Geographic Competitive Advantages on Court Surfaces in Men's Professional Tennis: Before and After the Introduction of New Tennis Balls

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Abstract:

National Tennis Associations (NTA's) across the globe attempt to gain competitive advantages over their peers by utilizing resources and developing superior strategies for competition. One area of the sport that is influenced by NTA strategy performance on the different court surfaces in tennis (grass, hard and clay), each of which demands a different skill set. In 2006, the International Tennis Federation (ITF) introduced new tennis balls which were intended to equalize the nature of play across the three different tennis court surfaces. This paper will address the impact of this 2006 decision on geographical competition. Specifically, it will explore whether geographical competitive advantages existed on different court surfaces prior to 2006, and, if so, whether those advantages have been altered.

I. Introduction

In many ways, tennis is a uniquely global sport. The sport developed in different parts of the world, and tournaments are held all over the globe. One of the most important features of tennis is that it attracts athletes from many different countries who compete against one another. Although players are free agents and don't formally represent their countries[1], regional institutions play a crucial role in player development. Many countries have National Training Centers (NTCs) and national associations (NA) of tennis, which oversee talent scouting and development, training non-professional athletes and preparing them for competition. In many ways, these national organizations can be seen as competitors vying for an advantage over other countries, with the goal of maximizing their players' performance and prize money. In economic terms, a firm, player or organization can gain a competitive advantage by evaluating its inherent resources and adopting unique tactics, or technologies, in order to outperform its peers. The activities of regional institutions in tennis can be seen as doing just that.

The work of tennis associations is to evaluate the unique resources, the available finances, talent pool and infrastructure, in their country and to create a strategy of player development around such resources that will maximize future player performance. Due to diversity in resources and adopted strategies, there will be varying degrees of success across regional organizations. One particularly successful case study is the Tennis Europe, a continental unit that has managed, through large financial investments and visionary planning, to assert its dominance in Men's and Women's Tennis. Whereas in the 1970's, when the ETA was established, European players took a backseat to Americans, who comprised 50%-80% of the top 100, Europe now contributes approximately 80% of the top

[1] Players do represent their own countries in the Davis Cup, an annual international competition in Men's Tennis. The scope of this paper is restricted to regular season singles competition.

100 players[2]. Such a drastic transformation is a salient example of how regional institutions can differentiate themselves and gain a competitive advantage.

There are several areas in which countries can specialize to gain an advantage, but one particularly important area is the development of a strategy for dealing with the different court surfaces, hard, clay and grass. Because each surface contributes different mechanics to the sport, success on each surface entails a distinct skill set. A regional institution, therefore, can compete with other countries by creating a superior technology, in this case a superior strategy for success across the three surfaces. Frequently, such a strategy entails specialization, where a country will focus primarily on excelling on one surface. However, other more complex strategy portfolios, focusing on straining on more than one surface, have proven successful as well. Anecdotal evidence and conventional wisdom, some of which will be presented and tested in this paper, suggest that countries can effectively use the diversity across courts to gain a competitive advantage.

In 2006, the ITF made a change to the sport of tennis that threatened the foundation on which certain national competitive advantages were based, the introduction of new types of tennis balls that would equalize the mechanics of the sport across different court surfaces. The reasoning for this decision was ambiguous, and no acknowledgment was made for how this change might affect the nature of international competition. One could expect, however, that changes in the competitive landscape might result from tampering with an aspect of the sport to which strategy is so finely attuned.

This paper will attempt to examine the impact of the 2006 introduction of new tennis balls on the global competitive advantages in Men's Professional Tennis. Specifically, it will use tournament data to provide quantitative evidence of any trends and changes.

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[2] MacCurdy, Doug. "A Global Look At Top Player Development." *ITF Coaching and Sport Science Review 2008;* Issue 46, pp. 27-29.

Central to my examination will be two questions: 1. Prior to 2006, did countries possess significant competitive advantages on different court surfaces? 2. To what extent did those competitive advantages change after 2006? I hypothesize that geographical advantages did exist prior to 2006, and that such advantages have been diminished since the introduction of new tennis balls.

II. Background Information

This section contains some background information relevant to my study. It presents a brief overview of the different tennis court surfaces, further exposes the role of international organizations, and finally explores the reasoning behind and implications of the ITF's 2006 decision to introduce new balls.

Tennis Court Surface

That professional tennis is played on several types of surfaces speaks to the globalized nature of its development into a sport. Lawn tennis, the earliest incarnation of the game, began its development in the 14th century in England[3], where it continued to evolve until the debut of the Wimbledon tournament in 1877. The U.S. National Lawn Tennis Association[4] was founded in 1881, and by 1905 the tennis world saw the establishment of the four Grand Slam tournaments- Wimbledon, French Open, Australian Open, U.S. Open- as well as the Davis Cup, all played on grass. By the early 1900's, clay court surfaces, which were made of crushed brick and required less maintenance than grass courts, had gained popularity, and in 1928 the French Open was moved to a new facility that had clay courts. Finally, hard court surfaces composed of asphalt and concrete became the

[3] "History of Tennis", ITF website. See References.
[4] Now the U.S.T.A

surface of choice at the U.S. Open when the competition was moved to Flushing Meadows in 1978, and at the Australian Open in 1988. Since then, Wimbledon, U.S. Open, French Open ad Australian open have been played on grass, hard court, clay and hard court, respectively.

Whether or not the authorities that introduced clay and hard courts new this at the time, the three surfaces tend to skew the mechanics of the game in different ways and demand different skill sets from competitors. Grass courts tend to be the 'fastest' courts, meaning that the ball skids and bounces low, forcing the player to react very quickly to the movement of the ball. Because of the speed of the game, grass courts favor players who have intense short-term concentration, can dictate the tempo of points, volley well, posses very strong serves and who can return serves well, among other things[5]. Unforced errors occur more frequently than in other surfaces, so players must be psychologically prepared to make many mistakes without getting discouraged. In contrast, clay courts are considered the "slowest", in that the ball bounces higher on clay and allows players more time to react to its movement[6]. This has a number of implications for player performance. First, speed of serve is not as important on clay. Second, rallies tend to last longer, so physical endurance, patience, a more consistent game, strong groundstrokes, and the ability to force the opponent to make mistakes are all crucial to success[7]. Hard courts are moderately paced, so multiple types of skills and strategies are effective.

