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Do You Want To Run a Regression? Nah, I Think I'll Dance One Instead: Physicalizing Econometrics

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By

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Abstract

This project asked how can one make use of an econometric tool, specifically the regression model, as a source for choreography. Through integrating my research on dance choreography and econometrics, I created a dance piece that demonstrates the numerical relationships of a realized regression equation. The dance was separated into three sections, with each examining an econometric concept. Taking the primary question at hand one step further, this project also explored how this approach to choreography can be generalized so that almost any regression model can be a choreographic tool. Subsequently, a guideline was devised to provide other choreographers various ways to visually manifest econometric concepts in a dance. Despite the difficulty in reconciling many econometric concepts into one dance, I found the regression equation an effective tool to structure and determine elements of choreography. The final dance piece and guideline exemplify interdisciplinary research on dance and econometrics, two seemingly unrelated subjects.

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Physicalizing Econometrics

Introduction

Dancing and studying economics both require a great amount of dedication and practice. For those who develop the persistence to perform in these areas, the pursuance of those skills can meaningfully contribute to broader societal conversations. In both dance and economics, there is an interaction between the discipline and various elements of society, including political values, culture, and philosophical ideas; they are captured in dance choreography, and they are reflected in economic policymaking. Although the disciplines cross through many elements of society, they naturally manifest themselves in different ways, as dance and economics use very different approaches to produce knowledge. While dance is founded on artistic expression, the discipline of economics is founded on dispassionate analytical tools. Dance and economics are different, but they do have commonalities. To expand academia's understanding of dance as a multidisciplinary subject, my Theatre & Dance Senior Independent Study (I.S.) investigates the intersection between two seemingly disparate areas of knowledge: dance and economics.

Dance is often studied in conjunction with other disciplines such as music and anthropology (Albright and Dils 30). To a lesser extent, dance is viewed in a quantitative manner because it is considered a physical activity, as opposed to the stationary process of solving a mathematical equation. Dance is rarely thought of in terms of econometrics, a highly mathematical branch in economics that measures and analyzes economic phenomena. However, is it possible to intentionally use economic relationships to aid the creation of a dance? I asked, "How can one make use of an econometric tool, specifically the regression model, as a source for choreography? How can this approach to choreography be generalized so that any regression model can be a choreographic tool?”

To demonstrate how I used an econometric tool as a source for choreography, I showcased a dance piece that embodied econometric concepts in the Spring Dance Concert of 2019 at The College of Wooster. The choreography of this dance reflects certain aspects of the linear regression model, one of many econometric concepts. A linear regression model establishes a relationship between two things to show how one thing affects another. The linear regression model that I used in the final dance performance establishes how dancers’ technique affects consumers’ willingness to pay (WTP) to watch their performance while considering other factors that affect their WTP. The many relationships present in different components of a regression equation can be captured in the relationships among the dancers and in the choreography.

Next, I generalized this choreographic approach by creating a guideline that allows for almost any linear regression model to be used as a choreographic tool. This guideline consists of formulas, directions, and rules to physicalize almost any regression equation within certain parameters. Since the relationship in every regression equation is different, every dance following a different regression equation would look different and achieve a different effect. Following this logic, a different choreography will be produced when a different equation is used as a choreographic tool. Although not all the elements of regression that I discuss in this guideline appeared in my final performance, the guideline provides suggestions translate to these elements of regressions into dance.

In using the regression equations in my own choreography, I was not interested in providing the audience any context of what the equations actually represented. Rather, I focused on the numerical values by portraying their relationship in the choreography. While the regression equation I used establishes a relationship between dancers' technique and consumers' WTP, my dance only represented the numerical relationship between the two. The goal of the dance was not about what the regression equation signified, but rather how the numerical aspects of the regression equation interact with one another.

This project relied on background research in dance, mathematics, economics, and the overlap among the three fields. Even more so, this project demanded the input of my five physically talented and mentally intellectual dancers. But before transforming economic concepts into movement, I had to bridge the gap between econometrics and dance. The process of intertwining the two subjects required an additional step; I had to establish a relationship between mathematics and dance. Owing to the highly mathematical nature of econometrics, my work benefited from investigating the role that numerical relationships play in the artistic decision-making process of choreography. Chapter One examines how choreographers in the past have made use of numerical relationships in producing dance and the effects of using them. These works cover two subfields in mathematics, including geometry and probability. My comprehension of these works gave me ideas about choreographing a dance based on econometrics.

Geometry is a mathematical field that deals with points, lines, angles, surfaces, shapes, size, and space. The works of Samuel Beckett, Alessandro Carboni, and works from the Renaissance period embody various geometrical relationships and properties. Samuel Beckett was an Irish playwright who choreographed *Quad* in 1982, a television play without dialogue (Beckett, *Quad*). It features four dancers dressed in different colored long, loose-fitting robes performing in a space outline as a square. The first impression of this movement piece, which I refer to as dance, comes off as minimalistic. However, the choreography is created mathematically according to a geometric pattern as shown by the aerial view of the stage in figure 1.

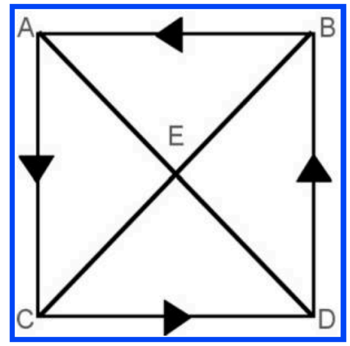


Figure 1. Floor Pattern Created in *Quad* (Woycicki 142)

The original script of *Quad* (Beckett, *The Complete Dramatic Works of Samuel Beckett* 293) provides instructions to perform the choreography, giving me first-hand information regarding his piece. In "'Mathematical Aesthetic' as a Strategy for Performance: A Vector Analysis of Samuel Beckett's *Quad,*" Piotr Woycicki studies the mathematical relationships found in *Quad*. The focus is predominately on the fleeting geometrical patterns created by the dancers as well as the mathematical structure of the choreography. In the performance, the dancers follow a strict spatial path in the performance space. A single point located in the center of the stage, called the "origin," serves as an underlying numerical concept affecting how the dancers move. By making precise turns before they reach the origin, the dancers change direction, never passing the origin or each other.

Studying Beckett's piece allowed me to see how geometry can be used as a source for choreography. By reviewing the video recording of the original performance of *Quad* (Beckett, *Quad*), I saw the resulting effects brought about by using this mathematical form. Graley Herren (47) discusses the depersonalizing effect of *Quad* in his article "Samuel Beckett's *Quad*: Pacing to Byzantium." He argues that the repetitive nature of the geometrical relationships in the dance strips away the personalities of the dancers. Additionally, the dancers appear to lack any freedom in the timing of their movement sequences and the precision of the movement to produce a sense of inescapability. While dances based on numerical relationships can be evocative for viewers, they are inherently neutral and portraying them can depersonalize dancers. Rather than more traditional concepts such as emotion and narrative, Beckett produced a dance that adhered to geometric ideas.

An extension of the mathematical ideas of Beckett's *Quad* is *ABQ*, a solo dance piece choreographed and performed by Alessandro Carboni. In "ABQ – From Quad to Zero Mathematical and Choreographic Processes –between Number and Not Number: Performance Research," Carboni describes his process of creating *ABQ*. Starting with the extraction of the concept of the origin found in the *Quad* in which he calls the "degree zero" ("ABQ – From Quad to Zero Mathematical and Choreographic Processes –between Number and Not Number: Performance Research" 50), he transformed this mathematical relationship into his own. He created a geometric concept by combining mathematical relationships and his research on southern Indian dances, which will be discussed later on. This transformation enabled him to construct a choreographic score for *ABQ*. Even though there is an overlap between Beckett and Carboni's use of mathematical relationships, their works present themselves differently. Where Beckett's *Quad* appears to be depersonalizing, Carboni's solo appears to be more uplifting because he creates a relatively stronger character on stage than the dancers in *Quad*. This is expressed from the recording of his live performance on Vimeo, which will be elaborated later.

Differing from the choreographies of Beckett and Carboni, dances during the Renaissance period in the 16th century in Italy and France did not use mathematical relationships as a source for choreography. Instead, the choreographers used mathematical relationships to achieve a specific goal, which is to present order and unity in dance. The scholarly research of Françoise Carter in *Number Symbolism and Renaissance Choreography* describes and explains instances where dances during the Renaissance period were choreographed based on geometrical patterns. These patterns represented the view of the universe at the time. Through dance and choreography, people at the time embodied their belief that the universe was created in the image of God (Carter 22). To help people visualize the metaphysical aspects of life, it was necessary for choreographers to use forms that captured geometrical relationships. In this way, dances observed during the Renaissance period utilized numerical relationships not as a source for choreography but as a tool for choreography. Through movement, geometry was used to demonstrate Christian and spiritual cosmology of the universe during that time period. This article provides countless descriptions of the geometrical elements in the choreographies from the time period as well as the meaning behind the choreographic choices.

Another important source is Jennifer Nevile's "Dance and the Garden: Moving and Static Choreography in Renaissance Europe." The emphasis of Nevile's research is on the principles of order and proportion in the Renaissance period (806). She examines two variations of choreography to study these principles. The first is dance choreography, a type of dynamic choreography I have referred to earlier. The second is a type of static choreography, relating to the design of gardens of the nobility. Through detailed study of Renaissance history, Nevile demonstrates how the choreography in both dance and gardens makes use of geometry to reflect the ideals of the Renaissance period. This article also provides diagrams of the floor patterns of a selection of dances. By identifying the geometric properties of the floor patterns in these diagrams, I saw how important principles at the time manifested as numerical relationships in dance. I also briefly compared these to the geometrical qualities of Renaissance gardens because they parallel the effect of the dances.

Deviating from the three previously mentioned works, Merce Cunningham took another approach in his choreographic career in terms of the use of numerical relationships. As an alternative to intentionally exercising the use of geometric aspects in dance, as seen in the previous three cases, Cunningham turned to probability in his choreographic process (Siegel 292). Probability is the likeliness of an event to occur. Unlike geometry, the presence of probability in dance cannot be easily seen visually because of the theoretical nature of probability. Through studying Cunningham's experimental choreographic method, I saw how the intentional use of probability can be a determining factor in the effect of a dance. Cunningham's approach to dance performance prompted him to create a guideline for his dancers, which is comparable to the guideline of my I.S. thesis.

Cunningham's interview at the Walker Art Center, titled *Chance Conversations: An Interview with Merce Cunningham and John Cage*, improved my understanding of his approach to dance. Cunningham's aim to achieve unconventional effects in his dances, such as disorder, unpredictability, and an emphasis on the pure physicality of the body, prompted him to use unconventional choreographic methods. Some of his many choreographies falling under the category of "chance dances" relied on randomness to achieve the effect he wanted. Despite placing randomness as a guiding principle, Cunningham's decisions were associated with elements of probability. Note that probability and chance are used as interchangeable terms because the same concept is not given the same name in the different disciplines of interest. Mathematicians describe it as "probability," whereas dance scholars use the word "chance" as the term for Cunningham's choreographic method of chance procedures.

The books *Ballet and Modern Dance* by Susan Au and *Time and the Dancing Image* by Deborah Jowitt explain how Cunningham used chance procedures to create his chance dances. The aspects of his dances that relied on probability include the number of repetition of a movement sequence, the duration of a phrase, the order in which the dancers entered the stage, as well as many more elements. The end goal was to examine how a variety of Cunningham's works used a mathematically-rooted strategy as a means to achieve dances that emphasized movement.

The outline of the paper is as follows: Chapter One entails research on dances that utilize mathematical relationships. I studied relevant sources to learn how others have used numerical relationships in their choreographies. But to choreograph a dance and to create a guideline for my dancers, it was essential that I understood the various elements of movement and dance. To inform my choreographic decisions, I examined Doris Humphrey's book, *The Art of Making Dances*, on the composition of dance in Chapter Two. I drew mostly upon the second chapter of her book, provides the "ingredients and tools" for building dances (45). She discusses the creation of the overall design of a dance through aspects in choreography, including symmetry, the phrase, stage space, and the relative relationships of dancers. The other elements relevant to my study that she discusses are dynamics, rhythm, and motivation. This book highlights the elements of movement and dance I kept in mind when I choreographed the final dance piece and created the guideline. The many contributions of my dancers along with my choreographic and performance experiences in my college career also spurred the development of creative ideas.

Since I intended to portray relationships in regression equations through dance, I needed a working knowledge of the regression model. Chapter Three introduces econometrics as a subject matter in relation to my dance choreography and guideline. It establishes how theory in regression analysis can be portrayed and represented through dance. *Using*

Econometrics: A Practical Guide (Studenmund) is a useful source to introduce beginners to econometrics. This book starts from the basics of econometrics, including what it is and how it is applied to the explanation of the regression model. With the groundwork built, I explored more complex econometric theories, including four of the seven Classical Assumptions of one type of regression equations, ordinary least squares. The knowledge I gained from this book was not only used as an inspirational springboard for the choreography, but it also acted as a choreographic score.

Chapter Four discusses how the findings of my research from chapters 1, 2, and 3 translated into both my final choreography and guideline that informs how others can utilize almost any regression equation as a choreographic tool. The research from chapters 1, 2, and 3 consisted of relevant mathematics-related dances, as well as knowledge of dance choreography and the regression model. Following each rehearsal, I reflected on my progress on translating econometrics into dance to improve the physicalization of regression equations. Thus, the series of post-rehearsal reflections complement my discussion on the application of my research to my critical question.

As stated, this paper discusses a narrow area of the interconnection between dance and economics. However, this approach of keeping the research focused came at an expense. I did not completely examine all aspects of the dances choreographed by the chosen artists, let alone all the relevant works of the artists. Furthermore, this paper does not cover all the existing dance pieces that make use of numerical relationships. This suggests that the econometrics-based choreography I developed would differ vastly based on what research I applied to my work. Similarly, the mathematical components I explored are limited to geometry and probability. Since I do not have a comprehensive set of information, the conclusions from my discussion have limitations. These problems may have interfered with my evaluation of the answer to the critical question.

Despite these limitations, my study contributes useful analysis to an unconventional field. To summarize, I first explored dances that represent or make use of mathematical principles because econometrics involves using mathematics. I then separately studied dance choreography and econometrics to give me the tools and skills to write the guideline and choreograph my piece. My interdisciplinary work delves into an infrequently studied area, which could interest other scholars. Apart from the academic interdisciplinarity, my work allows for students and scholars of dance and economics to interact with one another. This interaction may stimulate conversations and inspire people to further connect and develop an appreciation for both dance and economics. My choreography captures my contribution towards the two fields, but the overall experience of my choreography provides a platform for people from the two fields to form a larger and more diverse community.

Chapter 1. Intersection Between Math and Dance: Math as a Choreographic Source

Surprisingly, mathematics unifies dance and econometrics. This connection is essential because it shows that mathematical concepts, such as my study of econometrics, can be used or portrayed in dance. This chapter demonstrations the relationship between mathematics and dance. More specifically, I explored two mathematical concepts, geometry and probability, to communicate the possible links between numerical relationships and movement.

Geometry

As Wasilewska (453) contends, there are unquestionable interactions between dance and geometry that is often times coincidental. The geometrical relationships in dance are something that is experienced by dancers with their bodies. In contrast, these geometrical relationships produced by dancers are visually understood and perceived by the audience. For example, dancers form geometric shapes in space with their bodies, whereas spectators observe the outcome of dancers' bodily experience in geometric shapes. *Mathematics in the World of Dance* (Wasilewska 454) examines the relationship between dance and mathematics through analyzing images of dancers' bodies. The author points out how the bodies of various types of dancers form geometrical shapes and reveal the mathematical relationships captured by the bodies in stillness. These dancers include ballerinas, modern dancers, and Argentine Tango dancers.

In one instance, Wasilewska gives the example of a ballerina holding a grand plié on relevé in second position with arms stretched upwards. She points out that from the front view, the legs of the dancer are positioned 90 degrees from the floor and thus, form a rectangle. The dancer's upper body and arms depict an image of a triangle. Moreover, one can imagine a line of symmetry through the middle of the dancer's torso. Other geometric concepts are revealed when the audience changes their perspective from the conventional front view to an aerial view. In the same position of a grand plié in second position, the dancer's body forms a line. Depending on which body parts is emphasized, different types of angles can be discerned, including adjacent, reflex, and acute angles. The many embodiments of mathematical ideas in a dancer's movements highlight the fact that it is possible for choreographic decisions to reflect specific geometric patterns.

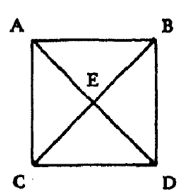
With this knowledge in mind, I explored how this mathematical relationship has been used in the production of dances. By analyzing dances of Beckett and Carboni, I investigated how these two choreographers used math as a starting point in their choreographic process. Then, I explored how the dance pieces in the Renaissance period reflect geometrical ideas.

Samuel Beckett's *Quad*

More commonly known as a playwright, Samuel Beckett also explored movement in his works. Many of these works used numerical relationships to structure the performance, which differed from his earlier works such as *Endgame* and *Come and Co*. (Woycicki 136). Instead of keeping the mathematical relationships and forms of his work subtle and unnoticed, Beckett enunciated them. In December of 1982, he submitted his television play, *Quad*, to BBC2 (Beckett, *The Complete Dramatic Works of Samuel Beckett* 292). This piece lasts for approximately 15 minutes and consists of only non-verbal elements, including movement, lighting, costumes, and sound. Otherwise, *Quad* was primarily performed through the movements of four people. Their costumes are long, draped, and hooded gowns with a cowl to hide their faces. They are each in a different solid color, of white, yellow, blue, and red.

Beckett used a geometrical framework for the underlying compositional methodology in *Quad*. The use of this mathematical relationship made the dancers in his piece appear dehumanized. Before understanding how the effect was produced, I studied the geometrical elements in *Quad*. Embedded in the spatial patterns that are carved by the dancers of *Quad* are geometrical properties. If one were to look at the performance directly from above, they would see all four dancers create the same geometric pattern at different times. However, the dancers create the patterns starting and ending at a different corner on the square-shaped stage of six walking paces long.

