%)	30 (47%)	14 (42%)	11 (52%)	59 (51%)	19 (32%)	60 (41%)	35 (42%)	3 (50%)
	Deep tube well	29 (39%)	33 (53%)	27 (42%)	14 (42%)	5 (24%)	40 (35%)	29 (49%)	62 (43%)	38 (46%)	2 (33%)
	Rain water	9 (12%)	5 (81%)	4 (6%)	1 (3%)	2 (10%)	9 (7%)	6 (10%)	13 (9%)	5 (6%)	0 (0%)
	Pond or well	3 (4%)	2 (32%)	3 (5%)	3 (10%)	2 (10%)	4 (4%)	5 (9%)	8 (6%)	3 (4%)	1 (17%)
	Don't know	1 (1%)	0 (0%)	0 (0%)	1 (3%)	1 (4%)	3 (3%)	0 (0%)	2 (1%)	2 (2%)	0 (0%)
Who is mitigating arsenic contamination in your area at present?	Government health workers	14 (19.5%)	11 (17%)	13 (20%)	5 (15%)	5 (8%)	21 (18%)	14 (24%)	23 (16%)	23 (28%)	2 (33%)
	Research team	1 (1%)	1 (2%)	1 (1%)	1 (3%)	0 (0%)	1 (1%)	0 (0%)	1 (1%)	3 (4%)	0 (0%)
	NGO	14 (19.5%)	7 (10%)	16 (25%)	9 (27%)	7 (12%)	34 (30%)	5 (9%)	39 (27%)	7 (8%)	2 (33%)
	Self	3 (4%)	2 (3%)	3 (5%)	2 (6%)	1 (2%)	9 (7%)	1 (1%)	4 (2%)	7 (8%)	0 (0%)
	No body	40 (56%)	41 (66%)	31 (49%)	16 (49%)	47 (78%)	50 (44%)	39 (66%)	79 (54%)	43 (52%)	2 (33%)
Who do you think should take the initiative to arsenic mitigation methods?	Government	61 (81%)	42 (68%)	51 (80%)	25 (75%)	58 (86%)	50 (73%)	37 (63%)	113 (78%)	62 (75%)	4 (68%)
	Research team	1 (1%)	3 (5%)	1 (1%)	1 (3%)	2 (3%)	0 (0%)	3 (5%)	5 (3%)	1 (1%)	0 (0%)
	NGO	11 (15%)	10 (16%)	7 (11%)	5 (15%)	6 (9%)	14 (20%)	10 (17%)	19 (13%)	13 (16%)	1 (16%)
	Self	2 (3%)	7 (11%)	5 (8%)	2 (6%)	1 (2%)	5 (7%)	9 (15%)	9 (6%)	7 (84%)	1 (16%)
Are you willing to participate in the arsenic mitigation and to pay the cost?	Yes	64 (85%)	57 (92%)	57 (89%)	29 (88%)	19 (90%)	99 (86%)	55 (93%)	125 (87%)	79 (95%)	5 (83%)
	No	11 (15%)	5 (8%)	7 (11%)	4 (12%)	2 (10%)	16 (14%)	4 (7%)	21 (13%)	4 (15%)	1 (17%)
How much money are you willing to spend for arsenic mitigation process per month?	No capacity to pay	6 (8%)	3 (5%)	3 (4%)	1 (3%)	1 (5%)	6 (5%)	2 (3%)	9 (6%)	2 (2%)	1 (20%)
	Taka 100-200	15 (20%)	14 (23%)	20 (30%)	5 (15%)	3 (14%)	26 (22%)	15 (26%)	31 (21%)	24 (29%)	1 (20%)
	Taka 200-500	1 (1%)	1 (1%)	2 (3%)	4 (12%)	0 (0%)	1 (1%)	4 (7%)	0 (0%)	7 (8%)	1 (20%)
	>Taka 500	0 (0%)	2 (3%)	1 (1%)	0 (0%)	0 (0%)	2 (2%)	1 (2%)	1 (1%)	2 (3%)	1 (20%)
	As per capacity	53 (71%)	42 (68%)	41 (62%)	23 (70%)	17 (81%)	80 (70%)	36 (62%)	105 (72%)	48 (58%)	1 (20%)

1. Taka 50 is equivalent to US\$1.00.

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In the awakening of modern times and its technologies, energy and the generation of electricity has brought concern to the present and the near future. Just about a hundred years ago, energy was free and readily available in the earth's biosphere, like Mother Nature's air and water. Energy came in such forms as fossil fuels and hydroelectric power. But with the global population ever increasing, the world has had to consume more energy and has had to introduce new sources of energy. One of these new sources is *nuclear energy* – the energy stored within atoms or the energy resulting from a nuclear reaction.