There have been some quantitative studies demonstrating the differences in the game across surfaces. One study found that grass and clay competition is so different that

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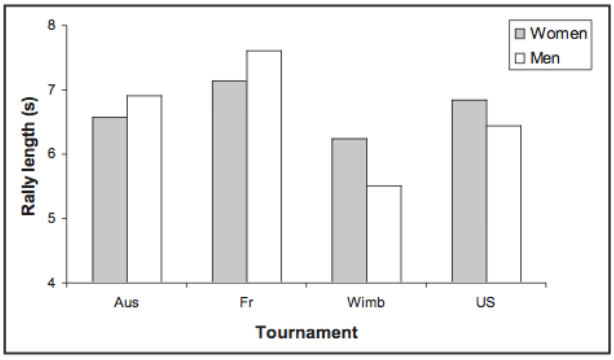
[5] Gullikson, T. and MacCurdy, D. "Fast Court Tactics- Part 1" *ITF Coaching and Sport Science Review, 2008; 27, 12-1.*

[6] Blackman, Samuel and James W. Casey. "Development of a Rating System for All Tennis Players." *Operations Research,* Vol. 28, No. 3, Part 1 (May- Jun 1980), pp. 489-502.

[7] Cascales, Antonio Martinez. "Tactics for Advanced Clay Court Tennis." *ITF Coaching and Sport Science Review 2002;* Issue 27, pp. 9-12.

dominating on each one requires difference metabolic responses[8]. The figures below are taken from another study[9] of Men's and Women's professional tennis competition in 2008, and give an overview of some of the observed differences in the nature of play across the three surfaces. They indicate that more service points (first and second serve) were won at Wimbledon, and that rally duration, in seconds, was shortest at Wimbledon and longest in the French Open. These differences are attributed to the unique physical properties of each surface.

Game	Tournament			
	Australian	French	Wimbledon	US
%1st Serves in				
Women	61.9	61.5	65.1	61.0
Men	61.2	65.0	62.8	62.9
%Points won when 1st serve in				
Women	62.2	59.9	65.7	60.8
Men	70.8	68.3	75.8	69.1
%Points won when 2nd serve needed				
Women	46.3	45.8	45.6	47.1
Men	49.6	47.1	57.3	53.3



Given the drastic differences in the nature of the game, it is truly remarkable that all surfaces are equally encompassed and treated as 'tennis', with one ranking system. In fact,

[8] Girard,O. and Millet, G.P. "Effects of ground surface on the physiological and technical responses in young players." Science and Racket Sports III Routledge. 2004, pp. 43-48.

[9] Brown, Emily and O'Donoghue, Peter. "Gender and Surface Effect on Elite Tennis Strategy." *ITF Coaching and Sport Science Review 2008;* Issue 46, pp. 9-11. This study will be revisited later in the paper.

there have proposals to include a surface speed correction factor into the algorithm for ranking players[10]. In any case, players must grapple with the challenge of three different court surfaces, and must consider this challenge in deciding what skills to focus on in training, which tournaments to compete in and how to organize their training schedule over the course of a year[11].

Regional Tennis Organizations

To understand how regional organizations consider court surfaces, a closer look at the features of these organizations will be helpful. What makes a regional organization effective? Returning to the model of organization as competitive firm, national tennis associations function by doing two things: first, by evaluating their 'natural resources'; second, by developing technologies, or strategies, that allow them to outperform their peers. Because resources and strategies can be vastly different, there is a lot of diversity across countries. The 'natural resources' refers to all of the exogenous factors unique to a country that determine the raw material that an organization has to work with. Most obviously, the quality and quantity of athletic talent available differs based on demographic composition of the population, for example average age or ethnicity, as well as on cultural trends in nutrition, fitness and work-ethic. Furthermore, incentives for competitors can vary. For example, in Eastern Europe many see tennis as a road to a better life and are more incentivized to take the necessary measures to excel[12]. Additionally, the quality and quantity of available talent will be determined by the attractiveness of substitutes for professional tennis, specifically other sports or avenues of competition. There is, for example, concern that U.S. tennis player development is waning because athletes are opting

[10] Blackman, 1980

[11] One way players factor this in is through periodization, wherein they train for different surfaces and different times of year.

[12] MacCurdy, 2008. p. 27

to pursue college scholarships in basketball, soccer and even lacrosse[13]. In addition to differences in player talent, national organizations will have different levels of financial investment. Funds for development can come from wealthy parents, management companies, equipment companies, private goodwill investors and lenders, or coaches. Finally, included in the category of 'natural resources' are inherited factors, such as equipment, facilities, institutions and public opinions, from past tennis activity in a particular region. For example, Spain's history as a predominantly clay-court oriented country has consequences for today's Spanish Tennis Federation, in that they have mostly clay-court facilities to work with and that most of their emerging talent grew up playing on clay[14]. Similarly, Serbian players are fortunate that, since many tournaments are played in or around Serbia, they can compete 30 weeks a year in tournaments that are driving distance without having to pay exorbitantly[15]. The different types of resources, such as player talent, finances and tennis history, can all interact with and influence one another. For example, it is easy to see how a country's history of success, or lack thereof, can influence the number of both athletes and investors attracted to the sport.

After considering the 'natural resources' with which it has been endowed, a national tennis association then develops and implements what it hopes are superior technologies, in this case strategies for training and competition. Among such strategic choices to make are whether to build a national training center (NTC), what type of player to recruit, at what age to begin recruitment, and how to train the players. Of all of these, the tactics employed in training players are the most specialized and competitive, and organizations will invest much effort and money in developing superior best practices.