The piece starts off with an empty stage. Once the dancers enter, they follow a systematic course by taking small but quick steps, as if they are walking in a hurry. It is through the repetition of their pathways that the audience notices the geometrical relationships in the choreography (Woycicki 143). Although the geometric patterns they inscribe on the stage are identical, the order in which they complete it are not. Beckett's own book, *The Complete Dramatic Works of Samuel Beckett*, illustrates four possible courses that correspond to the four dancers. This sequence is shown in figure 2. Dancer 1 starts the performance by completing course 1 once. As dancer 1 completes course 1 the second time, dancer 3 completes course 3 for the first time. As dancers 1 and 3 both perform their own sequences once more, dancer 4 joins them by completing course 4. Lastly, dancer 2 enters performing course 2 so that all the performers are completing their own courses together. In the same order as they entered, dancers 1, 3, and 4 exit one by one after the repetition of every subsequent courses. As the only dancer remaining on stage, dancer 2 repeats the cycle as the first dancer on stage. The cycle is repeated a total of



Course 1: AC, CB, BA, AD, DB, BC, CD, DA
Course 2: BA, AD, DB, BC, CD, DA, AC, CB
Course 3: CD, DA, AC, CB, BA, AD, DB, BC
Course 4: DB, BC, CD, DA, AC, CB, BA, AD

Figure 2. Script of *Quad* (Beckett 293)

Table 1

Permutations of Dancers on Stage in *Quad*

Cycle	Dancers on stage
1	1, 13,134,1342, 342, 42
2	2, 21, 214, 2143, 143, 43
3	3, 32, 321, 3214, 214, 14
4	4, 43 ,432, 4321, 321, 21

four times until all the possible permutations of the courses are performed. Table 1 presents a summary of the possible orders in which the dancers appear on stage. Figure 2 and table 1 function as the script and choreographic score of *Quad*, which can also be considered as a mathematical formula for this movement piece. The nature of the dance's structure suggests that numerical relationships are dictating the choreography.

The sequencing of the pathways is choreographed so that they dancers never collide with one another, even when all four of them appear on stage and are crossing center stage at the same time. This is made possible because the dancers avoid the middle area of the stage, labelled as the "origin" of the stage. Beckett represents the origin as point E in figure 2. As a result, the actual geometric pattern that is followed by the dancers is the one shown in figure 3. The figure illustrates that every turn the dancer makes is either 90 degrees or less. In geometry, angles smaller than 90 degrees are called acute angles.

As the dancers follow their assigned paths, the only movement they carry out is walking with a hunched back. Other than those of a walking position of the lower body and a hunched back, the dancers do not create other distinct shapes. However, they do create fleeting shapes on the performance space as they walk across the floor.

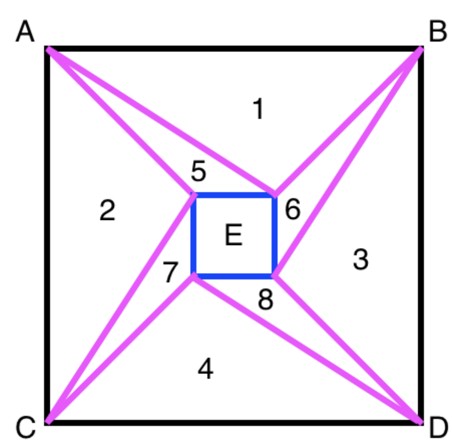


Figure 3. Geometric Patterns in *Quad*

Every time a dancer completes one cycle of their course, they create the geometric pattern in figure 3. The surrounding shape is a square, which is the same shape as the outline of the stage, as outlined in black. The stage has four corners, labelled A, B, C, and D.

The square-shaped stage encloses several other shapes. Apart from the square, connecting the four corners is a polygon, as outlined in purple. This polygon is a two-dimensional shape that is made of straight lines. The lines of a polygon must form a closed shape so that someone could trace the shape forever without taking the pencil off the paper. There are a number of properties associated with this polygon in purple. First, it can be classified as an octagon because it has eight sides. As opposed to a square, this is an irregular octagon because the length of its sides and its interior angles are unequal. Moreover, it is a concave polygon because there are internal angles that are greater than 180 degrees. It is also a concave polygon because it has angles that point inward. These inward-pointing angles are attached to the square surrounding origin E, as outlined in blue.

Apart from squares and the octagon, there are eight triangles labelled between 1 and 8 in figure 3. These triangles can be identified as scalene triangles because each side is unequal in length. Triangles 1 through 4 are identical in size but face a different direction. Moreover, they are positioned on the outer part within the square and they each have one side overlapping the square of the stage. Triangles 5 through 8 are smaller and are positioned in the inner part of the square. Similar to triangles 1 through 4, these triangles are identical in size and face a different direction. Additionally, one side of each triangle overlaps the center square surrounding origin E.

As demonstrated, there are numerous geometrical concepts in the choreography of *Quad*. By following a strict mathematical structure, scholars argue that *Quad* depicts dehumanized people in a dehumanizing world (Herren 47). The use of mathematics in choreography results in a plotless piece. The lack of variation in the movements of the four dancers and the repetitive nature of their paths strip away their personality. The dancers carry out the same movements and wear the same type of costume. Coupled with their covered faces, the dancers are left with little individuality. Moreover, the dancers never make eye contact with one another, let alone experience any physical contact with one another. These aspects further contribute to the dehumanization of the dancers, and they make it hard for the audience to discern a clear storyline.

An additional layer of the dancers' humanity is stripped away because of the decisions of the playwright Beckett, and his crew (46). In the script, Beckett states that "each player has his particular light, to be turned on when he enters, kept on while he paces, turned off when he exits." The script also states that each player has a particular sound accompanying their movements during their appearance on stage. In terms of both lighting and sound, each dancer is assigned their own unique aspect. Despite their hidden faces, the dancers are distinguishable from one another. However, for the final performance, Beckett and his crew collectively decided to light the entire stage and entire performance with neutral lighting. In comparison to the instructions of the original script, the final performance makes it more challenging for the audience to discern the dancers, especially since the dancers' movements already show no apparent variation. The dancers' reduced individuality translates into a smaller emotional element in the play. Additionally, the lack of dynamics and the consistent tempo of the movements give off a monotonous and unlively quality as well as a sense of purposelessness to the dance. For these reasons, one could argue that the repeated geometrical course the dancers follow symbolize the entrapment of the daily routine of life (Davis and Butler 145).

Alessandro Carboni's *ABQ*

The influence of Beckett's work extended beyond its direct contribution to the development of the arts. Currently based in Sardinia, aspiring Italian artist Alessandro Carboni created the dance piece *ABQ* in 2007 that was inspired by one geometrical concept explored in Beckett's *Quad*. Although Carboni and Beckett both choreographed a dance piece starting with an underlying geometrical relationship, the effect of their dances show large variations. While Beckett's *Quad* dehumanized his dancers, Carboni's self-performed solo piece, *ABQ*, draws forward a personality.

Carboni obtained his doctorate degree in Creative Media from City University of Hong Kong. As both an independent and interdisciplinary artist, Carboni's interests do not only lie in the performing arts. His interest in body, urban space, and cartography led to his numerous research studies and dance choreographies (Carboni, "Alessandrocarboni | ABOUT"). Although most of his bodily performances reflect his research in the evolution of urban areas, he took on a new approach in *ABQ* by incorporating mathematical ideas. The inspiration for this piece came about in 2006 when Carboni left London to Kerala, India for a four-month research project (Carboni, "ABQ – From Quad to Zero Mathematical and Choreographic Processes –between Number and Not Number: Performance Research" 50). That year marked the 100th anniversary of the birth of Samuel Beckett. In honor of Beckett, Carboni decided to use the numerical ideas present in *Quad* as a component in his choreography.

From my previous analysis on *Quad*, I pointed out that the dancers never surpass the center region of the stage. As defined by the spatial paths of the dancers, this space in the center is shaped as a square, as outlined in blue in figure 3. Seeing that the movement of the four dancers revolve around the center of the stage, Carboni identified this pivotal space as "degree zero." From there, he sought to explore degree zero and discovered how it can be used in his choreographic process. At the School of Drama di Thrissur and the Sree Sankaracharya University of Sanskrit, Carboni studied two classical Indian dances of the South, Kathakali and Bharatanatyam. *ABQ* primarily uses his research in Bharatanatyam, which places a great importance on the hand, body, and space because they are used by the dancers as a vehicle for expression ("ABQ – From Quad to Zero Mathematical and Choreographic Processes –between Number and Not Number: Performance Research" 52).

Through a mathematical lens, Carboni considered these three components of Bharatanatyam as a hierarchical structure that possessed alternate dimensions. The relationship of the hand, body, and space and its corresponding dimensions is represented in figure 4.

3-D < 2-D < 1-D (degree zero)

body moving < body lying flat < hand (*mudras*)

Figure 4. Dimensions of the Body Moving, the Body Lying Flat, and *Mudras*

Although the hand is the smallest unit of Bharatanatyam in comparison to the body and to space, it is an important aspect. In Bharatanatyam, the hands facilitate storytelling and evokes an emotional reaction from the audience. For these reasons, Carboni positioned the hand on the top of the hierarchical structure to capture the importance of the hands. In Vedic mathematics, the fundamental building block of numbers is zero, and zero is viewed as a single point in space. Basing off this concept, Carboni also considered the hand as degree zero, or as a single point existing in a one-dimensional (1-D) space. The use of Vedic mathematics is also relevant to his research in India because it is a branch of mathematics based on *Veda*, one of the four Indian scriptures. Below the hand on the hierarchical structure is a human body lying flat on the floor that exists in a two-dimensional (2-D) space. At the bottom of the hierarchical structure is the moving body in space, appearing in a three-dimensional (3-D) space.

In Carboni's *ABQ*, I saw how Carboni established the body as an instrument that embodies geometrical and Vedic mathematical relationships to create a 3-D dance. In Bharatanatyam, *mudras* are a set of hand gestures. Since mudras are associated with the hands, Carboni considered them as degree zero existing in one dimension. He only used the mudras for its shape and structure but not for its traditional meaning and purpose in Bharatanatyam. Based on the appearance of mudras, Carboni assigned positions using the entire body according to each mudra. Thus, the mudras are enlarged into "hyper-mudras" ("ABQ – From Quad to Zero Mathematical and Choreographic Processes –between Number and Not Number: Performance Research" 53). Carboni then created a choreographic score by placing the hyper-mudras into an imaginary cube and assigning different body parts to the nearest geometric property of the cube. Body joint-articulations were paired with the eight vertices of a cube, bones were joined with the 12 edges of a cube, and the body's skin was assigned to the six surfaces of a cube. From there, Carboni made a choreographic score using the hyper-mudras ("ABQ – From Quad to Zero Mathematical and Choreographic Processes –between Number and Not Number: Performance Research" 54). Unlike Beckett who created a rigid formula for the dancers' spatial paths in *Quad*, Carboni created a set of instructions for the movement sequences in *ABQ* that embody many geometrical relationships ("ABQ – From Quad to Zero Mathematical and Choreographic Processes –between Number and Not Number: Performance Research" 56).

The video recording of *ABQ – Mechanical Extension in Four Arithmetic Operation* captures Carboni's multiple layers of geometrical manipulation. This approximately 40-minute-long solo is performed by Carboni himself. Considering that Carboni was inspired by Beckett's *Quad* to create *ABQ*, his artistic choices clearly reflect and mirror those of Beckett. Just as in *Quad*, the performance space of *ABQ* is shaped as a square without an elevated platform. Moreover, the concept of both pieces revolve at degree zero. Where the dancers in Beckett's *Quad* avoid degree zero and never approaches the center of the stage, Carboni actively uses the space occupied at degree zero. This is made obvious right at the beginning of the piece since Carboni's starting position is in center stage, which is precisely at degree zero. Unlike in *Quad* where all the dancers are always in a standing position, the majority of Carboni's movements are on the floor, and his body deviates between straight and curved.

Carboni starts in the center with his knees tucked in, curling up into a ball. This movement represents Carboni occupying a single point in space, called point number one. The soft-edged spotlight on Carboni also represents degree zero as a single point in space. Remaining in a ball at point number one of his starting position, he travels counter-clockwise to three other points. His spatial path forms a square when he returns to his original point. The spotlight does not change when this occurs so it seems like he is building a square around degree zero. At a faster pace, Carboni forms two more squares in his spatial path by travelling from point to point. Up to this point, he represents one point in a 1-D space.

The shift from a 1-D space to a 2-D space is indicated when Carboni expands his kinesphere by lying down flat on the floor facing the ceiling. His body forms a line in space with starting and ending points. These points are represented by his head and his toes, respectively. Thus, he is in a 2-D space. Carboni moves around the square-shaped stage in this

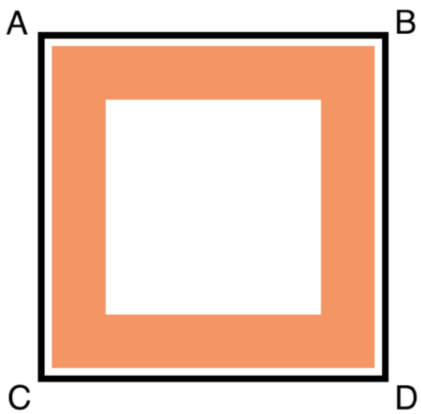


Figure 5. Carboni's Spatial Path in *ABQ*

space, which he repeats for five times. The direction of his movements is again anti-clockwise. The spatial path created by his movements is a square along the inner edge of the performance space. The outer black and thin line in figure 5 symbolizes the square-shaped performance space, whereas the inner orange and thick line displays Carboni's spatial path. The lighting clarifies his spatial path because it physically manifests the spatial path. As Carboni travels from point C to point D to create one of the four lines of the square, the lighting also forms that straight line. As he travels from point D to point B to create a second line, the previously lit line disappears as a new line of light emerges. This formation of spatial and lighted lines continues for five cycles.

The next transition from a 2-D space to a 3-D space is indicated by Carboni's further expansion of his kinesphere. In this 3-D space, his body is vertically on a high level rather than horizontally on a low level. Nevertheless, he maintains following the same square-shaped spatial path as the one outlined in the orange and thick box in figure 5. This time, the lighting highlights his spatial path even more obviously than before as the entire shape of a square is lit with the center left completely dark. Similar to the dancers in *Quad*, Carboni travels by walking. However, his steps are big and slow. Towards the middle of the piece, Carboni travels in the diagonal of the square, just like in *Quad*. Consequently, the change in his directions are no longer 90 degrees but 45 degrees. By doing so, Carboni creates four distinct isosceles triangles, or triangles with two sides of equal length, through his spatial path. These are

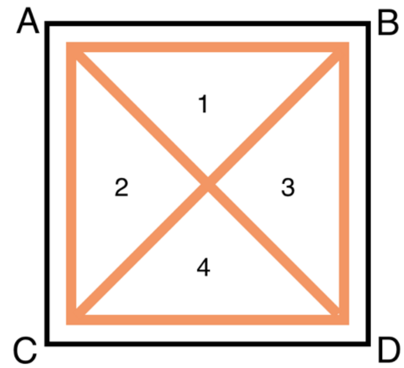


Figure 6: Carboni's Spatial Path in *ABQ*, part two

illustrated in figure 6. After this section of the piece, some earlier parts of the dance are repeated in retrograde so that *ABQ* ends with Carboni a 1-D space again. Just as he had begun the piece, he is curled up in the location of degree zero with a dim spotlight also in the center of the stage.

To some extent, the music of *ABQ* parallels with the mathematical structure in the dance. The complexity of the sounds of the performance correspond to the number of dimensions in space. As the number of dimensions increases, the number of instruments that is played also increases. Since Carboni moves in a 1-D space in the beginning of the piece, the only sound is one that Carboni makes on stage as he moves. It is only when Carboni moves in 2-D space that there is music, or non-bodily sounds produced by instruments. The first of these non-bodily sounds produces a specific low tone to create a constant beat. As Carboni transitions into 3-D space, more instruments are played. Thus, the layers in sound reflect the dimensions in space.

The overall piece is very dynamic as it contains fluid and flowy movements as well as angular and fast-paced movements. The effect of *ABQ* is thus different than Beckett's *Quad*. *ABQ* not only does not strip away the dancer's individuality, but also brings forward a personality portrayed by the dancer. Despite the frequent use of repetition, the piece has a lot of variation, particularly when Carboni executes percussive movements as he travels across the stage. These movements often look convulsive and explosive, making Carboni appear lively and active. In contrast, this is not the case in *Quad* because the dancers seem unlively and plain.

Using a choreographic score derived from various *mudras* of Bharatanatyam, Carboni demonstrates mathematical elements in *ABQ*. Through investigating the choreographic process in the creation of his piece and the outcome of the dance, I gained a better understanding of how dance and mathematics, specifically geometry, can interconnect. Although Carboni and Beckett both used geometrical relationships as a starting point in their pieces, the end result and the effect of their dances differ vastly.

Renaissance Dances in the 16th Century

Through inspecting the works of Beckett and Carboni, I observed one way in which geometrical relationships manifest in dance. Apart from being a starting point in choreography, numerical relationships can also be used as a choreographic tool in dance. Like hammers and nails, tools make a construction possible. The same logic can be applied to the process of choreography. Hoping to create dances that reflected their view of the universe, choreographers of the Renaissance period made use of geometrical relationships as choreographic tools. *Number Symbolism and Renaissance Choreography* by Françoise Carter spells out why the choreographers of the time wanted to achieve that effect and why they specifically chose geometry to achieve that effect (Carter 21).

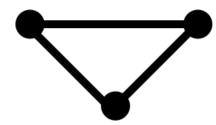
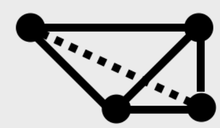
During the Renaissance period, the structure of the well-ordered universe was an important concept because people believed it originated from God and was created in the image of divinity (22). Since they also believed that relationships among numbers reflect the universe's state of being, numbers were considered to be beautiful compositions that possessed divine qualities. Thus, the use of numbers in everyday life was desirable as it helped attain beauty. The relationship between numbers and the religious view of the universe can be traced back to the work of Greek mathematician and philosopher, Pythagoras, in 5th century BC.

Pythagoras saw that the harmonic characteristics of mathematics captured an element of eternity, as does the universe (21). Because the numerical system exists on its own and is free from any influence of the human world, it symbolized eternity.

Owing to the fact that numbers have a direct relationship with geometrical shapes, Renaissance choreographers placed a large emphasis on geometrical figures. As presented in the first row of row table 2, a single point can create bulk. As shown in the second row, using two different points and connecting them creates a line with breadth. As seen in row three, taking three other points and connecting them creates a surface, or a flat shape with depth to it. Finally, the last row exhibits a solid shape that connects four additional points. Notice that the sum of the points used to create these four figures add up to ten. Ten was considered a powerful number because with ten points, one could construct the four geometric structures in table 2. These structures are important because they possess different geometric properties, including bulk, breath, surface, and shape.

Table 2

Building Figures with Points

Points	Geometry
1	
2 and 3	
4, 5, and 6	
7, 8, 9, and 10	

Geometry is one of the many areas of mathematics embedded with numerical relationships. Using the bodies of dancers, geometry can be easily visualized and recognized. To express the ideals of their society, 16th century choreographers used geometric shapes and patterns as compositional tools. For example, the dance figures observed in Renaissance dances follow imaginary geometric patterns on the floor. Apart from the dance itself, the music accompanying the dance functioned in a similar way. Again, Pythagoras made the connection between music and mathematics. Dancing to music was especially important when Pythagoras identified mathematical ratios in musical harmonies (22). This music sought to mimic the harmony of the universe beyond movements.