Through years of research, scientists and engineers have developed nuclear reactors to convert this energy into enormous amounts of electricity. Today, these highly controlled reactors are

found in nuclear power plants located all over the world. In fact, nuclear power plants account for 20% of our nation's electric power. Although energy from *fission* – or the splitting up of nuclei into smaller nuclei – has improved and continues to improve the quality of human life, it has also produced many radioactive wastes within the last five decades. Unfortunately, this accumulated waste can alter the living cells of organisms; such waste poses a potential risk to human health and the environment and requires proper disposal (Berlin and Stanton 1). Therefore, every process involved with the production of nuclear energy or every process that belongs to the nuclear fuel cycle must require *radioactive waste management* (Liu and Lipták 127).

The Need for Computer Codes and Simulations

The management of radioactive waste ranges from the characterization of the waste to the monitoring of the waste's activity after final disposal. To ensure successful management, engineers, scientists, and environmentalists need to obtain a detailed knowledge of the waste before and after disturbance and thoroughly assess the risks, reliability, and performance of chosen management procedures. For these vital needs, *computer codes* and *simulations* have been developed. Without computer codes and simulations, those related to the field of radioactive waste management would spend valuable time acquiring the pertinent data, performing complex calculations, writing documents, and finding lawyers.

Importantly, simulations model the natural phenomena that affect radioactive materials. Their multi-faceted tasks revolve around the computations of codes. Computer codes not only aid simulations but also facilitate the design and analysis of management systems. Together, they exhibit craftsmanship and beauty. This article focuses on radioactive waste management through the use of computer codes and simulations. It attempts to present a wide scope of simulations and codes. Although simulations employ codes, they are not necessarily a subset of the latter. Each simulation or code concentrates on a particular aspect of management and can be treated in its own respects.

Engineers depend on simulations and codes to represent real-time processes in nature and synthetic constructs. With the simulation of processes, researchers, engineers, and scientists can avoid exposure to radioactive isotopes. Moreover, they can investigate areas “not conveniently modeled by analytical techniques” and represent “highly complex models [in] a sufficiently short time scale” (Walton Foreword). With fast and speedy codes, the technically oriented can understand the long-term effects of wastes on the world and its inhabitants. Then, they can take precautions to preserve the future of the environment, ecosystems, and other human beings.

Introduction to Simulations

In our current state of academia, we always hear the words “simulation,” “models,” and “computers.” We will now define modeling, simulation, and codes and discuss their interrelationship.

According to a workshop on modeling and simulation for environmental management sponsored by the Los Alamos National Laboratory, a model is “a mental, physical, or mathematical construct intended to capture some aspect of nature or a process” (Boyd). There are two kinds of models: conceptual and quantitative. Conceptual models rely on observations, experiments, and facts, and they extrapolate from this knowledge. A conceptual model, then, brings forth a quantitative model. Such quantitative, or numerical, models depend on mathematical equations to describe the conceptual model.

After models have been conjectured, researchers try to imitate the desired natural phenomenon or process by solving the mathematical equations or making the necessary calculations. Completion of these steps may yield new hypotheses and/or unexpected conclusions, which would lead to modifications in the original models. When researchers have accepted their quantitative models, programmers may implement the mathematical equations and data in a programming language or into a software module, thus simplifying and allowing the execution of the derived quantitative models (Boyd).

Specific Classification of Nuclear Waste Simulation

Simply stated, simulation for nuclear waste can be divided into four categories, which can be further divided into sub areas. These four categories are particle behavior, container behavior, tool behavior, and target behavior. After a general description of these areas, we will give several examples that cover the scope of nuclear waste simulation.