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[13] Amdur, Neil. "U.S. Tennis Losing Ground in Developing Players." *The New York Times;* April 5, 2009.
[14] Cascales, 2002.
[15] MacCurdy,2008. p. 28

An important component to most institutionalized training strategies is an approach to the different court surfaces. Like all other parts of strategy, surface strategy is determined partly by preexisting resources, specifically by which type of courts are most prominent in the region. Countries who train primarily on clay include Serbia, Czech Republic and Slovakia, Croatia, Russia and Argentina[16]. However, the picture is much more complex and leaves room for more specialized strategy. For example, Spain trains primarily on clay, but also prepares on hard to help players be well-rounded[17]. The USTA employs an even more generalized approach, one that has been criticized as being *too* general. Although Martin Blackman, the senior director for talent development for the U.S.T.A, has praised the U.S. strategy by saying, "There's no secret formula, and that's our strength…. What we're doing at a national level is complementary and inclusive," tactical expert Pancho Segura believes that, because of this fragmented approach, American players "don't know how to win tennis matches.[18]" Developing a comprehensive and well-thought-out approach to succeeding across the different court surfaces is a central part of national tennis organizations' strategic work[19].

ITF Decision 2006: New Balls

The ITF, or International Tennis Federation, is the highest governing body of international tennis for men and women. Formed in 1913, its objectives are to grow the sport worldwide, to monitor and administer the rules of the game, and to preserve the integrity and independence of tennis as a sport. The ITF plays a role in everything from

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16 MacCurdy,2008.

17 Cascales, 2002

18 Both quotes from Amdur, 2009.

19 For a wonderfully insightful and detailed account of different strategies, see ITF coaching and sport science review issue 27 (August 2002). Coaches of top players and tennis strategy all-stars share their best practices.

sports medicine to technology research and development, from tournament organization to rule-writing. Although its main offices are located in London, it has 205 member National Associations, 144 of which have full voting rights in annual meeting. [20]

From 1999 to 2006, the ITF entered a period of heavy research into the inconstancies of the game across different court surfaces across. ITF commissions began to investigate surface parameters like shock absorption, frictional characteristics, and surface permeability, and to develop a system of rating court paces based on such parameters[21]. These efforts culminated in 2006, with the formal introduction of new rules about tennis balls and court surfaces. The new rules[22] specified different types of balls to be used on different court surfaces. Since 2006, Type 1 balls are used on clay courts; they are harder and more resistant to compression upon impact, resulting in a faster game. Type 2 balls are the standard balls used previously, and remain in use on hard courts. Type 3 balls are 8% larger in diameter, and so result in greater air resistance, greater deceleration and a slower game; these are used on grass courts. Thus, the fastest court, grass, has been slowed down, and the slowest court, clay, has been sped up.

The rationale behind this decision is slightly ambiguous, and different reasons have been offered. Most vocal in explaining the ITF decision has been Andrew Coe, Head of Product Development and Technical for the ITF. Coe, however, he has sent some mixed messages about the ITF's motivation. In an official public statement[23], Coe suggests that the increasing speed of the game is detrimental to sport spectatorship. He states that "the new Larger Ball (Type 3) will we hope produce longer rallies… (and) reduce the dominance of the serve, which will make tennis more attractive to spectators". Members of the tennis

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[20] "About the ITF" ITF website

[21] Cislunar Aerospace, I. (1999). "Technology and Tennis- The Balancing Act." *Aerodynamics in Sports Technology.*

[22] "History of Rules" ITF website

[23] ITF, *This Week, July 9, 1999*

community have found fault with the opportunistic nature of this logic, arguing that it is problematic to alter the rules of the sport in order to make more money off of spectators[24] [25]. A bigger problem with this rationale, however, is that it does not explain why faster balls were introduced on clay. In a 199 interview with Cislunar Aerospace[26], Coe provides a motivation for the ITF's actions that is more consistent with the actual rule change, stating that, with further research, "appropriate standards for courts and regulations can be defined to ensure consistency among different surfaces".

The rationale behind the ITFs decision, intriguing as it may be, is of less concern to this study than the consequences the decision has had for global competitive advantages in the sport.

III. Related Studies

Geographical Trends

The most relevant study to this paper's interest in geographical advantage is Roger Holder and Alan Nevill's, "Modeling Performance at International Tennis and Golf Tournaments: Is There a Home Advantage?"(1997)[27]. Holder and Nevill examine whether there is home advantage, whether "competitors will perform above their expected level when competing in events held in their own country", in tennis and golf. Their model regresses result rank of a player in a specific tournament on their world rank from previous

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[24] Miah, Andy. "New Balls Pleas: Tennis, Technology, and the Changing Game." *Tennis, Science and Technology.* London: Blackwell Science, pp. 285-292.

[25] Miah, Andy. "Is Bigger Better? A Response to the International Tennis Federation's 'Bigger Balls' Proposal" *International Sports Studies* (2002).

[26] Cislunar, 1999

[27] Holder, Roger and Nevill, Alan. "Modeling Performance at International Tennis and Golf Tournaments: Is There a Home Advantage." *Journal of the Royal Statistical Society. Series D (The Statistician),* Vol. 46, No. 4 (1997), pp. 551-559.

tournaments and a dummy variable for home or away status.[28] They culled their data from the 4 grand slam tournaments in 2007, which gave their study 127 x 4 = 508 data points. In their results, the coefficients on the home or away variable were insignificant for all tennis tournaments, offering limited evidence for any home court advantage in tennis.

The applications of Holder and Nevill's study to the study of this paper are limited, in part because the scope of the model fails to capture some important effects in tennis. They aimed to study the trends in home advantage as it is defined traditionally in other sports, assuming that such factors as crowd and officials' support, familiarity with venue and travel fatigue would play an important role. It is not surprising that their study found no significant home advantage, because the aforementioned factors are not very applicable in tennis[29]. What their model does not capture, and what is likely to influence performance, is the advantage in playing on what can be considered "home surface", or the surface on which your native country dominates. In dividing players by nationality, and in looking at performance only in tournaments held in players' literal 'homes', Holder and Nevil's model misses the potentially significant trends in geography. The goal of this study will be to capture those trends.

Comparative Studies (Pre and Post 2006)

Several studies have been conducted to show the effects of the newly introduced Type 1 and Type 2 balls on the nature of the sport.

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[28] The model is: ln(result rank)= a + b ln(world rank) + c home + d homeln(world rank). The final variable, which has coefficient d, takes into account the interaction between home and world rank, i.e. the degree of home advantage that changes with rank.

[29] The authors themselves admit to this, explaining that, for example, tennis players travel in advance and so are not fatigued in away tournaments.