By demonstrating order and measure in a dance through geometric form, the separation between the artificial and incomplete world of human beings and the perfect universe created by God would be closed (Nevile 809). The manipulation of space to create geometrical shapes allowed the choreographers to emulate the visible universe and the implicit structure underlying the universe. The square was associated with the earth and its elements, and the circle was thought to symbolize heaven and divinity (823). The suggestive nature of these shapes explains the abundant geometrical forms in the Renaissance dances. For example, choreographed by Balthazar de Beaujouleux in 1581, *Le balet comique de la royne* exhibits a total of 40 geometrical figures (808). Straight lines are also a reoccurring form in the choreography because it reveal order and control.

Ballet piece *Dolce Amoroso Foco* also exemplifies the use of geometrical figures in 16th century Renaissance dances. In the first part of the piece as shown in figure 7 (a), three male (M) dancers line up on one side of the stage with the female (F) dancers lining up parallel to them. As the males and females travel past one another to take each other's positions, a square (that is representative of the earth) is created. Producing this square on the pattern of the floor indirectly reveals one aspect of the universe's structure. As for the second half of the piece, the three pairs of male and female dancers create the pattern in figure 7 (b) by tracing an imaginary circle with perpendicular lines in the center of the circle. Additionally, the circle represents the sacred and divine aspects of the universe.

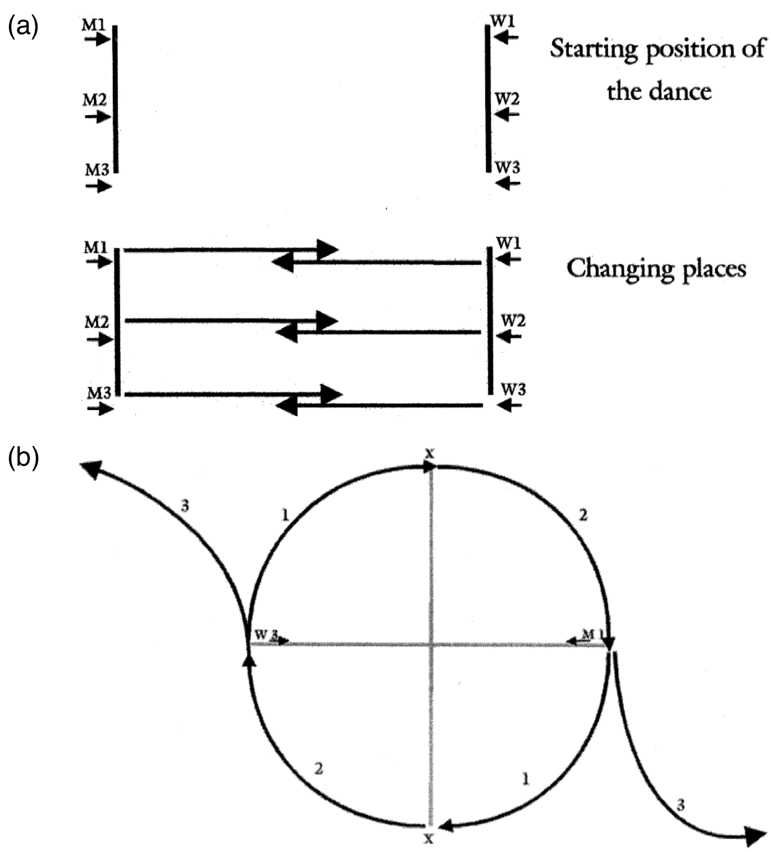


Figure 7. Aerial View of Floor Patterns from *Dolce Amoroso Foco* (816)

In the 16th century, dance choreographies were not the only choreographies made according to a set of design principles and values. Like the forms created in dance, garden structures of the nobility reflected important values of the Renaissance period, including order, measure, symmetry, geometrical forms, and straight lines (806). Dances and garden structures can both be seen as the products of choreography, with the former having a dynamic quality and the latter having a static quality. Just as the designers of gardens, the choreographers of dances produced large geometric shapes because they were meant to observed by the nobles who were seated at an elevated angle. A simple comparison between *Dolco Amoroso Foco* and the garden at L'Ambrogiana, Italy exemplifies how the choreographies of both dance and gardens made use of the same design principles (814). The circular shape created in the ballet in figure 7 (b) is similar to the one created by the trimmed plants in L'Ambrogiana, as shown in the top left corner of figure 8.

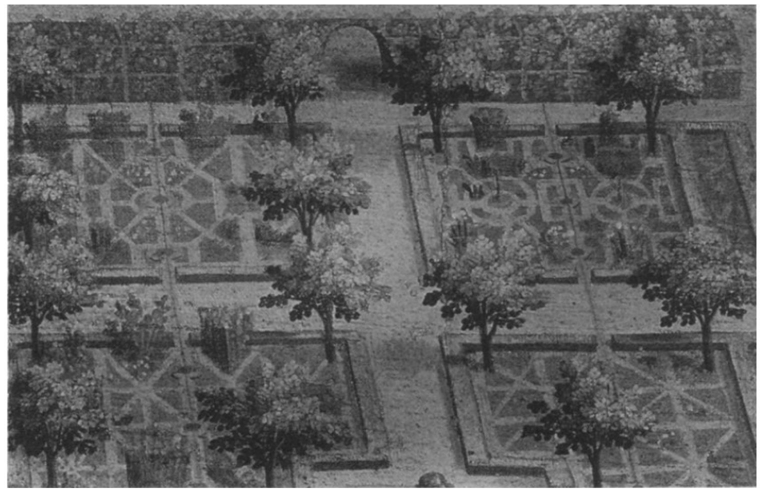


Figure 8. Aerial View of the Garden at L'Ambrogiana, Italy (813)

As scientific knowledge expanded in the 17th century, the Renaissance ideals of the universe gradually lost its significance (Carter 34). As the tie between science and religion was undermined, so did the tie between the religious world view and mathematics. As a result of this phenomenon, the use of geometrical relationships in dance decreased. Sir Francis Bacon was a prominent figure who advocated an empirical approach to research. He also established the foundation of the scientific method, which is still used today. His work and philosophy contributed to towards the push for the disconnecting mathematics from the arts (35). As a scientist, he disapproved dances that revolve around the use of geometrical figures and principles of order and symmetry to achieve divine perfection and to reproduce an image of the perfect world. Instead of reflecting divinity, he believed that dances should reflect the imperfect reality.

Probability

Merce Cunningham's Chance Dances

Despite Sir Francis Bacon's attempt to discourage the use of geometry in dance, the intentional use of mathematics persisted, as previously demonstrated in Carboni's *ABQ*. The use of mathematics as a compositional tool in choreography is not exclusively geometric. Born in Centralia, Washington, Merce Cunningham was one of the leading choreographers of the 20th century. His experimental use of quantitative methods as a score for his dances has influenced many artists who followed him. Although Cunningham's works are not directly associated with mathematics, the underlying mathematical principle in his dances is probability, the chance of something occurring. First, I inquired into why he explored the concept of chance in his works.

Cunningham studied dance and theater first at George Washington University and then in Cornish School in Seattle (Morgenroth 11). Afterwards, he danced with Martha Graham between 1939 and 1945. Several years later in 1953, he opened his own dance company called the *Merce Cunningham Dance Company*. Since his first choreography in 1942, he further developed his technique and continued to choreograph. Branching off from the work of Graham who emphasized the importance of dancing with emotion to express emotion, Cunningham was a strong believer that dance does not necessarily require an emotional aspect. He also believed that movement should exist for movement's sake because "[his] work always [came] from the same source–from movement" (14).

Unlike choreographers in the Renaissance period, Cunningham did not believe in a fixed structure of the universe. His belief in the arbitrariness and unpredictability of life initiated him to find ways to reflect these ideas in dance (Au 156; *Chance Conversations*). He did not want to portray order and structure in the universe like the Renaissance dances, but he wanted his dances to represent uncertainty in the universe. This interest led him to work with his close friend and colleague, John Cage, who explored the idea of indeterminacy in his music compositions. For Cunningham, indeterminacy was an attractive concept because it aligns well with the unpredictable conditions of nature (Franko 77). Indeterminacy meant that various elements of his work would be random and would differ in every performance, just as some aspects of nature are random every day. As with Cage, Cunningham was also interested in freeing his works from his own likes and dislikes (*Chance Conversations*). Playing with indeterminacy of space and time allowed for this.

Cunningham's choreographic process involved establishing a guideline with rules and directions for his dancers. Following Cage, Cunningham used chance procedures, or chance methods, to achieve indeterminacy. The chance procedures determined what his dancers would do in which situations and thus, determined the rules and directions in the guideline. An example of a chance method would be the use of playing cards to determine the order of a set of pre-choreographed movements, as employed in Cunningham's *Canfield* in 1969 (Au 156). In this piece, Cunningham appointed a word indicating a unique movement to every card in the deck, and he assigned the red suit as fast movements and the black suit as slow movements (Dance Capsules). The reliance on probability not only eliminated certainty of a performance, but also Cunningham's ability to choreograph dance in the traditional sense; he did not have the ability to make every choreographic decision in the way most choreographers did because he left the manipulation of various aspects of the dance piece to chance. Whether planned or unplanned, Cunningham could not completely express his choreographic intentions.

Seeing that there is standard mathematical terminology associated with probability, I will briefly identify and explain commonly used terms before using them in the context of Cunningham's chance dances. Suppose I flip a coin repeatedly to find out the probability of getting heads versus the probability of getting tails. The two outcomes of this experiment is either heads or tails. Similarly, rolling a dice produces six outcomes. The set of outcomes, called the sample space, from rolling a dice ranges from one to six. If I roll a dice 10 times and only got even numbers, each even number is labelled as an event, or a subset of outcomes in the sample space.

The concept of probability was introduced to dance when Cunningham based his dances off the idea of chance and randomness. Suppose a set of movements (outcomes) is obtained from a repertoire (sample space). If the movements were chosen at random, then each movement has an equal chance of selection. For simplicity purposes, I assumed that the method of achieving randomness is through rolling a dice. Suppose a dance based on randomness is created by selecting one of two movement sequences from a repertoire, A and B. Sequence A would be chosen if the dice lands on an odd number, and sequence B would be chosen if the dice lands on an even number. Given this information, sequences A and B have an equal chance, of 50%, of being selected as the dance. However, the probability of the sequences being selected as the dance would differ if the sequences are assigned to different numbers of the dice. For example, the probably of sequences A and B would differ if numbers 1 through 4 of the dice are assigned to sequence A, and numbers 5 and 6 of the dice are assigned to sequence B. The respective probabilities would be 66.67% and 33.33%. By using similar chance methods, Cunningham demonstrated in his dances the concept of indeterminacy and the role of chance in nature.

Performed in 1951, *Sixteen Dances for Soloist and Company of Three* was the first piece Cunningham choreographed that used a guideline to explore the potential role of indeterminacy in dance (Jowitt 284). In this piece, the guideline for his dancers was created using chance methods to order pre-choreographed movement sections. He also left to randomness and chance the timings of the sections and the directions of his dancers. To easily understand how probability comes into play in one of Cunningham's "chance dances," I only studied the relationships relating to probability through the ordering of movement sections using chance methods.

A summary of the numerical relationships in Cunningham's use of chance to order movement sections is illustrated in table 3. Assume that Cunningham starts with one movement section in a repertoire, section X. At this point, the only possible movement section that can be selected, or combination of movements, is X itself. In other words, there is a 100% chance that

Table 3

Relationship Between the Number of Movement Sections and Permutations

Number of Movement Sections (n)	**Number of Possible Permutations (P)**	**Possible Permutations**	**Probability of Permutation (pr)**
1	1	X	100%
2	2	X, Y Y, X	50%
3	6	X, Y, Z X, Z, Y Y, X, Z Z, X, Y Z, Y, X	16.67%
n	$P = \frac{n!}{(n-n)!}$ $= n * (n-1) * (n-2) \ldots * 1$		$pr = \frac{1}{P} * 100\%$

the dancers perform section X. With one more movement section, section Y, the sample space increases from one to two. With movement sections X and Y, the combinations of the dance increase. One possible order of movements, or permutation, is X and then Y, and another possible permutation is Y and then X. Each of these permutations has a 50% probability of appearance. Adding an extra section to the repertoire, section Z, further increases the permutations of the dance. With three sections, there are six possible permutations, where each outcome in the sample space of six has almost a 16.7% chance of occurring.

As the number of movement sections in the repertoire grows, the number of possible permutation increases and the probability of each permutation falls. To find the number of possible permutations (P) associated with any number of movement sections (n), one could use the formula to find P, as stated in the second column and last row of table 3. If $n = 10$, or if the repertoire consisted of 10 movement sections, then the number of possible permutations would be 3,628,800. The calculation is presented below.

$$P = 10(10-9)(10-8)(10-7)(10-6)(10-5)(10-4)(10-3)(10-2)(1)$$
$$= 10 * 9 * 8 * 7 * 6 * 5 * 4 * 3 * 2 * 1 = 3{,}628{,}800$$

Using the formula in the last row and column of table 3 to find P, the following shows the calculation to find the probability of each permutation occurring if there were 10 movement sections in the repertoire.

$$pr = \frac{1}{3{,}628{,}800} * 100\% = 0.00002755739\%$$

Undoubtedly, the difference between the numerical permutations of having three and 10 movement sections changed exponentially. Increasing the repertoire from three to 10 increases the sample space from six to 3,628,800 outcomes. This means that as Cunningham uses more movement sections, the possible dances that could be performed drastically increases.

However, every permutation would have a lower probability of presenting themselves on stage. Only by adding seven more movement sections, the probability of appearance of each permutation would fall from 16.67% all the way to 0.000028%. By using chance methods in the other elements of the dance, including the timing of the sections and direction of the dancers' facings, the dance and hence probability, change accordingly.

This framework of choreographing can even be further extended to create more complex dance pieces of varying probabilities. By 1953, Cunningham had experimented with other chance procedures, complicating the guidelines for his dancers. Rather than arranging the order of choreographed and thus, fixed movements by chance, Cunningham created guidelines for his dancers using chance procedures to formulate both indeterminate and fixed elements of the dance in *Suite by Chance* (Au 157). Cunningham started off choreographing a number of movement sequences that linked easily. He then made a chart that divided into different qualities of the dance such as timing and movement positions. To complete the dance composition, he tossed a coin to determine how the movements would both be combined and carried out. Complicating the use of randomness in choreography complicates the rules and directions guiding his dancers on how to perform the piece. Moreover, it also complicates the process of identifying and analyzing probability-related relationships in dance. Although possible, I did not derive more formulas to find the probabilities according to the chance method of coin-tossing and Cunningham's choreographic decisions on what characteristics of the piece relies on randomness.

In 1963, Cunningham used different chance procedures to choreograph *Field Dances*. Cunningham assigned each dancer a set of movement sequences. During the performance, the dancer could freely carry out the sequences in whichever order they wanted however many times they wanted. They were also allowed to enter and exit at any time. There were many other ways in which Cunningham used chance methods in his dance to achieve indeterminacy and unpredictability. These strategies include the number of dancers on stage, the shape of the path the dancers took to execute fixed movement sequences whether curved or straight, the duration of each execution, the approximate speed of the movements, the level of the dancers, as well as the relative spacing of the dancers (Jowitt 279). The relationships relating to probability in every chance dance depended on the chance method used and on how different movement qualities or choreographic decisions rely on randomness. Clearly, the guideline that Cunningham created for his dancers differed piece from piece, with each incorporating a range of various aspects of dance.

Besides the choreographic decisions in the dance itself, probability also replaced the certainty of other production aspects, including the costumes and music. This meant that Cunningham's guideline included not only rules and directions for movement, but also for costumes and music. For example, Cunningham allowed his dancers to pick their costumes for every performance of *Story* from a supply of second-hand clothing selected by designer Robert Rauschenberg. Although music still played a role in Cunningham's choreographies, the way in which it was used differed from more traditional dances because he choreographed independently of music (Morgenroth 15). Prior to the choreographic process, Cunningham and his music composer, John Cage, only decided on the length of the music and dance. Separately, they would create their pieces and then come together with their individual works. Without music to work with, Cunningham choreographed the dance with the help of a stopwatch to ensure that the dance would end at the same time as the music. This process guaranteed that only chance would dictate whether the music aligned with the dance or whether the music contributed to creating an emotional response in the audience.

By prohibiting the influence of dance on music and vice versa, the probability of the dance evoking a particular response in the audience changes every time it is performed. This means that not only is there indeterminacy in the chance dances, but also in the audience's responses. With music functioning as an additional element in the dance, more outcomes are created. A greater number of outcomes signifies a larger sample space. Thus, the probability of every response occurring falls. As with other elements of his pieces, Cunningham used the numerical relationships of probability to achieve indeterminacy.

Conclusion

My analysis of numerical relationships in various dances indicated a noticeable relationship between dance and specific fields of mathematics, including geometry and probability. Based on a number of choreographers and works, I discerned different ways in which the creation of dance can involve numerical relationships.

Through the discussion of three works, I revealed how geometry is manifested in dance. Beckett created a geometrical formula that dictated the movements of the dancers. Carboni transformed the numerical concept of the origin in Beckett's *Quad* into a new mathematical concept, which formed a choreographic score. The two artists used geometrical relationships as a starting point but achieved very different results. The former dehumanized his dancers, and the latter gave a strong personality to the soloist. I also saw how numerical relationships can be strategically used to create opposing effects. From the Renaissance dances, symmetry in geometrical patterns and figures aimed to represent divinity and the highly structured universe. Dissimilarly, Cunningham's chance dances used probability to achieve the effect of indeterminacy and randomness. His choreographic process involved creating a guideline of rules and formulas that determined what the dancers would do in their performance.

Chapter 2. Elements of Movement and Dance: *The Art of Making Dances*

I studied dances that incorporate mathematical ideas, including geometry and probability, because they illuminate how I may approach a dance based on highly mathematical econometric concepts. It was also important that I emphasized learning the art of choreography itself because knowledge of choreography provides a structure and framework to create new dance ideas. To further my understanding of choreography, I relied on the book *The Art of Making Dances* by Doris Humphrey. This book offers one of many perspectives and information on dance choreography.

Doris Humphrey was an important figure shaping the history of modern dance in the United States of America in the early 20th century. She formalized her choreographic theory in 1959 in *The Art of Making Dances*. Although her choreographic theory was written six decades ago, it is still largely applicable and used to this day and age. I selected her theory because it spells out basic yet vital elements of choreography that was required in my choreography. However, my use of her theory does not imply that I completely agree with all her choreographic ideas. Even Humphrey herself attests that "Discrimination and judgement are operating constantly, deciding what is agreeable and what is not" (50). Regardless of our opinions, her choreographic theory ultimately informed some of my choices in the final dance performance and guideline.