Particle Behavior

Particle behavior identifies the major group of simulation that deals with *ionizing radiation* (energy that can change the biological properties of cells), *activation products* (products created by nuclear reactions), and waste constituents. For this group, scientists use codes to simulate how radioactive particles move, break down, and interact with matter – especially in the forms of other radioactive wastes and chemical agents (generated in the reactor cores of nuclear power plants or in waste containers). Simulation in particle behavior also involves radiation transport, cross sections, and byproducts of decay reactions.

Container Behavior

Container behavior, a second important category of simulation, involves anything that encloses and isolates wastes. In other words, the container-behavior set comprises of small containers and their technologies that directly touch the wastes, such as casks, tanks, cylindrical shells, and shielding equipment, or macroscopic containers, such as waste repositories and domes. The materials that surround the containers or even entomb them make up the rest of this set. Simulation in container behavior concentrates on important characteristics used in siting high-level wastes repositories sites, such as rock and surface characteristics and plate tectonics. Additionally, many of the codes attempt to analyze shielding geometries, cask designs, and degradation of container material.

Tool Behavior

Simulation in tool behavior aids in the development of tools and vehicles used to transport radioac-

tive wastes, handle the stored, processed, or transported wastes, decompose such wastes, and label the wastes. National labs focus on the simulation of vehicles and robots used in radioactive waste transport, management, and characterization.

Target Behavior

Nuclear experts and even common folk have a particular interest in this category because ionizing radiation can harm or transform a target in contact with radioactive particles. Although target behavior is related to particle behavior – since targets could be chemicals, wastes, humans, buildings, or other items – simulation in particle behavior “sees from the perspective of the particles,” whereas simulation in target behavior sees from the point of view of people, targets, and machines. Simulation in target behavior specifically involves determining what risks exist when wastes leak and leach out from containers and how wastes affect the “spheres,” such as the hydrosphere, biosphere, and atmosphere, as well as living things, the food chain, and objects in the vicinity of power plants and waste storages.

Introduction to Codes

Numerous codes have been developed to serve a wide variety of purposes, such as specifying waste acceptance, developing transportation procedures, siting repositories, designing disposal packages, minimizing waste generation, optimizing waste-reduction processes, and controlling the release of effluents into the atmosphere. In fact, companies, like Intera Information Technologies, have been established to develop new and improved nuclear codes.

Classification of Codes

To recognize computer codes and their functions better, different agencies and independent groups have categorized codes. Notably, the Oak Ridge National Laboratory (ORNL) has classified codes into several subject areas, such as human factors engineering, isotope generation and decay, and nuclear criticality safety.

Understanding the Role of Codes

It is of utmost importance to realize that codes only support radioactive waste management and cannot be entirely trusted. For example, the Oak Ridge Isotope Generation and Depletion (ORIGEN) code has been benchmarked and extensively used to model the initial chemical content of spent fuel and “changes in this content subsequent to disposal” (Berlin and Stanton 7). However, the code’s estimated values have not always agreed with the Department of Energy’s findings (Tang and Saling 176). This example simply demonstrates that other sources must be consulted and compared with to check the accuracy of a computer code.

Foundation of Codes

The foundation of computer codes rests in mathematical models, numerical tools, and mathematical formulas. By understanding about these resources, programmers have written powerful codes that realistically simulate real-time applications.

A Brief Overview of the Monte Carlo N-Particle Code

During World War II, extensive work at the Los Alamos National Laboratory in New Mexico led to the formation of the Monte Carlo method. Generally attributed to scientists named Fermi, von Neumann, Ulam, Metropolis, and Richtmeyer, this mathematical tool provides the foundation for the famous Monte Carlo N-Particle code.

Many codes solve explicit equations and “turn a crank” to obtain complete, quantitative answers. By contrast, the Monte Carlo method does not solve equations and does not obtain complete answers. Named for its similarity to the throwing of dice in a gambling casino, the Monte Carlo method is “based on the selection of random numbers”. It realistically simulates the events of natural phenomena by recording tallies of their average behaviors and forming conclusions from these tallies. Because these phenomena are usually described by a large number of trials and iterations, computers are used for simulation (Briesmeister 3).