Research team Blackwell, Heath and Thompson[30] published an experiment wherein the effect of the Type 3 slower ball versus Type 2 ball on physiological responses is tested. Studying the responses of 20 participants from local tennis facilities, they found that the average heart rate when players used Type 3 balls (157) was significantly higher than when they played with Type 2 balls (153). Additionally, they found that the number 'good shots' per point was significantly higher using Type 3 balls (4.3) than Type 2 balls (3.6). These findings suggest that Type 3 balls do in fact slow down the game, making it easier to return shots and prolonging the point. Furthermore, they show that Type 3 balls demand more player endurance.

The findings from these experimental results are consistent with those of studies using data from professional tennis matches, specifically the studies conducted by Peter O'Donghue. O'Donogue is a frequent contributor to important tennis coaching and technology publications such as *ITF Coaching and Sports Science Review* and *Science and Racket Sports,* and is particularly interested in court surface effects. In series of studies[31] [32]he compared player performance across different court surfaces in 2007 to player performance in the 1990's, before the Type 1 and Type 3 balls were introduced. Specifically, he recorded the duration of rallies for men and women in each of the 4 Grand Slam Tournaments. The averages are summarized in the table below.

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[30] Blackwell, J.R., Heath, E.M. and Thompson, C.J. "Effect of the Type 3 (oversize, slow speed) tennis ball on heart rate, activity levels and shots per point during tennis play." Science and Racket Sports III Routledge. 2004, pp. 37-42.

[31] Brown, E. and O'Donoghue, P. 'Gender and Surface Effect on Elite Tennis Strategy', *ITF Coaching and Sports Science Review 2008; 15(46): 9-11*

[32] Over, Scott and O'Dooghue, Peter. "Whats the Point- Tennis Analysis and Why." *ITF Coaching and Sport Science Review 2008;* Issue 45, pp. 19-21.

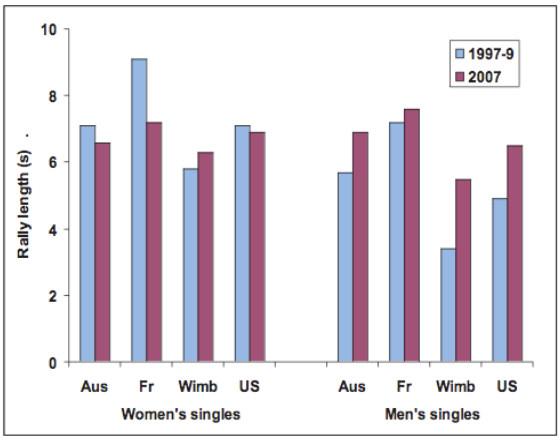

Figure 1. Rally Length for different Singles Games (1990s and 2007).

There are two holistic trends in this data. For the men, rally duration increased from the 1990's to 2007 while, simultaneously, rally lengths in the women's game decreased on most surfaces. These trends are likely related to changes in overall fitness and proficiency[33]. O'Donoghue's studies arrived at some interesting results which suggest that the introduction of new tennis balls did impact the nature of the game. Additionally, several phenomena in their results indicate the influence of new balls. First, the effect of Type 3 balls on prolonging grass rallies can be seen in that, for men, rally duration in Wimbledon increased sharply, and for women Wimbledon was the only tournament in which rally length actually increased. Similarly the rally duration decreased most for women, and increased the least for men, at the French Open, suggesting the influence of the faster Type 1 balls on clay competition. Despite the equalizing influence of the new balls, however, differences across the Grand Slam surfaces can still be observed.

Thus, there is some evidence for observed changes in the nature of tennis competition across surfaces due to the introduction of Type 1 and Type 3 balls. How those changes have impacted national competitive advantages is the work of this study.

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[33] O'Donoghue, in Brown, suggests that the increase in men's rally lengths can be explained by improvements in fitness and technical ability that allow players to retrieve more balls, prolonging rallies. No explanation is offered for the decreasing trend in women's tennis.

IV. Data

This paper is interested in how the introduction of Type 1 and Type 3 tennis balls in 2006 affected geographic dominance on different court surfaces. The aim of my study is to determine, one, whether countries managed to attain competitive advantages prior to 2006 and, if so, two, how those advantages have changed since 2006. In order to address these questions, I decided to run parallel regressions on tournament data from two years, one before the 2006 change and one after, and compare. I selected to study 2009 as the post-introduction year and 2004 as the pre-introduction year with two considerations in mind. First, there is some ambiguity as to the chronology of when the new balls were officially introduced, so I selected years that were unambiguously before and after the introduction. Second, in comparing the two years, I wanted to minimize amount of variability captured that is *not* due to the introduction of new balls. By choosing two years that are relatively close together, the natural changes in the nature of competition that occur with time will be relatively small, so the observed differences between the two years can be attributed more convincingly to the introduction of new balls. Finally, I was limited in time and resources, so I restricted my study to a smaller set of data. I chose to study men's singles competition because the ITF's decision was motivated by the men's side.

For the years 2004 and 2008, I collected data on the top 100 ranked male tennis players, using the database on TennisExplorer[34]. I recorded the following data for each player: home country, defined as the country the player identifies with now, not necessarily their country of birth; number of ATP tournaments played in that year on each surface; number of matches won in ATP tournaments on each surface that year; number of matches

[34] Database found at www.tennisexplorer.com

lost in ATP tournaments on each surface that year. For the 2009 data, I cross-checked the values reported on TennisExplorer with those on the ATP website[35].

V. Methods

Independent Variables: In order to measure the effects of different geographic origins on player performance, I created 5 dummy variables for geography, grouping together players from different countries into 5 different regions as follows[36]:

Variable	Countries
North America	United States; Canada
South America	Argentina; Brazil; Chile; Colombia; Uruguay; Peru
Central Europe	Czech Republic; Hungary; Poland; Slovakia; Germany
Western Europe	Belgium; Great Britain; France; Italy, Monaco; Spain; Portugal; Switzerland; Sweden; Netherlands; Finland; Denmark; Austria; Luxembourg
Eastern Europe	Albania; Bosnia; Croatia; Serbia; Ukraine; Cyprus; Greece; Georgia; Romania; Belarus; Russia; Armenia; Latvia; Uzbekistan

The variables defined above represent my estimation of which groupings would be most statistically significant, taking into account two opposing forces. First, in order to be significant, each dummy variable must be equal to 1 (rather than 0) for enough individuals, i.e. there have to be enough individuals belonging to a group in order for that group to be significant. However, in order for variables to be significant, the individuals within groups must be similar to another, and different from members of other groups, in important features that are correlated with performance. Thus, while groups need to be big enough to

[35] The website is http://www.atpworldtour.com/Rankings/Singles.aspx. It does not have a comprehensive database for previous years' results.
[36] Not all players were included in a dummy variable, for example Australians, Asians, Israelis, were excluded. Their performance contributes to the intercept term, β_0.

be significant, if they are too general they lose significance. The variables defined above are my best estimation of a good balance between these two forces.