Design

For Humphrey, the raw materials of dance are design, dynamics, rhythm, and motivation (46), with each material of dance containing its own elements. According to Humphrey, there are more elements in design than any of the other raw materials of dance. The two main aspects of design are space and time (49), and they are respectively referred to as space-designs and time-designs. On the one hand, people can view the design of a dance with respect to space at one point in time. For example, I can observe a different design at every moment of pause in a dance. On the other hand, people can perceive the design of a dance over time in one space. For example, I can observe a design in time from either the transition of one movement to another or the overall shape created in a section of dance.

Space-designs, or designs that are viewed in space at one point in time, fall under two groups – symmetry and asymmetry (50). In everyday life, symmetry suggests stability. For example, an architectural construction with a symmetrical structure signals stability, balance, and security. This can be contrasted with asymmetry in the Leaning Tower of Pisa, which offers a sense of instability, imbalance, and trepidation. Using symmetry in dance can create a calming effect because of its association with stability (56). Despite the appeal of a calming effect, there is a need for asymmetry in dance because "art is for stimulation, excitement, and adventure" (50). People often prefer a passionate and vibrant speaker over a monotonic speaker. Likewise, asymmetry in dance stimulates the senses and captivates the audience. However, both symmetric and asymmetric designs must not be excessively used because it may remove the excitement in the dance. A balance between symmetry and asymmetry prevents the dance from being dull.

Each of the two groups of design can either be oppositional or successional (57). Oppositional designs have lines that are angled and opposing. The narrower the angle, the weaker the angle becomes. At the extreme, two lines producing a right angle creates the strongest image. For example, the upper arm can be one line and the lower arm can be the second line. Bent at the elbows, the two lines form a right angle. When there are two lines pointing towards different directions, the two directions of energy "dramatizes and emphasizes the very idea of energy and vitality" (58). This suggests that oppositional designs are forceful, as with asymmetrical designs. In contrast, successional designs have lines that are curved and flowing. The gradual and gentle changes in successional lines relative to abrupt changes in oppositional lines create a soothing effect, as with symmetrical designs. For example, the upper body can be bent backwards into the shape of a C.

Apart from space-designs, there are also time-designs that are viewed over a certain period of time. Humphrey calls the organization of movement in time-designs the "theory of the phrase" (66). Phrases are shapes that are formed in the succession of time from one design in space following to another design in space. All phrases have a recognizable shape, a beginning and an end, peaks and troughs, and a time length (68). There three types of phrases, each differing in the position of its high point. When a dancer is performing the high point of a phrase, it either means that the dancer is at a high level in space or that there is a peak in dynamic, tempo, or other elements of dance. The first type of phrase has its high point at the beginning of the phrase. The second type has its high point at or near the end, and the third type has its high point at or near the middle. The types of phrases in a dance should be varied to interesting dances.

Another element of design in dance is the stage space. Different areas of the stage have specific names, as exhibited in figure 9. According to Humphrey, the most powerful spatial path of the stage is the diagonal, starting from one corner of the stage to another (75). Similarly, the most

upstage right (UR)	upstage center (UC)	upstage left (UL)
center right (CR)	center center (CC)	center left (UL)
downstage right (DR)	downstage center (DC)	downstage left (DL)

Figure 9. Stage Directions

powerful area of the stage is the Center Line of the stage, which includes UC, CC, and DC (80). As dancers move from UC to DC, their stature and power increases. Within the Center Line, the "dead center," or CC, is the strongest position on the stage (76). Like asymmetry, the dead center can lose its power when it is overused. Asymmetry maintains its power to stimulate the senses through the occasional and appropriate use of symmetry. Likewise, the dead center maintains its power through the use of other areas of the stage space. The most powerful spot on stage is thus refreshed and energized by its lack of use.

Although not as powerful as the Center Line, the four corners in UR, UL, DR, and DL are also strong. This is because they are nearest to the architectural support of the stage (74). The downstage corners in DR and DL can be strategically used because the close proximity with the audience gives an intimate feeling (78). This suggests that as the dancers move farther upstage, their performance becomes weaker. In comparison to the sides of the stage, the downstage and upstage corners are also strong spaces for entrances and exits (82).

Generally speaking, a stage has seven strong areas and six weak areas. Respectively, these areas are displayed by the filled and hollow circles in the aerial view of the stage in figure 10. Furthermore, it is crucial to consider the directions of the dancers relative to the stage space (85). The lines and shapes made by the body can be obstructed from the audience because of improper directional choices. A remedy for such a mistake would be to have dancers face downstage, perform circular movements, or position themselves at a forward diagonal (86).

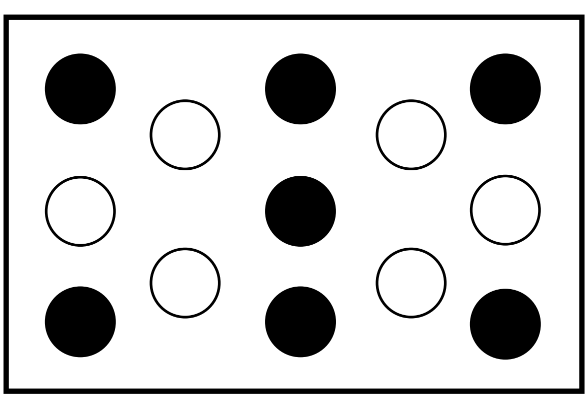


Figure 10. Power of Positions On the Stage

The last element of design is the spatial relationship of dancers in small groups (91). Dancers can be assembled into groups in a way that isolates a single dancer, giving them the most attention and power on stage. For example, the group of dancers in ballet called the *corps de ballet* often dances near stage left or right, highlighting the principal dancer in center stage. Similarly, a piece consisting of only five dancers can do the same. One dancer can attract the audience's attention if they perform a set of sharp movements in CC while the remaining four dancers are towards upstage slowly performing the same set of movements. This arrangement encourages the audience to place more of their attention primarily on the single dancer and less of their attention on the group of anonymous and indistinguishable dancers. In contrast, a group of dancers rather than one leading dancer can carry much of the weight of the piece by bringing to light the identity of the dancers within the group. It is important to equally highlight the personalities of all the dancers to reveal their identities.

Dynamics

The second raw material of dance is dynamics, which can be thought of as a scale possessing one end with the "smoothness of cream" and another end with the "sharpness of a tack hammer" (97). A simple approach to dynamics in dance is to vary the tempo of the movements. However, additional layers of elements of dance, such as tension, can be added to create variations of dynamics. Humphrey offers a list of examples of different effects within dynamics, including "slow-smooth with force," "fast-smooth without tension," "fast-sharp with tension (like pistol shots)," "moderate-sharp with little force (rather blunt)," and "slow-smooth without tension (dream, sluggish or despairing)" (97). However, she points out that the words sharp, smooth, fast, slow, tension, and relaxation cannot be defined in absolute terms because everyone evaluates each word subjectively.

Once a choreographer has a specific dynamic in mind, they must choose the appropriate movements to portray the effects within the dynamic (98). For example, it would be sensible to use angular movements to create sharpness for they are broken and harsh. It would not make sense to use circular movements to create sharpness because they are smooth and continuous in nature. Apart from the proper types of movements, the choreographer must also select appropriate body parts to carry out those movements. The segmentation of body parts is useful when a desired body part and movement cannot create a desired effect within the dynamic. For example, a swing of the leg from the hips is difficult to create sharpness because it cannot move fast enough and does not have any points of accent. To achieve sharpness, the dancer would have to perform accented thrusts on joints of the leg, such as the knee and/or ankle.

As with the use of symmetry and asymmetry and of the dead center, a dance should vary the use of dynamics to keep the audience engaged. For the audience, the combination of sharp dynamics and speed is stimulating, and the combination of smoothness and slowness is soothing. However, each effect should be used appropriately to maintain variation in dynamics. For example, if an entire piece is sharp and speedy, its constant stimulating effect loses its power and stops being stimulating. On the other hand, if an entire piece is smooth and slow, its constant soothing effect becomes tedious and weak. Dynamics can also be considered not only between movements, but also within movements (101). Dynamics can be created within movements by varying the uses of different body parts. For example, a dancer can move their torso in a circular motion while they flick their hands around. This would be more engaging to the audience due to the variation of effects within the movements that produce a larger effect.

Rhythm

Humphrey considers rhythm as the "most persuasive and most powerful element" (104) in the art of dance. A main reason is because it "permeates every aspect of human beings" and organizes human life (104). Humphrey identifies four sources of rhythmical organization in human life (105). The first is the vocal apparatus, which involves the breath, speech, and singing. This apparatus helps human beings develop a sense of rhythmic awareness. The second source deals with the unconscious functions of life such as the heartbeat, peristalsis, motion of muscles, and waves of physical sensation. The third is emotional rhythm, where the human mind experiences waves of different feelings of various intensities.

The fourth source of rhythmical organization is the most important for dancers. The motor and propelling mechanisms of human beings largely depend on the feet, as they provide the platform of body support to travel around in space. According to Humphrey, dance originated from the feet (105). The walking and dancing bodies create both rhythm and beat as weight shifts across different parts of the body. The process of this creation is facilitated through the interplay between the moving body and gravity (106). A walk is initiated by removing one leg off the ground, shifting the weight of the body to the other leg. As the leg in the air descends, gravity takes control to complete the step. The beat of a walk occurs on every step. The strength of the beat can be artificially amplified or softened by controlling the leg muscles. In other words, gravity provides the natural force for the production of beats, which can be manipulated by the person. During her choreographic career, Humphrey developed a theory of motion called *fall and recovery*. The fall alludes to giving in to gravity, and recovery refers to rebounding from gravity. Suppose the relationship of a dancer with respect to gravity is neutral in a standing position. If the dancer executes a leap, they give in to gravity when they are pulled down onto the floor. As the dancer lands and recovers to a neutral standing position, they rebound from gravity. The rhythm of a dance is created through variations in the movements that embody the concepts of fall and recovery.

Tempo is an aspect of rhythm because can describe the pattern and frequency of rhythm. Like the words associated with dynamics such as sharp and slow, words associated with tempo such as moderate, fast, and slow are defined in relative terms (108). Nonetheless, Humphrey provides a rule of thumb. Instead of thinking about tempo in terms of the name of the tempi (e.g. fast and slow), dancers should think of tempo in terms of movement. Humphrey considers the rate of normal walking as a moderate tempo. Hence, anything faster than that is fast, and anything slower is slow. In dance, a choreographer can modify the audience's perception of tempo. This alteration can be achieved by starting the piece faster or slower than moderate tempo and then further increasing or decreasing the speed of movements so that the original tempo appears moderate relative to the modified speed. Like the four rhythmical organizations of human life, tempi must change correspondingly to stimulate the audience.

Motivation

As Humphrey contests, "A movement without a motivation is unthinkable" (110). Humphrey believes that there is no point performing a movement that lacks purpose. She is especially critical of dancers executing pure technique, as it is empty and without substance. Nonetheless, a highly technical dance can still possess motivation for the movements can aim to demonstrate the advanced physical abilities of the dancers. Motivation makes a performance worthy of display, and it prevents a performance from becoming technical, cold, and mechanical (110). Humphrey draws a parallel between dance and drama (111). Everything a playwright puts on the script strategically communicates something. Actors would not say something bizarre on stage, such as "ah-ah-ah," unless it serves a purpose to the play. Similarly, every movement in dance should in some way have intent.

Apart from the motivation behind dancers' movements, Humphrey emphasizes on the intent of dancers' faces as she is "not a believer of the faceless dancer" and she sees "no reason for eliminating expression of the face" (85). Owing to the highly interactive and interpersonal nature of people's lives, the power of faces is inevitably felt in everyday life. Unless the purpose of a dance involves no or minimal human-related ideas, such as impersonality and total abstraction, then the impassive face is appropriate.

Conclusion

In this chapter, I explored the art of dance and choreography using Humphrey's *The Art of Making Dances*. I discussed Humphrey's ideas on the four raw materials of dance, including design, dynamics, rhythm, and motivation. More specific elements of dance were discussed for each raw material of dance. This knowledge was ultimately applied to the choreographic decisions in the final dance piece and was considered in the creation of the guideline.

Chapter 3. The Basic Model of Econometrics: Regression Equations

My main goal was to present a dance that was based on concepts of regression equations in the Spring Dance Concert. My secondary goal was to create a guideline that other dance and/or economics enthusiasts can foll6ow to transform certain regression equations into a dance. To do so, I had to develop a working knowledge of regression models. Then, I had to learn about other econometric concepts that were included in the guideline but were not necessarily included in my final choreography. As much as I could, my choreographic decisions were based on econometric concepts. To understand the logic behind my choices and how the audience could potentially interpret the dance as an embodiment of a regression equation, I explain relevant aspects of econometrics in this chapter. As I introduce these ideas, I will briefly indicate how they were expressed in the final dance performance and how they could be expressed in other dances that are based on econometrics. For a more detailed discussion of how my choreographic decisions reflect econometrics, refer to Chapter Four.

But first, what is it? Think of econometrics as the intersection between mathematics and economics. Econometrics is highly mathematical in nature because economic phenomena are often represented through math; it is a branch of study in economics that uses quantitative methods to measure and analyze economic phenomena (Studenmund 2). For example, econometrics can be used to measure and analyze how discrimination in the work force affects employment opportunities or how the number of reviews of a dance performance affects performance attendance. As brought up earlier, the regression equation I used as the choreographic score in the final dance performance explored the numerical relationship between the technique of dancers (represented by variable $TECH$) and the consumer's willingness to pay for their performance (represented by variable WTP), rather than the subject matter themselves. As expressed in [a] of figure 11, part of the regression equation I used in the final dance establishes how $TECH$ affects WTP. The unit of measurement for $TECH$ is levels, where the minimum of level zero signifies dancers with little or no technique, and the maximum of level five signifies dancers with a high level of technique. On the other hand, WTP is measured in U.S. dollars.

	(left column)		(right column)
[a]	WTP	<--affects--	TECH
[b]	Y	<--affects--	X
[c]	dance	<--affects--	dancer

Figure 11. Relationship Between Independent and Dependent Variables

Single-Equation Linear Regression Model

A common and basic method in econometrics is the single-equation linear regression model, which has two main components, namely the dependent variable (Y) and an independent variable (X). Dependent variable Y is also called the outcome variable because it is the output of the equation, and independent variable X is also called the explanatory variable because it explains the variation in dependent variable Y. A single-equation linear regression model establishes a relationship between independent variable X and dependent variable Y to see how the former affects the latter, as outlined in [b] of figure 11. As stated in [a], my regression equation shows how $TECH$ affects WTP. Therefore, WTP is dependent variable Y, and $TECH$ is independent variable X.

The concept of the independent and dependent variables could be captured in dance. In [b] of figure 11, it is stated that independent variable X affects dependent variable Y, and a dancer affects the dance. Following this logic, a dancer could represent independent variable X, $TECH$, and the dance itself could represent dependent variable Y, WTP, as outlined in [c] of figure 11. The elements grouped in blue on the left column are associated with the dependent variable, and the elements grouped in green on the right column are associated with the independent variable.

Equation 1 more formally represents the relationship between the dancers' technique ($TECH$) and consumer's willingness to pay (WTP) in a standardized format of a single-equation linear regression model.

$$\underset{\substack{\text{(term 1)}\\ \text{(dance itself)}}}{\overbrace{WTP}^{\text{dependent variable }(Y)}} = \underset{\substack{\text{(term 2)}\\ \text{(dancer 1)}}}{\overbrace{\beta_0}^{\text{constant}}} + \underset{\substack{\text{(term 3)}\\ \text{(dancer 2)}}}{\overset{\text{slope coefficient}}{\beta_1}\overset{\text{independent variable }(X)}{TECH}} \tag{1}$$

Term 1 on the left side of the equation is always the dependent variable. The right side of the equation consists of terms 2 and 3. Term 2 is the constant or intercept term, β_0, a number that indicates the value of dependent variable Y when independent variable X has no impact on dependent variable Y, or when $X = 0$. In equation 1, the number of β_0 would tell us the consumer's willingness to pay if the dancers' technique was level zero (low level of technique). Like independent variable $TECH$, constant β_0 could also be represented by a dancer. The reason is that constant β_0 affects dependent variable WTP, just as independent variable $TECH$ affects dependent variable WTP. To avoid confusion over the dancers, I continue by referring to the dancer representing constant β_0 as dancer 1 and the dancer representing independent variable $TECH$ as dancer 2.

Term 3 consists of two components, the beta coefficient and independent variable $TECH$. The two are paired together because all independent variables correspond to a beta coefficient that is signified by symbol beta, β. In the single-equation linear regression model, the specific name for beta coefficient β_1 is slope coefficient. β_1 is a dollar value that measures how much a one-unit increase in independent variable $TECH$ impacts dependent variable WTP. This impact can be positive if $\beta_1 > 0$, negative if $\beta_1 < 0$, or zero if $\beta_1 = 0$. While an impact of zero suggests no impact at all, a positive (or negative) impact means that a one-unit increase in independent variable $TECH$ increases (or decreases) the value of dependent variable WTP by the size of β_1 dollars. A positive impact is demonstrated in figure 12. The dark blue bar represents the original size of dependent variable WTP prior to a one-unit increase in independent variable $TECH$. Dependent variable WTP increases by the size of β_1 dollars after a one-unit increase in independent variable $TECH$, which is represented by the addition of the light blue bar in figure 12. On the other hand, a negative impact means the subtraction of β_1 amount from the original size of dependent variable WTP. Specifically, β_1 is a dollar amount that tells economists the magnitude of the effect of a one-level increase in the technique of dancers (represented by a dancer) on the consumers' willingness to pay (represented by the dance itself). When slope coefficient $\beta_1 = 0$, it means that $TECH$ has no impact on WTP. A large value of β_1 signifies a large impact of $TECH$ on WTP, meaning a larger light blue bar in figure 12. This can be compared to a smaller light blue bar when the value of β_1 is small due to the small impact of $TECH$ on WTP.