One ubiquitous nuclear code that revolves around the Monte Carlo method is the Monte Carlo N-Particle

(MCNP) code. Given an arbitrary three-dimensional configuration of radioactive materials, the MCNP code models the transport of photons, neutrons, electrons, or a combination of these particles. Because this transport code can simulate the movement of radioactive particles, it belongs to the category of radiation transport codes.

Radiation Safety Information Computation Center

In discussing nuclear codes, nuclear history cannot forget one of the most important sources of coding, the Radiation Safety Information Computation Center (RSICC). Although many nuclear-related software divisions exist in our national laboratories, one of the most influential is RSICC. In November 1962, the U.S. Atomic Energy Commission founded RSICC, formerly known as the Radiation Shielding Information Center (RSIC), at the Oak Ridge National Laboratory. Commissioners established the center to provide valuable information, especially computer codes, to researchers involved in the area of radiation shielding. The center wanted to keep an available library of codes (“RSICC”).

In March 1963, a division in RSIC sprang up to gather, analyze, and distribute computer codes in shielding calculations. This part of RSIC helped many organizations, such as the National Aeronautics and Space Administration (NASA) and the Defense Atomic Support Agency (DASA). RSIC supplied NASA with data about shielding from cosmic radiation, while it assisted DASA in gathering codes that included topics like accelerator shielding and shielding from nuclear weapons radiation. In August 1996, Oak Ridge renamed RSIC to RSICC for several reasons. The center began to handle computer code technology that dealt with subjects other than shielding, such as radiation transport and safety. In addition, the center upgraded its computer hardware in order to test software and to communicate with other major computing centers (Butler, Maskewitz, and Rosen 134-136).

Today, RSICC focuses on the radiation transport field and actively coordinates with the international shielding community on safety. RSICC reserves and disseminates technical info and codes about shielding

and protection from nuclear reactors, cosmic radiation, radiation from accelerators, weapons, wastes, and medical facilities. Overall, RSICC is a great contributor to radioactive waste management (“RSICC”).

The Yucca Mountain Project

The Yucca Mountain Project is a current study by the United States Department of Energy (DOE) to determine if Yucca Mountain, Nevada, can suitably host a geologic repository for the nation’s high-level radioactive waste and defense spent nuclear fuel. In order for Yucca Mountain to be characterized, extensive studies must be made on the mountain’s geology, hydrology, biology, and climate – hence, the Yucca Mountain Project (YMP). These extensive studies belong to the field of radioactive waste management and, thus, require the support of computer codes and simulations. Potentially the most critical flow mechanism that can contaminate the Nevada environment is fracture flow (Zyvoloski and Robinson). To facilitate a visual understanding of this process, the Geoanalysis Group at Los Alamos has been currently working on three codes funded by the YMP (“Porous Media Flow”).

Conclusion

Models, derived from mathematical and conceptual constructs, aid in simulation schemes and in the implementation of computational coding packages. Using a simple classification scheme, we can categorize all forms of simulation into four areas and all computational codes into approximately eleven areas. Uses of simulation are

found in a wide range of topics, such as the prediction of criticality, the design of transmutation systems, the improvement of robots, and the representation of human organs. As a counterpart to simulation, engineers greatly rely on the power of codes to understand complex nuclear scenarios, such as the diffusion of radionuclides through a geological medium. Other radioactive waste management codes have extreme importance to the macroscopic scientific world, such as the Monte Carlo N-Particle code. Lastly, a bright crystal of simulation and coding today lies within the Yucca Mountain Project, a project full of profound significance to not just scientists but also to our society.

By examining all the different areas that simulation and codes touch in radioactive waste management, we realize that simulation and codes represent a unifying attribute of the work of nuclear engineers. A further generalization leads to the notion that nuclear engineering, electrical engineering, mechanical engineering, and all other engineering disciplines share a common theme, the theme of simulation and computational codes. Moreover, the boundaries and distinctions that characterize these fields begin to blur and disintegrate when we enter the wonderful realm of radioactive waste management. Without simulation and codes, scientists and engineers could never fully understand the nature of radioactive wastes and its effects on the universe. Simulation and codes allow engineers to harness the beneficial power of radioactivity, prevent disasters in regions storing radioactive wastes, protect the lives of researchers and common folk, and preserve the world in which we live.

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