As explained earlier, each country has its own National Tennis Association that defines its unique strategy in competition, and in an ideal world there would be enough data points to measure the advantage of each country as a separate variable. However there are several reasons to suspect the groupings above will capture important geographical advantages, and that there will be important similarities between the countries within each group. Firstly, there some prominent continental and larger regional institutions that play an important role in collaborating player development, for example Tennis Europe, Confederacion Sudamericana de Tenis (South America)[37]. Second, similar 'natural resources' are available to national associations in the same region. For example, Eastern European countries will share similar incentives to compete, opportunity costs for competition, financial resources and tennis history relative to, say, North America. Countries in the same region will tend to have similar tennis traditions, and so will tend to train on the same surfaces. For these reasons, I expect that my independent dummy variables, as defined above, will be significant and influential.

Dependent Variable: The dependent variable must be some term that expresses player performance, specifically winning tendency, on the various surfaces. Initially, I created a variable "probability of winning a match on surface x", which was derived by dividing the number of matches won on surface X by the total matched played on surface X (wins on X plus losses on X). It occurred to me, however, that it does not make sense to speak of a stable probability of winning matches in this way, because obviously each match within the tournament gets increasingly harder for a player to win and has a lower probability associated with it. A much better measure is "Wins per Tournament Entered on

[37] A list of national and regional organizations can be found on ITF website, "National Organizations"

Surface X", or WPT-X, derived by dividing the number of wins on surface X by the number of tournaments played on surface X that year. In fact, I found that the regressions using WPT have higher significance, higher R^2 values, that the regressions using Probability of Winning.

The final model I used was WPT-Grass, WPT-Hard, WPT-Clay (2004, 2009)=

$$\beta_0 + \beta_1(\text{Rank}) + \beta_2(\text{NAM}) + \beta_3(\text{SAM}) + \beta_4(\text{EE}) + \beta_5(\text{CE}) + \beta_6(\text{WE})$$

Where Rank is a player's rank, NAM, SAM, EE, CE and WE are the dummy variables for, respectively, whether a player is from North America, South America, Easter Europe, and Western Europe. The coefficients β_2 through β_6 will represent the competitive advantage, or disadvantage, of the given geographical region on surface X. Throughout the analysis, I altered the above model in each regression, dropping dummy variables, to get the strongest possible model.[38]

VI. Results & Analysis

General (Non-Geographical) Findings[39]:

1. WPT Variable Summary

	WPT-Clay:	Mean	SD	**WPT Grass:**	Mean	SD	**WPT Hard:**	Mean	SD
2004		**1.36**	**0.93**		**1.28**	**1.16**		**1.39**	**0.815**
2009		**1.46**	**0.813**		**1.56**	**1.37**		**1.46**	**0.831**

	Number Clay:	Mean	SD	**Number Grass:**	Mean	SD	**Number Hard:**	Mean	SD
2004		**8.14**	**5.03**		**2.31**	**0.93**		**9.40**	**3.70**
2009		**9.37**	**5.93**		**2.27**	**0.96**		**9.67**	**3.50**

[38] Strength of the model is defined by the F-statistic. The regressions were altered to include those variables which yielded the highest F-statistics.

[39] Full data results are in the appendix

2. WPT Variable Correlations

	WPT-H / WPT- C	**WPT-H / WPT-G**	**WPT-C / WPT-G**
2004	**0.2250**	**0.4448**	**0.2609**
2009	**0.4735**	**0.3973**	**0.3970**

Before considering the regressions and geographical advantages, there are several significant trends in the general data that should be reported. First, the correlations between the WPT values on the three surfaces increased from 2004 to 2009, demonstrating a diminishment of the differences between the surfaces after the introduction of Type 1 and Type 3 tennis balls. The correlation between WPT-Clay and WPT-Hard rose drastically, from 0.23 to 0.48, as did the correlation between WPT-Clay and WPT-Grass, from 0.27 to 0.40. The correlation between WPT-Hard and WPT-Grass decreased slightly, from 0.44 to .40.

Second, the average number of tournaments played on clay increased sharply from 8.14 in 2004 to 9.37 in 2009. The reasons for such a drastic change are unclear. It is likely, however, that the introduction of Type 1 balls, which has sped up the game on clay, has made the surface more attractive to power-serve players who previously struggled during the long rallies on clay. Unfortunately, there is no available testimonial evidence that players have taken into consideration the changes in deciding which tournaments to compete in.

Third, the average values of WPT increased from 2004 to 2009 on the three surfaces: on clay, from 1.36 to 1.46 (+0.1); on hard, from 1.39 to 1.46 (+0.06); and on grass, from 1.28 to 1.56 (+0.3). This suggests that male tennis players are improving overall, a phenomenon evidenced in O'Donoghue's[40] findings that rally duration has increased on all

[40] Brown, 2008

surfaces post-2006. O'Donoghue postulated that this improvement could be because of increased fitness and strategic skill. I would add another suggestion, namely that the increased similarity among the three court surfaces has resulted in more productive conditioning circumstances; since the skills for each surface are more similar, competing and practicing on one has greater returns on the others than when the surface's games were very different. This is a possible reason for the observed improvements of WPT values across all surfaces.

Finally, WPT averages have increased most drastically on grass (+.03), followed by clay (+0.1), with the smallest improvement on hard (+0.6). The magnitudes of these improvements reflect the strong influence of Type 3 balls in slowing down the game on grass, as well as the influence of Type 1 balls in speeding up clay competition, and making it easier for the top 100 players to excel.

Geographical Regressions

The findings from running the regressions are summarized in the table below.