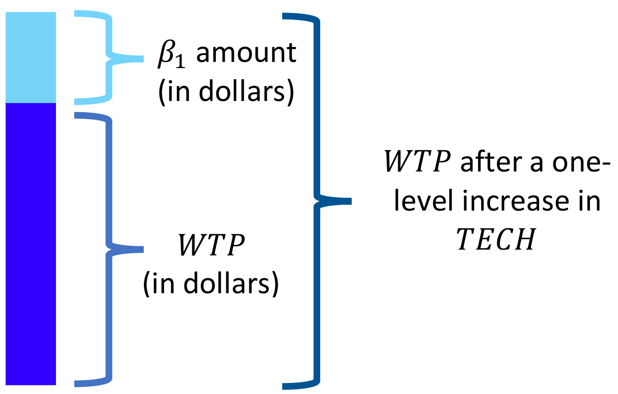


Figure 12. Change in Independent Variable $TECH$ on Dependent Variable WTP

In choreography, slope coefficient β_1 could be used to determine how dancer 2 (representing independent variable $TECH$) is impacting the dance (representing dependent variable WTP). Suppose independent variable $TECH$ represents an element of dance such as the speed of movements. Its corresponding slope coefficient, β_1, would dictate the speed of dancer 2's movements. If $\beta_1 = 0$, dancer 2 would have no impact on the speed of the dance and therefore, would perform movements at a moderate or normal pace. For the purpose of my study, any element of dance matched with a coefficient of zero is considered the default. Here, a moderate tempo is the default for the element of dance, tempo. If the slope coefficient is positive so that $\beta_1 > 0$, dancer 2 would perform fast movements; if the slope coefficient is negative so that $\beta_1 < 0$, dancer 2 would perform slow movements. In the example in figure 12, the addition of β_1 means that dancer 2 would perform faster movements.

The functional form of a model determines the shape of the regression equation. With different functional forms, regression equations have different shapes. In choreography, the regression equations and thus, varying shapes, could determine the spatial patterns that dancers make, the formations of the dancers, or the shapes that individual dancers or dancers together make in their movement. The functional form in equation 1 is called the linear functional form because it is a single-linear regression model. Graphically, equation 1 looks like a straight line, as demonstrated in figure 13. There are three ways to choreographically represent the functional form of equation 1 as a straight line, with dancer 1 as β_0 and dancer 2 as independent variable X. First, the two dancers could travel in a straight line to represent the linear functional form as a spatial pattern. Second, they could create a straight line to represent the functional form as a formation so that the relative positionings of the dancers create a straight line. Third, individual dancers or both dancers 1 and 2 could create a straight line to represent the functional form in the shape of the movement.

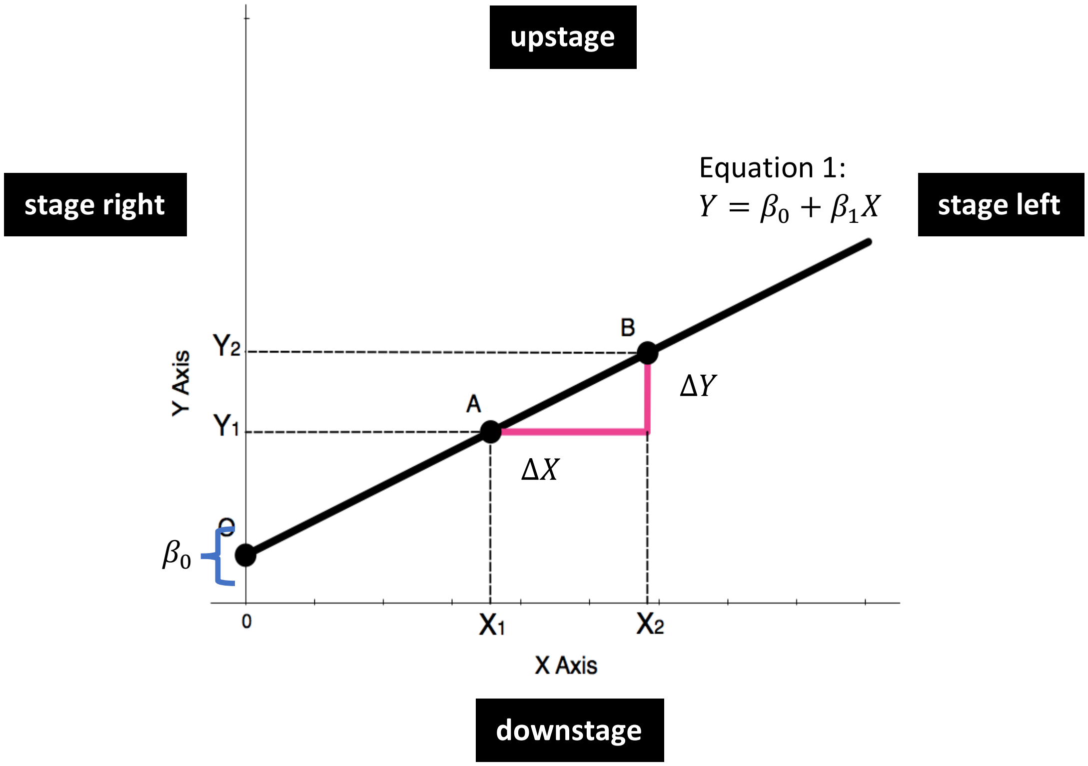


Figure 13. Graphical Representation of a Linear Regression Equation (Studenmund 7)

Equation 1 in figure 13 is displayed as a graph on a grid system on which coordinates, such as points O, A, and B, can be mapped. To visualize the graphical form of equation 1 as the formation of the dancers, imagine the performance space as the grid with the X-axis as downstage and the Y-axis as stage right. Dancers 1 and 2 could form the shape of equation 1 by forming a straight line from downstage right across upstage left. Seeing that dancer 1 represents β_0, they would start at point O where β_0 is located. At this point, the dependent variable or X-coordinate is zero, whereas the independent variable or Y-coordinate is β_0. Coordinates are represented as (X, Y). Therefore, the coordinate of point O is $(0, \beta_0)$, suggesting that dancer 1 would be situated at the edge of stage right and away from the edge of downstage by the amount of β_0.

Equation 1 only looks at how a single explanatory variable, $X = TECH$, affects dependent variable $Y = WTP$. In reality, there are often more than one explanatory variable affecting the dependent variable but are not included in the model. These excluded variables are called omitted variables. Any variation in the consumers' willingness to pay for dance concerts not explained by the technique of dancers is incorporated into the stochastic error term ϵ (9), as demonstrated in equation 2.

$$\underset{\text{(dance itself)}}{WTP} = \underset{\text{(dancer 1)}}{\beta_0} + \underset{\text{(dancer 2)}}{\beta_1 TECH} + \underset{\text{(dancer 1)}}{\epsilon} \tag{2}$$

Since constant β_0 and stochastic error term ϵ are numbers that can be added together, dancer 1 who is representing constant β_0 would also represent stochastic error term ϵ. This is an appropriate choice because both constant β_0 and stochastic error term ϵ affect dependent variable Y. Dependent variable Y on the left side of equation 2 depends on all the elements on the right side of the equation. Likewise, a dance depends on all its dancers. In this case, dancers 1 and 2 affect the dance.

Multivariate Linear Regression Model

Apart from the dancers' technique, there are many other things that affect the willingness of consumers to pay for a dance performance. A multivariate linear regression model takes into account more than one explanatory variable, compared to the single-equation linear regression model that takes into account only one explanatory variable. Although only partially developed for the purpose of simplicity, equation 3 is the regression equation I used for my choreography that takes into account two explanatory variables that may affect the consumer's willingness to pay, WTP. The first variable is the technique of dancers, $TECH$, and the second variable is JOB, the weekly hours of work of an audience member.

regression coefficients

$$\underset{\text{(dance itself)}}{WTP} = \underset{\text{(dancer 1)}}{\beta_0} + \underset{\text{(dancer 2)}}{\beta_1 TECH} + \underset{\text{(dancer 3)}}{\beta_2 JOB} + \underset{\text{(dancer 1)}}{\epsilon} \tag{3}$$

Any variation in WTP not explained by the two independent variables is incorporated into stochastic error term ϵ. These consist of all other factors affecting the consumer's willingness to pay. A dance based on the structure of multivariate linear regression model in equation 3 would require three dancers to represent the additional explanatory variable, JOB, in the model.

In a single-equation linear model, β_1 is called the slope coefficient. In a multivariate linear model, all beta coefficients, including β_1 and β_2 in equation 3, are called regression coefficients. The interpretation of slope coefficients differs from that of regression coefficients. As stated in the single-equation linear model in equation 1, β_1 is the change of dependent variable WTP from a one-unit increase in its corresponding explanatory variable $TECH$. However, when interpreting regression coefficient β_1 in the multivariate linear model in equation 3, the impact of the other explanatory variable, JOB, on WTP is assumed to be constant. Thus, β_1 is the change of Y from a one-unit increase in its corresponding explanatory variable, $TECH$, while holding the impact of variable JOB on WTP constant. In dance, it means that the dancer representing β_1 would keep other elements of dance constant by performing those elements of dance at the default.

Estimating Regression Equations

To avoid overcomplicating the next econometric concept, I now return to the simple single-equation linear regression model in equation 1. The regression equations I have been describing are purely theoretical; they have no actual numbers. The goal of regression analysis is to use a dataset to quantify a theoretical equation into an estimated regression equation (15).

This manipulation involved using data to estimate the impact of independent variable $TECH$ on dependent variable WTP.

$$\widehat{WTP} = \widehat{\beta_0} + \widehat{\beta_1}TECH \tag{4}$$

The symbol ^ (hat) on top of WTP, β_0, and β_1 tells economists that the values have been estimated into an assigned number. For example, $\widehat{\beta_0}$ is the estimated value of constant β_0.

The full estimated regression equation I ultimately used in my choreography is introduced in Chapter Four. However, the estimated regression equation in equation 5 is an example of an estimated regression equation.

$$\underset{\text{(dance itself)}}{\widehat{WTP}} = \underset{\text{(dancer 1)}}{15} + \underset{\text{(dancer 2)}}{2TECH} \tag{5}$$

The estimated value of β_0, as denoted by $\widehat{\beta_0}$, is 15, and the estimated value of β_1, as denoted by $\widehat{\beta_1}$, is 2. Notice that stochastic error term ϵ is not visible because it is factored into β_0. With actual and realized numbers in the regression equation, the relationship between WTP and $TECH$ is realized. These estimated values clearly tell my dancer what type of movements to perform in order to portray the numerical relationship between WTP and $TECH$. As suggested before, a positive value of β_1 would tell my dancer to perform fast movements. With $\widehat{\beta_1} = 2$, my dancer would perform fast movements. In econometric terms, it means that when the dancers' technique increases by one level, the consumers' willingness to pay for a dance concert increases by 2. In contrast, if $\widehat{\beta_1} = -2$, my dancer would perform slow movements. If $\widehat{\beta_1} = 0$, my dancers would perform at the default, or moving at a moderate tempo.

A common method of estimating regression equation, or finding the actual values of a theoretical regression equation, is using ordinary least squares (OLS). This regression estimation technique allows for the estimation of beta coefficients (35). Although common, OLS is not the only method to estimate a regression equation. To avoid overcomplicating my research, OLS was the only method I studied. Although I touch upon the assumptions of OLS, I did not investigate its mechanics and how it operates because it was not relevant to my choreography.

The Classical Assumptions

OLS is only effective when all seven rules are met, also known as the Classical Assumptions (93). Economists can test whether the rules are met to determine the reliability of OLS as a method to estimate a regression equation. Since it was not feasible to incorporate all seven Classical Assumptions into my choreography or guideline, I considered four of them, including Classical Assumptions I, III, IV, and VI.

Classical Assumption I: Functional Form

There are three elements to Classical Assumption I of OLS (94). First, the regression model must have an additive error term. The error term must be added and not multiplied or divided into the model such as the one in equation 4. To consider this in choreography, the dancer representing stochastic error term ϵ was added into the dance as a separate component independent of other dancers. Second, the regression equation must be correctly specified. This means that there are no omitted variables and that the chosen functional form is supported by theory. For the purpose of my work, I explore this part of Classical Assumption I when I consider Classical Assumption III because the two are related.

As previously suggested, a regression equation's functional form could be visually manifested into three elements of dance, including spatial patterns, formations, or the shape of movements. Different functional forms signify different shapes of equations and thus, create possibilities for the three elements of dance. Therefore, the study of different functional forms was important in determining these choreographic elements. To this point, I have only talked about one functional form, the linear form. Like the single-equation linear regression model in equation 6, the multivariate linear regression model in equation 7 could also be visualized as a straight line.

$$WTP = \beta_0 + \beta_1 TECH + \epsilon \tag{6}$$

$$WTP = \beta_0 + \beta_1 TECH + \beta_2 JOB + \epsilon \tag{7}$$

Hence, both two equations could be visually manifested into spatial patterns, formations, and the shape of movements that involve a straight line.

Due to the third part of Classical Assumption I, I only studied the linear form and a few other functional forms. The third part of Classical Assumption I states that the regression equation's functional form must be linear in the coefficients (211). I neither studied what that means nor why that is the case because I only needed to know what the forms look like visually. The other functional forms I studied that meet the last requirement of Classical Assumption I were the double-log, semi-log, and polynomial functional forms. Since all functional forms produce a different shape, the shape of the double-log functional form is different than the shape of linear form, which is a straight line. The difference between the two forms is the presence of natural logs in both the X and Y variables (213). The linear forms in equation 6 and 7 do not have any natural logs, symbolized by ln. In contrast, the double-log form in equation 8 has natural logs in WTP, TECH, and JOB.

$$\underset{\text{(natural log)}}{ln\, WTP} = \beta_0 \;+ \beta_1 \underset{\text{(natural log)}}{lnTECH} \;+ \beta_2 \underset{\text{(natural log)}}{lnJOB} \;+ \epsilon \tag{8}$$

By having natural logs, the shape of the double-log functional form differs from the shape of the linear forms, which is dependent on the magnitude of β_1. As demonstrated in figure 14 (a), the double-log functional form is a curved line instead of a straight line in figure 13.

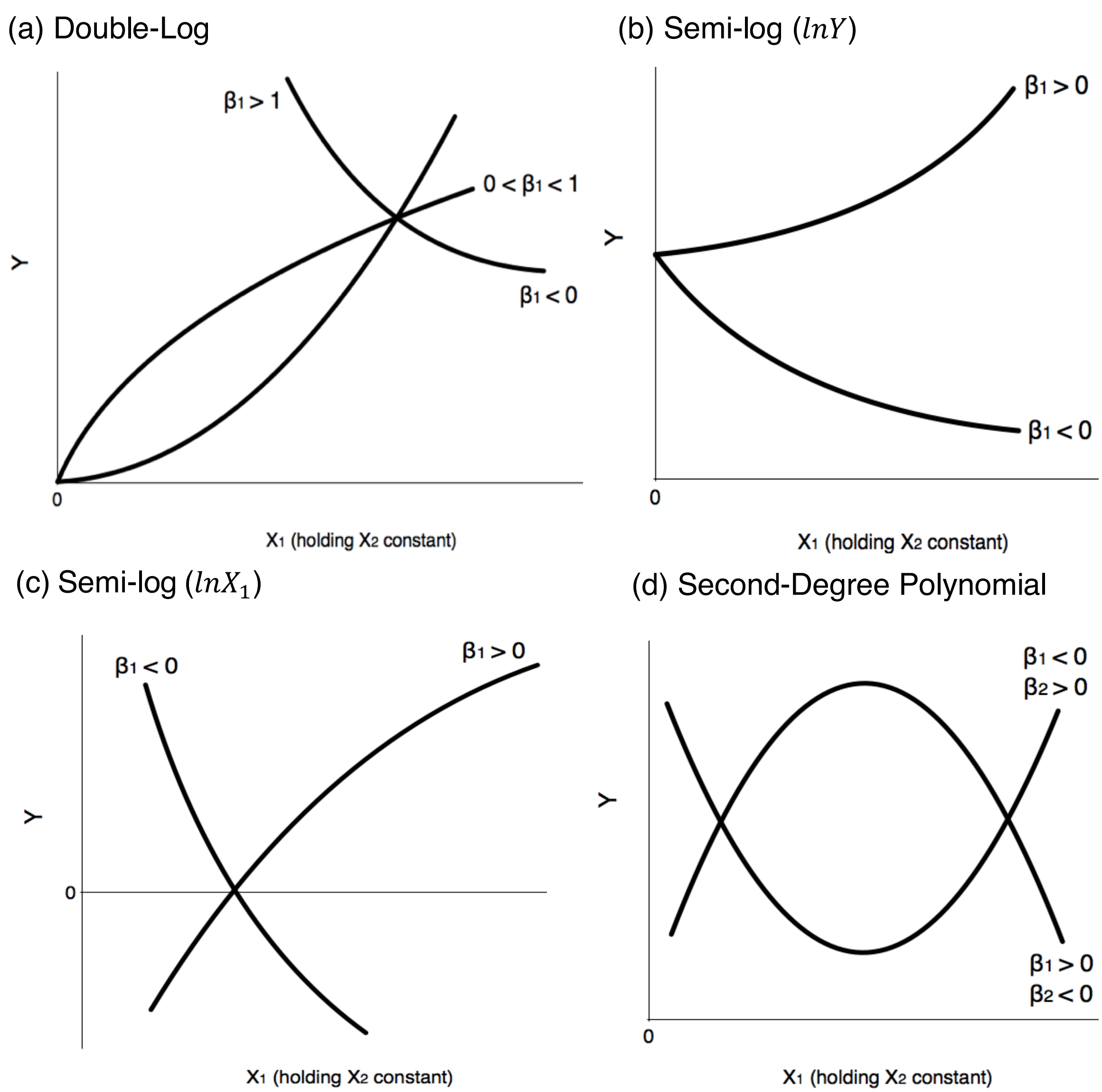


Figure 14. The Graphical Shape of Various Functional Forms

Another functional form similar to the double-log is the semi-log, which has some variables expressed in natural log form (216). Like the double-log, the shape of the semi-log varies according to the magnitude of β_1. When only dependent variable Y is in natural log form ($lnWTP$), as identified in equation 9, the shape of a semi-log form is the one in figure 14 (b).

$$\underset{\text{(natural log)}}{lnWTP} = \beta_0 + \beta_1 TECH + \beta_2 JOB + \epsilon \tag{9}$$

When independent variable $TECH$ is in natural log form, as in equation 10, the shape of the function appears to be the one in figure 14 (c).

$$\underset{\text{(natural log)}}{WTP = \beta_0 + \beta_1 lnTECH + \beta_2 JOB + \epsilon} \tag{10}$$

The remaining type of functional form is the polynomial functional form where independent variables are raised to a power other than one (218). A common type of polynomial is the second-degree polynomial or the quadratic form where an independent variable is raised to the power of two. This is exhibited by independent variable X_1^2 in equation 11.

$$\underset{\text{(power of 2)}}{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_1^2 + \beta_3 X_2 + \epsilon} \tag{11}$$

Again, I did not need to understand the details of the form, but only needed to know what the form looks like. As shown in figure 14 (d), the form could either be hill-shaped or u-shaped, depending on the magnitude of the regression coefficients.

Classical Assumption III: Endogeneity

An extension of part two of Classical Assumption I is Classical Assumption III, which states that all explanatory variables must not be correlated with the error term, also known as exogeneity (97). The opposite of exogeneity is endogeneity, when the explanatory variables and error term are correlated. If there is endogeneity, the results and analysis of the regression equation skew people's understanding of the relationship between consumer's willingness to pay (WTP) and the technique of dancers ($TECH$). The magnitude of the regression coefficients would be affected, leading to inaccurate interpretation of the estimated equation. To understand how this could translate into dance, I use the same multivariate regression model as before, displayed again in equation 12.

$$\underset{\text{(dance itself)}}{WTP} = \underset{\text{(dancer 1)}}{\beta_0} + \underset{\text{(dancer 2)}}{\beta_1 TECH} + \underset{\text{(dancer 3)}}{\epsilon} \tag{12}$$

In choreographic terms, exogeneity would mean that the movements of dancer 2 (representing explanatory variable $TECH$) and the movements of dancer 3 (representing stochastic error term ϵ) would not be the same. On the other hand, endogeneity in choreography could mean that dancers 2 and 3 perform similar, but not identical movements. The similarity of the dancers' movements would depend on the severity of endogeneity.

A major factor causing endogeneity is the presence of omitted variables, which are important explanatory variables not included in the regression equation that help explain the dependent variable. Explanatory variable JOB, the hours worked by audience members, is an example of an omitted variable. This is because JOB is an important variable affecting consumer's willingness to pay (WTP) but is not included in equation 12. The presence of omitted variables can either cause an upward or downward bias of the β coefficient estimates. This bias is labeled as the omitted variable bias.

To explain how omitted variable bias could be shown through dance, I must reiterate that β coefficients can determine the extent to which elements of dance are performed. As previously stated, speed is the element of dance corresponding to independent variable $TECH$ that is represented by dancer 2. This means that β_1 determines the speed of dancer 2's movements while keeping all other elements of dance at the default. A positive β_1 means that dancer 2 would perform fast movements so that the greater the β_1, the faster the movements. A negative β_1 means that dancer 2 would perform slow movements so that the smaller the β_1, the slower the movements. A β_1 value of zero means that dancer 2 would perform movements at the default, at a normal pace. Since omitted variable bias causes bias in the β coefficient estimates, an upward bias results in a greater value of β, and a downward bias results in a smaller value of β. In terms of dance, omitted variable bias exaggerates the value of β_1 and thus, would exaggerate the speed of dancer 2. For example, if the actual β_1 without omitted variable bias is positive, dancer 2 would perform relatively fast movements. If there is omitted variable bias causing an upward bias in β_1, dancer 2 would perform slower movements that are still faster than a normal walking pace. Likewise, omitted variable bias causing a downward bias in β_1 would cause dancer 2 to perform even faster movements.

My ability to choreograph a dance capturing all relevant explanatory variables was limited because I had a limited number of dancers. Since my original regression equation consisted of many independent variables, I had to omit enough variables to allow my available number of dancers to reflect the equation. By deciding which explanatory variables to exclude according to the number of dancers I had, I knew whether a regression equation had omitted variable bias and hence, whether endogeneity existed. The true and unmanipulated regression equation of my choreography is the one in equation 13, which requires 17 dancers to represent each term of the model.

$$WTP = \beta_0 + \beta_1 RELAT + \beta_2 JOB + \beta_3 TECH + \beta_4 AGE + \beta_5 HIGHS + \beta_6 INCOME + \beta_7 GENDER + \beta_8 COLL + \beta_9 ARTSed + \beta_{10} DANCEed + \beta_{11} ATTEND + \beta_{12} ATTENDmd + \beta_{13} MUSIC + \beta_{14} LIGHTS + \beta_{15} COSTUME + \beta_{16} SPACE + \epsilon \tag{13}$$

Since I only had five dancers, I removed 12 terms. I only took away independent variables because constant term β_0 and stochastic error term ϵ are essential in a regression equation. The removed independent variables become omitted variables. The remaining explanatory variables were $RELAT$ (whether the audience member is in a relationship), JOB (hours of work per week), $TECH$, and AGE (age of the audience member). Such alterations turn the regression model into the one in equation 14.

$$\underset{\text{(dance itself)}}{WTP} = \underset{\text{(dancer 1)}}{\beta_0} + \underset{\text{(dancer 2)}}{\beta_1^* RELAT} + \underset{\text{(dancer 3)}}{\beta_2^* JOB} + \underset{\text{(dancer 4)}}{\beta_3^* TECH} + \underset{\text{(dancer 5)}}{\beta_4^* AGE} + \underset{\text{(dancer 1)}}{\epsilon^*} \tag{14}$$

The effect of the omitted variables on WTP is now captured in the new stochastic error term, ϵ^*. This implies that there is endogeneity because there is a correlation between the four explanatory variables and stochastic error term ϵ^*. The presence of omitted variables due to the removal of important explanatory variables causes a bias to the beta coefficient estimates. Not only does omitted variable bias change the stochastic error term, but it also changes beta coefficient estimates. For example, omitted variable bias changes β_1, the beta coefficient estimate corresponding to variable $TECH$, into β_1^*.

Classical Assumption IV: Serial Correlation

Unlike Classical Assumption III, much of the translation of the next assumption to dance was not applicable in the final dance performance but was included in the guideline to account for a common type of regression model, called the time-series model. I decided to study Classical Assumption IV to improve the applicability of the guideline to suit dances based on time-series models. This model examines the impact of independent variables on the dependent variable observed not in one period of time, but throughout multiple time periods.

The regression equation I utilized in my choreography was not a time-series model but was a cross-sectional model. This is because the relationship between WTP and $TECH$ is observed in one time period and not over time. An example of a time-series model is one that examines the relationship between the number of dance practices I receive weekly ($PRACTICE$) and my appreciation of dance (APP) over time. As modelled in equation 13, $PRACTICE$ is independent variable X and APP is dependent variable Y, with one dancer representing each term on the right-hand side of the equation to produce an overall dance.

$$\underset{\text{(dance itself)}}{APP_t} = \underset{\text{(dancer 1)}}{\beta_0} + \underset{\text{(dancer 2)}}{\beta_1 PRACTICE_t} + \underset{\text{(dancer 1)}}{\epsilon_t} \tag{13}$$

The unit of time, such as days, months, and years, is represented by t, where the maximum number of observed periods is T. Any time period is represented by t, so that the first time period is $t = 1$ and the last time period is $t = T$. The distinction of the time periods can separate the dance into different sections, whereby the entire dance is divided into however many time periods exist in the regression equation. An example of how different time periods in a regression equation could be reflected in dance is visualized in figure 15. The regression equation in (a) has t, the unit of time, in months with a maximum of three months so that $T = 3$. A dance reflecting this equation would be divided into three parts. In (b), the dance is divided into three sections, where each one-minute-long section reflects each of the three months.

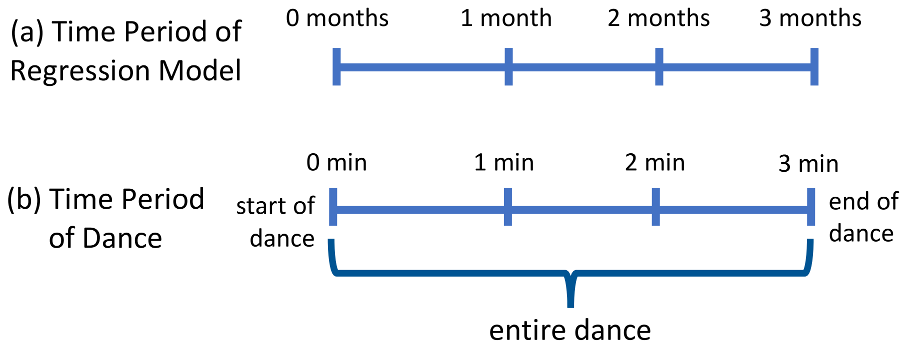


Figure 15. Time Period of Regression Model vs. Time Period of Dance

Classical Assumption IV states that there must not be a presence of serial correlation (97). Serial correlation deals with the relationship between observations of the stochastic error term ϵ in different time periods, as displayed in figure 16. Stochastic error terms in different

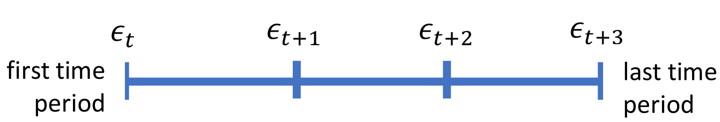


Figure 16. Stochastic Error Terms in Different Time Periods

time periods must not be positively or negatively correlated with each other; the stochastic error term in period t, ϵ_t, cannot be correlated with the stochastic error term in the next period, ϵ_{t+1} (305). To ensure that Classical Assumption IV is not violated, ϵ_t must not affect ϵ_{t+1}. This implies that serial correlation would affect dancer 1 who is representing stochastic error term ϵ. If a positive stochastic error term in one period affects the chance of the stochastic error term in the next period of having a positive value, there is positive serial correlation. Similarly, if a negative stochastic error term in one period affects the chance of a negative value in the next period, there is negative serial correlation. In dance, the presence of serial correlation could be portrayed when the movements of dancer 1 in one time period affect their movements in subsequent time periods.

Tests that use an already estimated regression equation are called post-regression estimations. The Durbin-Watson d test is one method to detect serial correlation (318). The details of how a d test functions were unnecessary for the purpose of my work; however, it was important to know what the test results signified and thus, could be demonstrated in dance. If the value of the test is greater than 1.66, there is no serial correlation. This would mean that the movements of dancer 1 in one time period would not affect their movements as the dance progresses. A value smaller than 1.12 implies the presence of serial correlation, so the movements of dancer 1 in one time period would affect their movements later in the dance. A value anywhere between 1.12 and 1.66 suggests an inconclusive result, meaning there is uncertainty in whether there is serial correlation in the regression equation. In this case, the movements dancer 1 in one time period.

Classical Assumption VI: Collinearity

The next assumption I explored refers back to the regression model in equation 14 where the consumer's willingness to pay (WTP) is the dependent variable and where the technique of dancers ($TECH$) and the audiences' hours of work (JOB) are the independent variables.

correlation causes
collinearity

$$\underset{\text{(dance itself)}}{WTP} = \underset{\text{(dancer 1)}}{\beta_0} + \underset{\text{(dancer 2)}}{\beta_1 TECH} + \underset{\text{(dancer 3)}}{\beta_2 JOB} + \underset{\text{(dancer 1)}}{\epsilon} \tag{14}$$

There must not be a violation of Classical Assumption VI for OLS to best estimate of this regression model. The explanatory variables must not have perfect collinearity; they cannot be a perfect linear function of another (99). In other words, if explanatory variable $TECH$ is a perfect linear function of explanatory variable JOB, then $TECH$ can be completely explained by JOB because they have everything in common. If the movements of dancer 2 represent variable $TECH$, and if the movements of dancer 3 represent variable JOB, perfect collinearity suggests that their movements are exactly the same. Imperfect collinearity would exist when an explanatory variable strongly but would not perfectly explains the variation of another explanatory variable, suggesting that the movements of dancers 2 and 3 are similar but would not be exactly the same. When more than two explanatory variables are involved, it is called multicollinearity, suggesting that more than two dancers are representing explanatory variables.

Like the test for serial correlation, Variance Inflation Factor (VIF) is a post-regression estimation method that determine the severity of multicollinearity in an estimated regression equation (259). As with the d test, I did not investigate the procedure of finding values of VIF because I did not physicalize the process of finding multicollinearity. Rather, I embodied the presence and extent of collinearity into my choreography. VIF is achieved by examining how much an explanatory variable can be explained by all other explanatory variables. Therefore, a VIF value can be calculated for every coefficient estimate that corresponds to an explanatory variable. An explanatory variable with a VIF value of one indicates that it is not correlated with any other explanatory variables. Economists typically draw the line between high and low multicollinearity at five (260). An explanatory variable with a low VIF value, one that is between one and five, suggests a low degree of multicollinearity. In dance, this could be observed through the lack of or minimal physical contact between the dancer representing that explanatory variable and the other dancers representing other explanatory variables. In contrast, an explanatory variable with a VIF value greater than five suggests severe multicollinearity. In dance, the dancer representing that explanatory variable would experience a lot of physical contact with other dancers representing other explanatory variables.

Conclusion

To this point, I have covered a lot of material on econometrics. From the basic concepts of the dependent variable Y and the independent variable X, all the way to the various Classical Assumptions, my understanding of these concepts provided me the foundation to choreograph a dance based on regression equations and to create the guideline. After exploring various tools of choreography and learning more about how regression equations operate, I had more skills and tools to answer the question, "How can one make use of an econometric tool, specifically the regression model, as a source for choreography and subsequently, a dance performance?"

In this chapter, I studied various econometric ideas that allowed me to choreograph a dance based on a specific regression equation. Since the purpose of the guideline was to broaden the applicability of my choreography so that others could transform other regression equations into dance, I needed a more extensive understanding of regression equations. Hence, I also explored some econometric concepts outside of the ones that were required to form the final dance performance based on one specific regression equation. The guideline incorporated a total of four out of the seven Classical Assumptions of regression equations, including Classical Assumption I, III, IV, and VI.

Chapter 4. Application of Research to Choreography

The final dance performance and the creation of the guideline were made possible by integrating my research on dance and econometrics. In the previous chapter, I explained the mechanics of fundamental econometric concepts as well as how those concepts can be physicalized in dance. In the current chapter, I first discuss how I used a specific regression equation as a choreographic tool for the final dance performance in the Spring Dance Concert. Next, I introduce a guideline that allows for the general physicalization of regression equations and discuss its limitations.

The Final Dance Performance

The final dance piece (Appendix A) is separated into three sections, with each section aiming to demonstrate a different econometric concept. The goal of the first section is to introduce the different independent variables of the regression equation. The goal of the second section is to explore the concept of multicollinearity, a part of Classical Assumption VI. The goal of the third section is to explore the concept of endogeneity, a part of Classical Assumption III. Although entire sections are not devoted to other aspects of the regression equation, they are considered through other aspects of the dance. For example, although the shape of the equation is not considered in an entire section, it is embodied in the shape of the dancers' movements as well as the formations they form.

The complete and unmanipulated theoretical regression equation I used as a choreographic score in my choreography is equation 15, which was taken from my other I.S. for the Department of Economics.

$$WTP = \beta_0 + \beta_1 RELAT + \beta_2 JOB + \beta_3 TECH + \beta_4 AGE + \beta_5 HIGHS + \beta_6 INCOME + \beta_7 GENDER + \beta_8 COLL + \beta_9 ARTSed + \beta_{10} DANCEed + \beta_{11} ATTEND + \beta_{12} ATTENDmd + \beta_{13} MUSIC + \beta_{14} LIGHTS + \beta_{15} COSTUME + \beta_{16} SPACE + \epsilon$$

(15)

Assuming that no key explanatory variables are missing, this is the true regression equation with exogeneity, or without an endogeneity problem. However, I shortened equation 15 into equation 16 by removing 12 explanatory variables because I did not have enough dancers to represent all the components of the initial equation. Compared to equation 15, equation 16 has an endogeneity problem. Since section one of the dance does not consider endogeneity, it only uses equation 16, and since section three of the dance explores endogeneity, it uses both equations 15 and 16 to contrast the presence and absence of endogeneity.

$$\begin{array}{ccccccccccccc} WTP & = & \beta_0 & + & \beta_1 RELAT & + & \beta_2 JOB & + & \beta_3 TECH & + & \beta_4 AGE & + & \epsilon \\ & & & & \text{(first)} & & \text{(second)} & & \text{(third)} & & \text{(fourth)} & & \\ \text{(dance itself)} & & \text{(dancer 1)} & & \text{(dancer 2)} & & \text{(dancer 3)} & & \text{(dancer 4)} & & \text{(dancer 5)} & & \text{(dancer 1)} \end{array} \quad (16)$$

Equation 16 has one constant term and one stochastic error term, which are β_0 and ϵ, respectively. One dancer, dancer 1, represents these two components. Equation 16 also has four independent variables, including variables $RELAT$, JOB, $TECH$, and AGE. One dancer is required to represent each independent variable. Thus, to physicalize the entire equation in a dance, a total of five dancers is required.

Section One: Elements of Dance

The first section of the final dance performance introduces the four independent variables in equation 16. The numerical relationships of these variables provide motivation for the dancers' movements, which align with Humphrey's theory on the motivation of movement. Since the beta coefficients determined the type of movement my dancers performed, they provided the motivation for my dancers to execute movements within parameters. Also following Humphrey's philosophy on dancers' facial expressions, I found it appropriate for my dancers to maintain a neutral facial expression. I believe this choice was appropriate as my dancers were trying to represent abstract and intangible concepts of econometrics rather than depict or elicit human emotions.

From Doris Humphrey's *The Art of Making Dances*, I identified four elements of dance to pair with each dancer representing a different independent variable, as labeled in parentheses in the first two rows below equation 16. The first two columns of table 4 summarize which explanatory variable is paired with which element of dance. The first element of dance, tempo, is one of the components from the raw element of rhythm, which is paired with variable $RELAT$. The second element of dance, the direction of the dancer, is from the raw element of dynamics and is paired with variable JOB. The dancer either faces forward, sideways, backwards, or any direction in between. The third element of dance, the level of the dancer, is paired with variable $TECH$ and ranges from high to low. Lastly, the dancer's kinesphere is paired with variable AGE, which is large, small, or anywhere in between.

Table 4

Relationship Between Elements of Regression Equations and of Dance

Explanatory variable	**Element of Dance**	**Regression Coefficient**	$\boldsymbol{\beta_k < 0}$ **(negative)**	$\boldsymbol{\beta_k = 0}$	$\boldsymbol{\beta_k > 0}$ **(positive)**
$RELAT$	Tempo	β_1	slow	*moderate*	fast
JOB	Direction	β_2	left	*forward*	right
$TECH$	Level	β_3	low	*middle*	high
AGE	Kinesphere	β_4	small	*medium*	big

The remaining four columns of table 4 outline both the type of movement the dancers would perform and the way in which they would perform the movements. The movement is determined by the sign of the regression coefficient, which is positive, negative, or zero. The elements of dance performed at the default are italicized in the fifth column of the table. To clarify what these coefficients entail, I will provide an example of what each dancer representing each variable would perform according to their corresponding regression coefficient. Take $RELAT$, the variable that is paired with the element of tempo, as the first example. If its corresponding regression coefficient, β_1, is a negative value, dancer 2 representing variable $RELAT$ would perform slow movements; if β_1 is a positive value, dancer 2 would perform fast movements. If $\beta_1 = 0$, dancer 2 would perform movements at a moderate tempo or the pace of normal walking. This means that a moderate tempo is the default for the element of dance, tempo. Likewise, the dancer representing variable JOB, dancer 3, would alter the direction of their phrases according to their corresponding regression coefficient. Dancer 3 would dance to the left of the forward-facing direction if β_2 is negative, and they would dance to the right if β_2 is positive. If $\beta_2 = 0$, dancer 3 would face the front, meaning that a frontward-facing direction is the default. Representing variable $TECH$, dancer 4 would perform movements at a high level if β_3 is negative or at a low level if β_3 is positive; if $\beta_3 = 0$, dancer 4 would perform movements at a medium level, one that is neither high nor low, which is the default for levels. Lastly, dancer 5 who is representing variable AGE would perform movements either within a big kinesphere if β_4 is positive or within a small kinesphere if β_4 is negative. Otherwise, their kinesphere would be medium-sized if $\beta_4 = 0$, which is considered the default for the size of kinesphere.