	WPT-G	**.**	**WPT-H**	**.**	**WPT-C**	**.**
	2004	**2009**	**2004**	**2009**	**2004**	**2009**
β_0	2.94	2.81	2.13	2.02	1.81	2.04
	(-9.11)	*(-6.65)*	*-10.3*	*-13.09*	*(-10.06)*	*(-13.61)*
Rank	-0.018	-0.0221	-0.01	-0.01	-0.009	-0.013
	(-4.79)	*(-4.64)*	*(-3.78)*	*(-4.41)*	*(-3.31)*	*(-5.12)*
NAM			0.58		-0.6	
			(-1.93)		*(-1.95)*	
SAM	-1.7	-0.85	-0.46		0.63	0.4
	(-3.86)	*(-2.13)*	*(-1.83)*		*(-2.59)*	*(-1.91)*
WE	-0.68		-0.38			
	(-2.28)		*(-2.00)*			
CE	-0.84					
	(-2.24)					
EE	-1.3		-0.54			
	(-3.43)		*(-2.13)*			
F-stat	7.4	5.93	5.87	10.5	9.33	9.94
R^2	0.31	0.26	0.24	0.18	0.23	0.24

Note, again, that dummy variables were dropped if they were statistically insignificant to reach higher F-statistic. T-statistics are in parentheses under value of the coefficients.

Returning to the first of the main questions of this study, were countries or geographical regions able to attain competitive advantages on specific court surfaces prior to 2006? The data reflects that such geographical advantages, as well as certain disadvantages, did exist in 2004. On clay, South Americans won, on average 0.63 more matches per tournament than their peers, while North Americans won 0.6 fewer. On hard surfaces, North Americans tended to win .6 more matches per tournament, while South Americans, Western Europeans and Eastern Europeans showed marked disadvantages of -0.46, -0.38 and -0.54 matches per tournament. Finally, on grass, South American and Eastern Europeans showed extreme disadvantages of -1.7 and -1.3 games, respectively, while Western and Central European underperformed relative to their peers by -0.68 and -0.84 matches per tournament, respectively. The disadvantages on grass are the highest in magnitude and significance. The geographical trends are quite substantial, considering that tournaments usually have 6 rounds, and one more match per tournament on average implies placing a full round higher than your peers.

The competitive advantages and disadvantages in each region in 2004 are logical when considering the natural resources and strategy of each country. As explained earlier, South American countries train heavily on clay, so their advantage on the surface is deserved. Additionally, the skills needed on clay are most different from those that are rewarded on grass, and many of the regions that train on clay appear to be at a disadvantage on grass. Finally, North America's advantage on hard court, the most versatile surface, is likely an outcome from their generalized training strategy. Thus, the data suggest

that regional organizations' unique resources and strategies did allow them to attain competitive advantages on different surfaces prior to 2006.

What has happened to those advantages after the introduction of Type 1 and Type 3 tennis balls in 2006? According to the data, they have disappeared. North American's 0.6 match per tournament advantage on hard court has disintegrated. South America's advantage on clay, which had a very high significance[41], has diminished from .63 matches per tournament to .4. Although the changes from 2004 have caused certain nations to lose their hard-won advantages, they have also allowed nations with a prior disadvantage to compete more equally. North America, which used to win, on average .6 fewer matches per tournament entered on clay, no competes equally. Similarly, those regions who suffered greatly on grass, South America, Western, Central and Eastern Europe, have reduced or abandoned these disadvantages after 2006.

The role of the new tennis balls is logical here. Traditionally clay-dominant countries can perform better on grass now that Type 3 balls have slowed down grass-court play. Similarly, after the introduction of faster Type 1 balls, competition on clay courts is more similar to that on hard. This allows hard-dominant North America to perform better, but forces South American countries, who have honed their game to unique mechanics of clay courts that existed before 2006, lose their advantage.

The disappearance of the geographical trends on hard, specifically the lost advantage of North America and the lost disadvantage of South America, Western Europe and Eastern Europe, cannot be explained by the introduction of new balls, because the same type 2 balls have been used throughout. There is, however, a possible explanation. Note that the geographical coefficients on hard in 2004 were the smallest in magnitude and the least significant. Thus, not that much had to change between 2004 and 2009 for those coefficients

[41] T-stat of 2.59

to disappear. What, then, did change? As was just discussed, male players have improved overall, as is evident in this study's findings that WPT values increased from 2004 to 2009, and as was shown in O'Donoghue's findings about rally length. This could explain why the geographical trends on hard courts, which were small to begin with, disappeared.

Interestingly, while several regions lost their disadvantages, indicating improvement on surfaces, no region actually improved to *gain* an advantage. This means that, in general, geographic factors have become less statistically significant and influential in determining player performance. Concurrently, rank has become a more important influencer of performance, as the Rank coefficient increased[42] in the WPT-Grass regressions, from -0.018 in 2004 to -0.021 in 2006, and in the WPT-Clay regressions, from-0.009 to -0.013. However, this slight increase in the importance of rank is not enough to offset the loss of explanatory variables in geographic regions, and the R-squared values of regressions generally decreased. This means that, after 2006, there are more of the causes of variability in player performance that are unexplained by rank and country.

VII. Conclusions

The initial questions this study hoped to address were, one, whether there existed geographical advantages across court surfaces prior to 2006, and, two, whether those geographical trends changed after 2006. The results of this study have shown that regional advantages did exist in 2004, and that those regional trends have been significantly diminished, if not erased, in the 2009 data. The previously existing geographical trends that were found in 2004 are consistent with background information on the unique features of specific National Tennis Associations, suggesting that NTA-crafted strategies were

[42] The Absolute Value, or magnitude, of the Rank coefficient increased. Rank coefficient is negative because better players have 'lower' numbered ranks. The Rank coefficient in the WPT-Hard regressions remained the same, at -0.01.

responsible for performance on different surfaces. Regions showed advantages on those surfaces for which they train, and disadvantages on those surfaces which are most different from their dominant surface.