In equations 15 and 16, which are previously presented as theoretical regression equations, the actual sign and size of the regression coefficients are unknown. Once these equations are estimated, the sign and size of the regression coefficients become realized, as in estimated regression equations 17 and 18, respectively.

$$
\begin{array}{ccccccccccccc}
\widehat{WTP} & = & 73 & + & 9\,RELAT & - & 0.4\,JOB & - & 2\,TECH & - & 0.9\,AGE & & (17) \\
\widehat{WTP} & = & -58 & - & 4.7\,RELAT & - & 0.5\,JOB & + & 0.3\,TECH & + & 0.1\,AGE & + \cdots & (18) \\
\text{(dance itself)} & & \text{(dancer 1)} & & \text{(dancer 2)} & & \text{(dancer 3)} & & \text{(dancer 4)} & & \text{(dancer 5)} & &
\end{array}
$$

Where the first section of the dance only uses equation 17, the third section of the dance uses both equations 17 and 18. To interpret equation 17 in dance, take regression coefficient β_1, the regression coefficient corresponding to variable $RELAT$, as an example. The regression coefficient of variable $RELAT$ is 9. According to table 4, dancer 2 performs movements at a fast pace since the value of the regression coefficient is positive ($\beta_1 > 0$). As pointed out in Chapter Three, the impact of other variables on dependent variable WTP is held constant when interpreting a regression coefficient. Thus, dancer 2 keeps other elements of dance constant so that those elements of dance are the default.

Table 5 provides more guidance for the performance of each dancer. The second row is the guide for dancer 2. The second column under "Tempo" indicates that dancer 2's movements are fast because β_1 is positive; the third column under "Direction" indicates that they are forward-facing (default); the fourth column under "Levels" tells them to perform

Table 5

Elements of Dance for Each Dancer

		1	2	3	4
	Element of dance	**Tempo**	**Direction**	**Level**	**Kinesphere**
1	dancer 1 (constant and error terms)	moderate (default)	forward-facing (default)	middle (default)	medium-sized (default)
2	dancer 2 ($RELAT$)	($\beta_1 > 0$) fast ($\beta_1 < 0$) slow	forward-facing	middle	medium-sized
3	dancer 3 (JOB)	moderate	($\beta_2 > 0$) right ($\beta_2 < 0$) left	middle	medium-sized
4	dancer 4 ($TECH$)	moderate	forward-facing	($\beta_3 > 0$) high ($\beta_3 < 0$) low	medium-sized
5	dancer 5 (AGE)	moderate	forward-facing	middle	($\beta_4 > 0$) large ($\beta_4 < 0$) small

movements at a middle level (default); the last column under "Kinesphere" states that their kinesphere is medium-sized (default).

To clearly introduce each independent variable in the final dance, the dance starts with all the dancers doing the same movement, establishing the fact that they are all the same, or undifferentiated, at the beginning. While the dancers representing independent variables are introduced, dancer 1 (representing both the constant term and the stochastic error term) is consistently performing movements at the default for each element of dance; dancer 1 is always moving at a moderate tempo, facing the front, at mid-level, and using a medium-sized kinesphere. Seeing that independent variables are introduced one after another in the order presented in equation 16, dancer 2 is introduced first. The introduction of dancer 2 is achieved by only differentiating their tempo. Since the regression coefficient of dancer 2 is positive 9, dancer 2 performs faster movement relative to everyone else while keeping other elements of dance the same as everyone else. While dancer 2 speeds up their movement, they still keep their direction, level, and kinesphere the same as everyone else. It is important to note that when dancer 2 changes their tempo, their tempo is considered fast because it is relatively faster than the tempo of the other dancers.

The next dancer who is introduced as a different variable is dancer 3. With a regression coefficient of negative 0.4, dancer 3 performs to the left of the other dancers while keeping other elements of dance at the default. Similar to the previous case, the direction of dancer 3 is relative to the direction of the other dancers. For example, the direction of the other dancers, no matter which direction, is considered forward-facing. If the other dancers are facing stage right, then dancer 3 performs to the left of stage right. Since dancer 4's regression coefficient is negative 2, they perform everything at a low level while keeping other elements of dance at the default. Even when all the dancers lower their levels, in order to maintain at a low level, dancer 4 changes levels that is relatively lower than other dancers. Dancer 5 is the last independent variable who is introduced. With a corresponding regression coefficient of negative 0.9, dancer 5 performs movements within a small kinesphere while keeping other elements of dance at the default. To exaggerate dancer 5's use of a small kinesphere, the other dancers make use of a large kinesphere.

Section Two: Collinearity

A distinct change in the music accompanies the transition of the dance from section one to section two. The music not only slows down, but it also softens. This change in the music helps to hint at the introduction of a new econometric concept, collinearity. Using the post-regression estimation method of VIF, the results show that both estimated regression equation of equations 17 and 18 have no perfect collinearity. This is because the VIF values for all the explanatory variables are almost precisely one. The absence of collinearity means that no explanatory variable is correlated with any other explanatory variable. In terms of dance, the dancers would make no physical contact with one another.

Despite the lack of collinearity, I still wanted to capture this concept in the final dance. Therefore, I randomly assigned made-up VIF values to each dancer representing an independent variable, as displayed in table 6. Dancers 3 and 5 representing explanatory

Table 6

Assigned VIF Values of Dancers Representing Independent Variables

Explanatory variable	Dancer	VIF Value
$RELAT$	2	4
JOB	3	12
$TECH$	4	2
AGE	5	12

variables JOB and AGE, respectively, both have VIF values of 12. Since the high VIF values suggest a high degree of collinearity, not only do the two dancers have the most physical contact out of all the dancers, but they also maintain contact for the longest amount of time. Although they face different directions, the movements they perform are extremely similar, and they share the most body weight with each other. Dancer 2 who is representing the first explanatory variable, $RELAT$, has a VIF value of 4, indicating a moderate level of collinearity. Thus, they have some physical contact with other dancers. Lastly, variable $TECH$ that is represented by dancer 4 is associated with a VIF value of 2. Given this low value, dancer 4 is in contact with the other dancers for the least amount of time to signify the presence of minimal collinearity. Meanwhile, dancer 1 who is representing the constant and error terms makes no contact with any other dancer at all. To further isolate dancer 1 as someone representing a different component of the regression equation, they are placed upstage in a corner away from the other four dancers who are representing independent variables and are situated in center stage.

Section Three: Endogeneity

As the dance moves into its third section, there is another shift in the music. Since section three of the piece makes use of the regression equation that section one is based on, the music in section three has many similarities with the music in section one. As previously noted, the estimated regression equation ultimately used in my final choreography (as exhibited again in equation 19) removed 12 explanatory variables from the original equation (as exhibited again in equation 20). For an easier comparison between the two equations, I purposely exclude the 12 explanatory variables in equation 20.

$$\widehat{WTP} = 73 + 9\,RELAT - 0.4\,JOB - 2\,TECH - 0.9\,AGE \quad (19)$$
$$\widehat{WTP} = -58 - 4.7\,RELAT - 0.5\,JOB + 0.3\,TECH + 0.1\,AGE + \cdots \quad (20)$$

(dance itself) (dancer 1) (dancer 2) (dancer 3) (dancer 4) (dancer 5)

The exclusion of these important explanatory variables, or the presence of omitted variables, can cause omitted variable bias in altered regression equation 20. This bias can give rise to an endogeneity problem, whereby the included explanatory variables are correlated with the stochastic error term. Unlike equation 19, equation 20 has no omitted variable bias.

Clearly, there is a difference between the estimated coefficients in equations 19 and 20. To capture omitted variable bias in the dance, I first reestablished the dancers as variables from equation 19, as in the first section of the dance. I did so by having the dancers perform movements that are almost the same as those in section one of the dance. The point of bringing back previous movements is to remind the audience of which variable each dancer represented, and thus which element of dance each dancer was altering. After a moment of silence in the music, the dancers are suddenly introduced the dancers as variables from equation 20. For example, dancer 2 representing the variable $RELAT$ first performs fast movement, as dictated by the positive sign of the regression coefficient in equation 19. However, to capture omitted variable bias and endogeneity, dancer 2 performs slow movement, as dictated by the negative sign of the regression coefficient in equation 20. This stark contrast in the dancers' movements highlights them as variables in an equation with endogeneity (equation 19) versus as variables in an equation without endogeneity (equation 20).

Serial Correlation

The issue of serial correlation is not applicable to the cross-sectional model used in the final dance, as opposed to time-series models. The lack of serial correlation can be attributed to the lack of stochastic error terms in different time periods. Hence, the dancer representing the stochastic error term, dancer 1, does not have to worry about their movement over time.

Other Econometric Concepts

As explained, each section of the dance portrays a different econometric concept. Apart from what has been mentioned, there are additional ways in which the concept of the piece is embodied throughout the dance. The motif of diagonals was another way in which linear regressions are physically manifested in the final dance. There are four main ways in which diagonals appear and are achieved. The first way is through the shape of individual dancers' bodies. An example is the recurring movement of the piece, a sideway-leaning pivot with arms stretched at a diagonal. The second way is through the shape that multiple dancers' bodies make together. For example, towards the end of section two of the piece, two dancers standing upright with their arms stretched out each lean over on a different dancer to form a diagonal line. The third way is through the formations in the dance. The dancers are often placed to create a diagonal line either within certain boundaries or across the stage. The last way in which diagonals are present in the piece is through the spatial patterns that the dancers form.

Aside from the dance itself, other visual aspects work to support the concept of the dance, which is to physicalize econometrics. As stated before, the music, an edited instrumental version of Billie Eilish's "COPYCAT," changes when the dance shifts between sections of the dance. However, it particularly enhances the way I introduce each dancer as a different variable in the first section of the piece. The music begins with a rhythm produced by one instrument. Once the first dancer is introduced as a variable, there is different sound added on top of the previous rhythm. The introduction of the remaining three dancers is accompanied by a change in the music, either through the addition of a sound or a change in the beat or rhythm.

The lighting designer, Mike Schafer, used lighting techniques to help the audience comprehend when and how a dancer is introduced as a variable. An extra layer of light is added whenever a dancer was introduced as a variable. Lights forming a diagonal across stage were also consistently used. Furthermore, there was a light projected through a gobo on the upper part of the cyclorama, a large curtain positioned upstage of the theater. As a result, the projection mimicked data points scattered along a linear regression equation. Fortunately, this effect was neither overwhelming nor distracting the audience from watching the dance. Instead, it was a subtle but strong complement to the piece.

The costumes were also strategically designed to support the idea of regression equations. Figure 17, designed and produced by Rebecca Callan, is an example of the dancers' costumes. The fabric of the costume is patterned as the grid of a graph. Hence, the pattern is evidently geometric and linear. Aside from the costume of the dancer representing both the constant and stochastic error terms, the basic structure of the other dancers' costumes is manipulated into a distinct design as they each represent a different variable. Each of the four dancers representing an independent variable has diagonal black bands on top of mesh that is placed across different parts of their upper bodies. For example, in figure 17, the black bands make a diagonal across the chest area.

Figure 17. Costume Design

Lastly, even the performance space aligned well with the concept of the piece. Although performed in a standard proscenium stage, a black drape was hung from the ceiling at an angle to change the performance space. This angled drape created a diagonal, reflecting a linear regression equation. Not only did the drape provide a literal and visual representation of a linear regression equation, but it also effectively transformed the performance space into one that is abstract and mathematical.

The three sections of the final dance performance each demonstrate a different econometric concept. Apart from these concepts, other aspects of the dance such as the lighting and costumes reveal or hint at the idea of regression equations. However, this dance is only one way in which a specific regression equation can be physicalized. A different regression equation and naturally, a different choreographer, would produce a different dance.

The Guideline

Using the final dance performance, I devised a general guideline (Appendix B) on how to physicalize regression equations. Apart from the econometric concept of serial correlation, I have explained how other econometric concepts were applied to the final dance piece. This guideline can be used by others who are interested in physicalizing a different regression equation than mine. The guideline does not dictate a choreographic work, but rather it provides suggestions on how to visually manifest econometric concepts in a dance.

Limitations

The final dance piece and guideline are embodiments of research on the overlap between dance and econometrics. My works aimed to physicalize the numerical relationships in regression equations but not the subjects of the regression equations. However, these are incomplete explorations as they are only one of many physical and visual representations of econometrics, meaning my work only provides one way of physicalizing econometrics. My work would have varied if my background research on the topic had been different. My background research affected the final dance piece and guideline in two ways. First, if I had used a different resource on dance choreography instead of Doris Humphrey's *The Art of Making Dances*, I would probably have had a very different choreographic approach. This is especially the case since I based my dance off of the elements of dance that Humphrey identifies in her book. Second, the outcome of my work would have changed drastically if my econometric focus was something other than the linear regression model, such as the probit model. Since the numerical relationships of other econometric models differ to those of linear regression models, physicalizing other econometric models would also be different than physicalizing linear regression models. Hence, there are other possible ways of physicalizing econometrics, which prompts further research in this interdisciplinary field.

Conclusion

As previously stated, my final choreography was based on a specific regression model, which explores the relationship between the technique of dancers and the consumer's willingness to pay (WTP) to watch a modern dance performance. I was not interested in showing the technique of the dancers or depicting the consumer's WTP in the dance, but rather in representing the numerical relationships between the two. Based off the final choreography, I also formalized a guideline to physicalize other regression models.

Conclusion

As cited in *Dance Composition* by Jacqueline Smith-Autard, "Composing involves the molding together of compatible elements which, by their relationship and fusion, form an identifiable 'something'" (3). I have demonstrated the compatibility of econometric concepts and choreography. To answer the first part of the critical question, how can one make use of an econometric tool, specifically the regression model, as a source for choreography, I used a specific regression equation as a choreographic tool to visually manifest econometrics in dance. The result was demonstrated in the final dance performance in the Spring Dance Concert at The College of Wooster between April 11th and 13th of 2019. Once produced, the final dance was used to create a guideline that allows this approach to choreography to be generalized, which answers the second part of the critical question: how can this approach to choreography be generalized so that any regression model can be a choreographic tool?

The first step to this project was to study choreographies involving the use of mathematics because they help to connect dance and econometrics. On the one hand, mathematical relationships, particularly geometry, are present in movement and in choreography. On the other hand, econometrics is a field that is highly mathematical. Samuel Beckett's *Quad*, Alessandro Carboni's *ABQ*, and 16th century Renaissance dance choreographies provided me with a clear understanding of how mathematical concepts can be utilized in dance. Similarly, Merce Cunningham used probability, another mathematical concept, to explore the intersection between mathematics and dance.

The detailed study of Doris Humphrey's *The Art of Making Dances* provided the basis for my choreographic ideas and choreographic approach. In the final dance piece and guideline, I used fragments of Humphrey's ideas on the raw materials of dance. My research on econometrics, specifically the linear regression model and the Classical Assumptions, gave me the knowledge to integrate econometric relationships with dance. The three sections of the final dance piece each explore a different econometric concept. In addition, other visual elements, such as lighting and music, contributed to the goal of physicalizing econometrics. With the dance piece, I devised a guideline for future choreographers seeking to represent similar econometric concepts through dance using different linear regression models.

As I reflected on the entire choreographic process in hindsight, I realized something important for my future self as a choreographer. I believe that I often wrongly change my choreographic decisions too soon, which is largely owed to my impatience. Perhaps my choreographic ideas would have worked, but when my dancers failed to quickly create the effect that had I hoped for, I changed it to something new. I made it a habit to remind myself not to be easily discouraged.

My semester-long choreographic journey taught me to value the process as much as the product itself. Commitment and mental endurance is necessary when engaging in experimental and explorative works. The concept of the final dance piece, to physicalize econometrics, is not a straightforward task. The clarity of my dancers' relationships and the flow of the phrases, and hence, the concept of the piece, have come a long way since the beginning of the choreographic process. At the end of the day, although the audience member with no context of the final dance performance may be clueless, the dance is still an evocative piece of art that can be enjoyed by all, whether dancers, non-dancers, economists, or non-economists.

It is crucial to take note that by no means do I claim that my choreographic decisions in the final dance piece and guideline reflect all the intended econometric concepts. With endless possibilities in the movements of the human body come endless possibilities in choreography. Coupled with the extensive systems in econometrics, a field shown to be connected with dance, there are countless econometric-related dances yet to be discovered. This expansive space for academic research allows for the growth in scholarship bridging the gap between dance and economics. The increasing use of quantitative and mathematical structures in dance could potentially evolve into either a new style of dance or a new approach to choreographing dance.

A main takeaway from this project is that in contrast to econometrics, there is no right or wrong in dance. Econometrics and dance may appear to be mutually exclusive disciplines and difficult to reconcile. However, I have demonstrated through my work that they can be fused into one. The physicalization of econometrics may be an unconventional and ambitious endeavor, but I have proved it possible.

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Appendices

Appendix A: Video of Final Dance Performance

http://www.youtube.com/channel/UCZ1qfqnDF7zdH1gJg5GQwYg?view_as=subscriber

Appendix B: Guideline for Translating Econometric Concepts into Dance

Econometric Concept	Application to Dance
Dependent Variable $\boldsymbol{Y}$	Represented by the dance itself.
Independent Variable(s) $\boldsymbol{X}$	Each is represented by a dancer. If there are more independent variables than dancers, take away as many independent variables as needed when estimating the regression model. Every dancer is assigned one element of dance (e.g. repetition, speed, angle) to vary in their movements while keeping other elements of dance fixed. The dancers must be able to vary the element of dance according to a scale. For example, if the element of dance is speed, the dancer could perform at various speeds. The two ends of the scale (e.g. very fast and very slow) are assigned either a positive or negative sign. Note: If independent variables are removed, refer to Classical Assumption III.
Estimated Beta Coefficients $\boldsymbol{\beta_k}$, where $\boldsymbol{k} = \mathbf{1, 2, 3}, \ldots$	The sign (+/-) of an estimated beta coefficient (e.g. β_1) determines how the dancer representing the independent variable corresponding to that beta coefficient (X_1) would perform movements of the assigned element of dance relative to other dancers (e.g. if the estimated beta coefficient is positive and if a positive sign is assigned to very fast movements, the dancer would perform fast movements relative to other dancers).
Classical Assumption III: Endogeneity	Show the presence of endogeneity by contrasting the estimated regression equation containing all the original independent variables with the estimated regression equation that removed independent variables. This contrast is represented through different movements as the estimated coefficients from the two regression equations are different.
Constant Term $\boldsymbol{\beta_0}$	Represented by a dancer.