There is strong evidence to conclude that the observed diminishment in these geographical trends was caused by the introduction of Type 1 and Type 3 tennis balls. First, in addition to the findings of previous related studies, this study has found proof of the influence of Type 1 and Type 3 balls on the nature of competition on the different surfaces. Performance measures on the three surfaces have become more closely correlated, indicating that the skills needed to excel on each surface are more similar. Second, just as the existing geographical trends in 2004 were most logically explained as the result of the unique strategies of each geographical region, the disappearance of such trends can be explained most convincingly as the result of decreasing effectiveness of those strategies post-2006. The hard-won advantages, as well as the meaningful disadvantages, on each surface were significantly diminished when new tennis balls were introduced that changed the mechanics of the sport, to which strategy is so finely attuned, on each surface. In summation, the results of this study indicate that there existed geographical advantages on different surfaces in 2004, that those trends have disappeared from the data in 2009, and that these changes are likely the result of the introduction of Type 1 and 3 tennis balls in 2006, which drastically altered the mechanics of the sport.

VIII. Implications

The implication of such conclusions are perhaps most important to those national organizations that hope to gain competitive advantages over their peers. As was described earlier in this paper, NTAs invest heavily in developing superior technologies, or strategy practices. The conclusions of this paper suggest that such national specialization

technologies have been rendered ineffective and inconsequential by the introduction of new balls. This could have a number of implications. First, it could lead to a race for new methods of differentiation by national organizations, which will search for new exclusive best practices that are unknown to other countries. What I believe is more likely, on the other hand, is a homogenization of training across the globe. Regional organizations will capitalize on mass media and ease of travel and will share best practices, a phenomenon that is already taking place[43]. It is possible that training on hard court will gradually become most popular, because the mechanics of the other surfaces now more closely resemble those of hard courts. As there is no longer a tradeoff in acquiring the skills for different surfaces, players will learn those skills that are advantageous on all surfaces. Thus, top players will have more well-rounded records across the surfaces, and there will cease to exist distinct champions of different surfaces and game styles.

IX. Further Research

There are some limitations to this study and its conclusions which would be further explored and remedied in future research. First, my study was only able to demonstrate the advantages of broad geographical regions[44], which do not reflect the nuanced and important differences in each countries strategy. Further research could create more exact dummy variables to capture these national advantages. Second, I studied data from only two years, which poses a number of problems. First, it shows only the abrupt changes between 2004 and 2009, rather than the gradual trends over time, which could be telling. Second, a there is a risk that a portion of the difference I observed between the two years is due to random variability. A future study that examined multiple years could uncover gradual

[43] This paper, in fact, has repeatedly cited one of the most prominent examples of best-practice sharing, the *ITF Coaching and Sport Science Review.*

[44] The dummy variable for Western Europe was particularly broad, encompassing around 40% of the players. This could be divided more significantly in the future.

chronological trends and could eliminate the doubt that the changes were random. Finally, this study did not trace changes in performance of individual players. It would be fascinating to see how the performance of specific competitors changed after the balls were introduced.

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Appendix (i)

WPT Variable Summary

**** nhard, nclay and ngrass are the number of tournaments played on each surface**

2004

Variable	Obs	Mean	Std. Dev.	Min	Max
wpt_hard	99	1.389478	.8157824	0	4.3
wpt_clay	100	1.364792	.9310289	0	5.5
wpt_grass	87	1.281609	1.162454	0	6
nam	100	.08	.2726599	0	1
sam	100	.14	.3487351	0	1
ce	100	.15	.3588703	0	1
we	100	.43	.4975699	0	1
ee	100	.13	.3379977	0	1
nhard	99	9.939394	3.683438	2	26
nclay	100	8.14	5.033263	1	31
ngrass	87	2.310345	.9314947	1	5

2009

Variable	Obs	Mean	Std. Dev.	Min	Max
wpt_hard	100	1.461227	.8310826	.25	3.888889
wpt_clay	98	1.461282	.8134759	0	4
wpt_grass	91	1.562271	1.372492	0	7
nam	100	.06	.2386833	0	1
sam	100	.14	.3487351	0	1
ce	100	.14	.3487351	0	1
we	100	.38	.4878317	0	1
ee	100	.19	.3942772	0	1
nhard	100	9.67	3.484613	2	21
nclay	99	9.373737	5.93431	0	29
ngrass	91	2.274725	.9668498	1	4

Correlations between WPT Variables

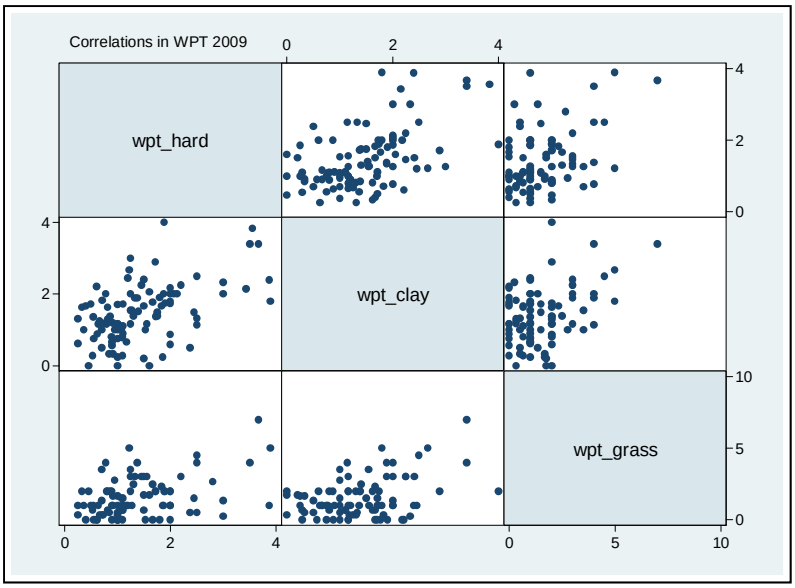
2004

	wpt_hard	wpt_clay	wpt_gr~s
wpt_hard	1.0000		
wpt_clay	0.2250	1.0000	
wpt_grass	0.4448	0.2609	1.0000

2009

	w_hard	w_clay	w_grass
w_hard	1.0000		
w_clay	0.3016	1.0000	
w_grass	0.2747	0.1345	1.0000

Appendix (ii)


Correlations in WPT 2009
wpt_hard
wpt_clay
wpt_grass
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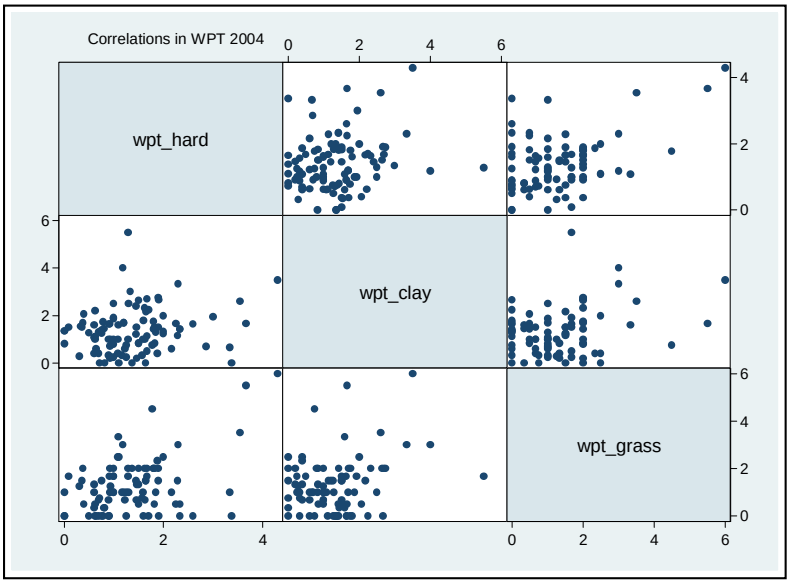
2
4
0
5
10


Correlations in WPT 2004
wpt_hard
wpt_clay
wpt_grass
0
2
4
6

Appendix (iii)

Wins-Per-Tournament Grass (WPT-G)

2004

Source	SS	df	MS		Number of obs =	87
					F(5, 81) =	7.40
Model	36.4542524	5	7.29085048		Prob > F =	0.0000
Residual	79.7574326	81	.984659661		R-squared =	0.3137
					Adj R-squared =	0.2713
Total	116.211685	86	1.35129866		Root MSE =	.9923

wpt_grass	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rank	-.0180624	.0037747	-4.79	0.000	-.0255728	-.010552
sam	-1.702018	.4404666	-3.86	0.000	-2.578408	-.8256275
ce	-.8414255	.3762193	-2.24	0.028	-1.589984	-.0928671
we	-.6897625	.3025832	-2.28	0.025	-1.291808	-.0877169
ee	-1.293901	.3766915	-3.43	0.001	-2.043399	-.5444033
_cons	2.941652	.3230616	9.11	0.000	2.298861	3.584443

2009

Source	SS	df	MS		Number of obs =	91
					F(5, 85) =	5.93
Model	43.8275568	5	8.76551137		Prob > F =	0.0001
Residual	125.708462	85	1.47892309		R-squared =	0.2585
					Adj R-squared =	0.2149
Total	169.536019	90	1.88373355		Root MSE =	1.2161

wpt_grass	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rank	-.0218148	.0045609	-4.78	0.000	-.030883	-.0127465
sam	-.9456818	.5031736	-1.88	0.064	-1.946126	.0547622
ce	.3883763	.4788518	0.81	0.420	-.5637094	1.340462
we	-.2961218	.4012812	-0.74	0.463	-1.093976	.5017327
ee	-.6814592	.4514968	-1.51	0.135	-1.579156	.2162374
_cons	2.954913	.4444534	6.65	0.000	2.07122	3.838605

Wins-Per-Tournament Hard (WPT-H)

2004

Source	SS	df	MS		Number of obs =	99
					F(5, 93) =	5.87
Model	15.643885	5	3.128777		Prob > F =	0.0001
Residual	49.5751998	93	.533066665		R-squared =	0.2399
					Adj R-squared =	0.1990
Total	65.2190848	98	.665500866		Root MSE =	.73011

wpt_hard	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rank	-.0099068	.0026193	-3.78	0.000	-.0151081	-.0047054
nam	.5823628	.3015892	1.93	0.057	-.0165336	1.181259
sam	-.4645539	.2532112	-1.83	0.070	-.9673812	.0382735
we	-.3840292	.1921714	-2.00	0.049	-.7656436	-.0024148
ee	-.5444719	.2559449	-2.13	0.036	-1.052728	-.0362161
_cons	2.13857	.2076218	10.30	0.000	1.726274	2.550865

Appendix (iv)

2009

Source	SS	df	MS		Number of obs =	100
					F(2, 97) =	10.50
Model	12.1725902	2	6.08629508		Prob > F =	0.0001
Residual	56.2065442	97	.579448909		R-squared =	0.1780
					Adj R-squared =	0.1611
Total	68.3791343	99	.690698327		Root MSE =	.76122

wpt_hard	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rank	-.0116244	.0026371	-4.41	0.000	-.0168583	-.0063905
nam	.3982786	.3205309	1.24	0.217	-.2378865	1.034444
_cons	2.024363	.1546418	13.09	0.000	1.717441	2.331284

Wins-Per-Tournament Clay (WPT-C)

2004

Source	SS	df	MS		Number of obs =	100
					F(3, 96) =	9.33
Model	19.3723323	3	6.45744408		Prob > F =	0.0000
Residual	66.4423358	96	.692107665		R-squared =	0.2257
					Adj R-squared =	0.2016
Total	85.814668	99	.866814829		Root MSE =	.83193

wpt_clay	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rank	-.009749	.002943	-3.31	0.001	-.0155908	-.0039071
nam	-.6020836	.3090328	-1.95	0.054	-1.215509	.0113416
sam	.6383604	.2461769	2.59	0.011	.1497032	1.127018
_cons	1.815911	.1809271	10.04	0.000	1.456773	2.175048

2009

Source	SS	df	MS		Number of obs =	98
					F(3, 94) =	9.94
Model	15.4641733	3	5.15472442		Prob > F =	0.0000
Residual	48.7249038	94	.51835004		R-squared =	0.2409
					Adj R-squared =	0.2167
Total	64.189077	97	.661743062		Root MSE =	.71997

wpt_clay	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rank	-.0129056	.0025202	-5.12	0.000	-.0179095	-.0079017
nam	.1145655	.3050201	0.38	0.708	-.491059	.7201901
sam	.403748	.2089813	1.93	0.056	-.0111893	.8186854
_cons	2.043979	.1502154	13.61	0.000	1.745723	2.342235