Stochastic Error Term ϵ		Represented by the same dancer as constant term β_0.
Classical Assumption I:	1. additive error term	Error term is represented by an individual dancer.
	2. correct functional form	This concept is reflected in the dance through Classical Assumption III.
	3. linearity in coefficients	The shape of the functional forms that are linear in the coefficients, including linear, double-log, semi-log, and polynomial functional forms, would be used. These shapes determine spatial patterns that dancers make, the formations of dancers, and the shapes that individual dancers or dancers together make in their movement.
Classical Assumption IV: Serial Correlation		In the presence of serial correlation, the movements of the dancer representing stochastic error term ϵ in one time period would affect their movements in the next time period. Otherwise, in the absence of serial correlation, the movements of the dancer would not affect other movements throughout the dance. Whether or not movements of one time period affect movements in the next time period is dependent on the presence of serial correlation, which is determined by the value of d. If d is greater than 1.66, there is no serial correlation. If d is smaller than 1.12, there is serial correlation. In the case of uncertainty when d is in between 1.12 and 1.66, the dancer would alternate between the presence and absence of serial correlation.
Classical Assumption VI: Multicollinearity		The dancer representing both the constant and stochastic error terms would have no contact with any of the other dancers. In the presence of perfect multicollinearity, the movements of dancer 1 who is representing independent variable X_1 would be in physical contact with dancer 2 who is representing independent variable X_2. Otherwise, in the absence of perfect multicollinearity, the two dancers would not have any physical contact. In the presence of imperfect multicollinearity, dancers 1 and 2 would experience some degree of physical contact. The level of contact between the movements of dancers is dependent on the degree of multicollinearity, which is determined by the VIF value. A VIF greater than 5 signifies severe multicollinearity, and a VIF smaller than 5 signifies a low degree of multicollinearity.

Appendix C: Journal of Choreographic and Production Processes

Saturday 19th January 4:00 pm – 5:30 pm, rehearsal (Elyse absent)

Prior to our first rehearsal, I felt as though there was a high chance that all my ideas in my writing may not work at all. I could think of so many potential challenges that my dancers and I would face when trying to piece my abstract ideas together. I hoped that combining econometrics and dance would definitely produce a work that I envisioned, as if combining one and one together to make two. Unlike the mechanics of numbers, mixing econometrics into dance cannot always create work that I envision in my head. One plus one may actually be three. Even worse, perhaps one and one cannot be added together.

I started the rehearsal by assigning a different variable and element of dance to each dancer. The elements of dance included tempo, high point in the phrase, symmetry vs. asymmetry, and smooth vs. sharp movements. We tested whether it was possible to have each dancer vary their assigned element of dance while keeping other elements of dance the same. As the choreographer who is not involved in the dancing but watching the dance, the scene appeared very disorganized and not 'choreographed.' It was extremely unclear that the dancers were provided a prompt. Following someone's suggestion, everyone focused on altering the same element of dance. This was more effective because everyone had the same goal. Between the dancers and I, the feedback given and the thoughts shared were applicable to everyone. This method also helped me figure out which ideas were better or worse.

This first rehearsal was relieving. As predicted, my dancers contributed a lot, especially since the production component of my I.S. is a rather explorative piece of choreography. When I posed a set of questions to my dancers, I found my reaction to their responses fascinating.

There were many instances where I would tell my dancers that their suggestion may not work because of a conflicting element in the structure of regression equations. For example, one of them said that to acknowledge the significance of the regression coefficient in the dance, those representing more significant variables could affect the movement of other dancers. I pointed out that it was a clever idea, but it would violate the concept of collinearity in linear regression models. It would be equivalent to saying that the "significant dancers" affect other variables when significance has to do with affecting the dance itself. Nonetheless, we found ways in which those suggestions could be utilized elsewhere.

Sunday 20th January 2:00 pm – 3:20 pm, rehearsal (Elyse absent)

It was during this rehearsal that I decided to change my approach in tackling my critical question that asks how one can use econometric regression equations not only as a source of choreography but also as a generalized approach to choreography applicable to any regression model. It all started when I felt that I was not making enough progress relative to the previous rehearsal and relative to the effort and thinking put into the rehearsal. I was disappointed when I found that many fun and theoretically appealing and stimulating choreographic ideas did not work with my concept, which is to reflect the rigid, black and white numerical relationships in econometrics. My dancers and I would come up with ideas, but we felt restricted by the need to precisely capture the structure and rules of the regression equation in the dance.

After experiencing several times of disappointment, I took a five-minute break to internally reflect on my current approach. I realized that I was overly fixated on physicalizing the exact structure and rules of the regression equation to a point where I started comprising my creativity. Henceforth, I made it clear to myself that my goal was to provide an econometric framework for dance, rather than eliminating or discouraging the aspects of artistry and individuality in dance. We also thought it would be wise to change some of the elements of dance. Symmetry vs. asymmetry as well as smooth vs. sharp movements were changed to high vs. low levels and the direction of the dancer, respectively. This was because the dancers found it extremely hard to portray the differences in those elements with clarity.

Before the next rehearsal, I plan to come up with set movement phrases for my dancers to work on so that there will be less improvisation and more practice on controlling different elements of dance. This would aim to physicalize, as accurately as possible, the impact of one independent variable on the dependent variable while controlling for all other variables.

Thursday 24th January 2:30 pm – 2:50 pm, meeting with costume designer

I had my first meeting with Rebecca Callan (Becky), the costume designer of the Spring Dance Concert. I did not have any ideas for her beforehand, but she gave me some things to think about, such as colors, patterns, or shapes that could be representative of my piece. Even at an early stage in the choreographic process, this meeting was very helpful. Now I have something to keep in the back of my mind.

Thursday 24th January 7:00 pm – 8:30 pm, rehearsal

Feeling overwhelmed by the conceptual part of my piece, I chose to focus on choreographing movement rather than figuring out the structural aspects of my piece. Even though I choreographed a phrase in advance, my movement often does not work on other bodies, or rather does not illicit a similar visual effect on other bodies. Unlike many of my experiences in choreography, my dancers were able to learn and perform the phrase without major changes. Furthermore, I picked out a piece of music to go along with the movement phrase. My dancers said they really like my choice of music, as well as the phrase. Their positive responses assured me that my work can head towards a promising direction.

In addition to working on setting movement, I asked my dancers to explore moving with one another while being in contact to various extents using different body parts. The purpose of the exercise was to begin the development of one of the sections of my piece that illustrates the concept of multicollinearity. While I observed the dancers, I noticed intriguing shapes. In particular, I enjoyed watching the ones where they shared weight because it reminded me of the Contact Improvisation class I took last summer.

Sunday 27th January 2:15 pm – 3:45 pm, rehearsal (Reyka absent)

Today's rehearsal could have went better. Not only did we miss a dancer, again, but we didn't start until ten minutes into the rehearsal since everyone took their time to get ready. As with the previous rehearsal, I choreographed movement in advance. Unlike last time, the choreography seemed awkward on the bodies of my dancers. I might consider adjusting the movements, but in the meantime, we will continue to work on the movements. I also felt that we spent too much time relearning phrases from last rehearsal. As someone with some experience in choreographing, I can attest that it is very frustrating when time is taken away from further developing the piece due to time spent working on material from the previous rehearsal. I tried being patient and understanding, but I don't think I tried hard enough. In an attempt to be assertive and honest, I asked my dancers to be ready to dance right when rehearsal starts, and I suggested them to work on the phrases outside of rehearsal.

Thursday 31st January 7:00 pm – 8:30 pm, rehearsal (Elyse absent)

It is already challenging to choreograph, but it is even harder to choreograph based on a regression model, to physicalize econometrics. Today, I experienced very strongly the struggles of not only a choreographer, but also of someone exploring a new area of knowledge. While I was helping my dancers perform choreographed movements in a specific way, I was faced with another task. I had to establish physical relationships among the dancers that respect the rules of regression equations. On top of that, I had to keep in mind that my five dancers naturally move very differently, meaning that my choreography must accommodate the five different bodies. These problems will be ongoing throughout the process. I think focusing on other aspects of my work will be more productive. For next rehearsal, I plan to work on the overall structure of the dance. Perhaps dividing the piece into sections will benefit my choreography.

Sunday 3rd February 2:15 pm – 3:45 pm, rehearsal

After working on existing choreography, we explored representing the graphical shapes of various types of regression equations. It was not an easy task, but since my dancers were cooperative and communicative, they managed the task well. It was helpful to simply watch as it allowed me to think and come up with suggestions that I otherwise would not have if I physically participated. After all, there are advantages to both carrying out an action yourself and watching someone else perform it. With some remaining time, we went back to trying out movements that involved physical contact. I find such movements especially hard to choreograph all by myself because it is puzzling to know how two or more bodies would interact without feeling a body. Thus, improvisation seems to be key to choreographing interdependent movements.

Thursday 7th February 11:00 am – 11:30 am, production meeting

The first production meeting involved talking about the needs and concepts of the different choreographers presenting in the concert. Since I have been a part of the production side of past concerts a number of times, what happened was consistent with my expectations. Quite a bit of the meeting was figuring out dates for tech rehearsal and deadlines. The meeting did leave me with a question. How does one light a piece about econometrics?

Thursday 7th February 7:00 pm – 8:30 pm, rehearsal (Ella present for 20 minutes)

The production meeting this morning may have left me with a question, but tonight's rehearsal left me in tears. I wish I could say that they were tears of joy. Despite what happened, I learned an important lesson. Unlike numbers, people are hard to predict. But like working with numbers, working with people demands patience.

Sunday 10th February 2:15 pm – 3:45 pm, rehearsal

In stark contrast to the previous rehearsal, today's practice was very productive and meaningful. We worked on physicalizing the concept of multicollinearity by doing partner work. By the end of the rehearsal, we developed some working movement phrases. Despite coming up with movement material, I still need to work on assembling the already-choreographed movements so that the section on multicollinearity is coherent with other parts of the dance piece. Our progress seems promising again.

Monday 11th February 4:00 pm – 5:10 pm, sharing

I shared the progress of my piece to some of the participants of the Spring Dance Concert for the first time. It was thrilling to hear positive feedback from someone involved in the concert who is also an Economics major (I am a double major in Theatre & Dance and Economics). I do not necessarily refer to positive feedback as people's comments about how much they enjoyed or appreciated the aesthetics of the piece. Here, I define positive feedback as comments that express one's understanding of what I am trying to do, mixing econometrics with dance. Even though I briefly talked about the goals of my piece, she said she could see how the relationships of the dancers' bodies and movements agree with concepts in regression equations. More specifically, she could tell that I was trying to "control explanatory variables in the regression equation" by controlling for the various elements of dance in movement.

The sharing got me in such a great mood because of the exchange of understanding between me and the other Economics major. As both Economics majors and dancers, she and I experienced a connection. To a varying extent, my dance piece induced the both of us to not only the artistic and creative part of our brains, but also the quantitative side of our brains to view dance. I see beauty in a dance that, in order to process grasp, calls the viewer to use knowledge from two opposing disciplines. It was during that moment of connection with the Economics major that reminded me of why I indulged into this complicated topic in the first place.

Someone pointed out that they did not see all the dancers differentiate to become a unique explanatory variable. They were in fact correct because I still have to figure out how to introduce the last dancer as their own unique variable. I have been struggling to come up with another element of dance that works with what I already have choreographed, is achievable for my dancers, and is clear to the audience.

Thursday 14th February 11:00 am – 11:40 am, production meeting

Thursday 14th February 7:00 pm – 8:30 pm, rehearsal

This rehearsal, we primarily worked on differentiating the last dancer representing the fourth variable in the regression equation. Beforehand, I came up with a number of movement qualities for them to work with. Some of these qualities were ones that I had previously planned for but did not seem to work. However, I decided it was worth revisiting them since so much has changed. With the intention of choosing the movement quality that was visually the clearest, we decided that the dancer representing the fourth variable will alter the use of their kinesphere. Although we figured out which element of dance to pair with the fourth variable, we did not have the time to choreograph a movement phrase. Considering the structure of the dance so far, I decided to extend the length of the music. It appears to me that we need more time to clearly present the last variable to the audience before going into the next section of the piece.

Sunday 17th February 2:15 pm – 3:45 pm, rehearsal

Even though everyone was very cooperative and willing to contribute, we still struggled to introduce the dancer representing the fourth variable. The goal for this dancer is to do the same basic phrase as everyone else while only altering the use of their kinesphere. It took some time for my dancers to learn and perform the phrase, let alone to work on the primary task we had at hand. As we practiced more, it became clearer that the dancer is changing the use of their kinesphere. However, the clarity did not seem to be sufficient. We tried other things, such as changing their position relative to the other dancers, which helped to some extent because it singled out the dancer and placed an emphasis on their movements relative to the movements of the others.

Monday 18th February 4:00 pm – 5:00 pm, sharing

Thursday 21st February 11:00 am – 11:50 am, production meeting

Thursday 21st February 7:00 pm – 8:30 pm, rehearsal (Karabella absent)

Despite missing a dancer, we successfully choreographed the majority of the second section of the piece, which aims to express multicollinearity, an econometric concept. Although this section uses the same piece of music as the previous section, the music is calmer as it slows down. I made the decision to start the second section when the music slows down because a new aural tone helps to introduce a new idea.

Using loose phrases that were previously developed, we worked to communicate different levels of multicollinearity through varying the use of skin-to-skin contact. This choreographic choice was strategically made because multicollinearity is about the correlations among the variables. Following this logic, I decided that the higher the correlation between two dancers, the more contact they would have with one another. Before working with any movement, we established the strength of the correlations among the variables they were representing. Accordingly, we portrayed these correlations by putting together partner and group movements. One obstacle was trying to maintain the same amount of contact based on their established relationships with one another.

Sunday 24th February 2:15 pm – 3:45 pm, rehearsal

Today we started working on the third and last section of the piece. Where the first section aims to reflect a modified regression equation that excludes many of the control variables, the third section aims to reflect parts of the original regression equation that include all the other control variables. The value of the regression coefficients corresponding to the dancers' assigned variables in the modified equation are different than those in the original equation. With this in mind, their movements are thus also different. In order to better evaluate the quality of this section, I need to work more on it.

Monday 25th February 4:00 pm – 5:00 pm, sharing

Thursday 7th March 11:00 am – 11:30 am, production meeting

Thursday 7th March 7:00 pm – 9:00 pm, rehearsal

With more feedback from other people, I not only found ways to further my work, but I also learned about the things that work and do not work. At the same time, I've been working with my lighting designer, Mike Schafer. I am so thankful that he has so many brilliant production ideas that align well with my concept. He was thinking of hanging a black drape from the ceiling at an angle to reflect a linear regression equation. Not only could this provide a literal visual representation of a linear regression equation, but it could also effectively change the shape of the performance space from a rectangular shape to an irregular shape, as if the audience is not in a theater anymore but in another dimension in an abstract world full of numerical concepts.

Even more than before, my dancers and I found it extremely challenging to develop a phrase that allows everyone to only alter their assigned quality of movement while "controlling" for other aspects of the dance. For example, we had to come up with a phrase that can both clearly and simultaneously portray contrasting use of levels, speed, and kinesphere among the dancers. Essentially, the goal is to have the audience identify the similarities and differences among the dancers who are each representing a different independent variable. Nonetheless, we made a lot of progress. However, Spring Break is approaching in less than a day…

Thursday 28th March 11:00 am – 11:20 am, production meeting

Thursday 28th March 7:00 pm – 8:30 pm, rehearsal

For me, choreographing a dance based on the concept of econometrics is a fairly ambitious task. As I am approaching the end of the choreographic process, I must say that it does not get easier. Perhaps the third section of the piece is the most difficult for both me and my dancers. Every time we think we have figured something out, we quickly realize that the movements are either conceptually incorrect or not completely reflective of the concept of the piece. Unfortunately, when the movements do align with the concept, they do not appear as visually appealing. We definitely need to continue to strive for a healthy balance between accuracy of conceptual ideas and esthetics of movements.

Sunday 31st March 2:15 pm – 3:45 pm, rehearsal

The choreography is almost complete! We were also able to work on spacing on the stage. I really appreciated the opportunity to view the piece farther away from the dancers. I could see the entirety of the piece and all the dancers together with more clarity as my eyes were not forced to only look at individual dancers. I decided that some of the parts that were choreographed during last rehearsal did not demonstrate the concept of the last section as clearly as I wanted. As the next resort, I made use of repetition, which made the movements not only more purposeful and less random, but also more familiar.

Monday 1st April 4:00 pm – 5:00 pm, sharing

Wednesday 3rd April 5:30 pm – 7:00 pm, rehearsal

The piece is completed!! The remaining time until the show can finally be used to clean up the dancers' movements, which I am very grateful for. Working on stage has been quite a different experience than working in the dance studio. Spacing is vastly different when you get to view the dance from the perspective of the audience. What may seem appropriate in the studio may be less suitable on stage. For example, the V-shaped formations are not as strong when the dancers are spaced closely and evenly on stage but are stronger when spread out and unevenly spaced on stage.

Thursday 4th April 7:00 pm – 8:30 pm, rehearsal

Today's rehearsal started and ended strongly. Given the current performance of my dancers, I am confident that the Spring Dance Concert will turn out wonderfully. This rehearsal was also the first time that I saw the first draft of the lighting design. I think the lighting really does further explore the concept of my piece.

Saturday 6th April 4:00 pm – 5:00 pm, tech rehearsal

Monday 8th April 6:15 pm – 10:00 pm, dress rehearsal

Tuesday 9th April 6:00 pm – 9:20 pm, dress rehearsal

Wednesday 10th April 6:15 pm – 9:00 pm, dress rehearsal

Thursday 11th April 5:45 pm – 9:00 pm, opening night

Friday 12th April 5:45 pm – 9:00 pm, second performance

Saturday 13th April 5:45 pm – 9:00 pm, last performance

Appendix D: Initial Development of Costume Ideas

CoW DANCE COSTUME DEVELOPMENT

COMPLETE your COSTUME THOUGHTS.
DISCUSS your ideas with Rebecca Callan, Costume Designer/Shop Supervisor.
TRANSLATE your ideas into realistic costume.
TIME/MONEY/LABOR

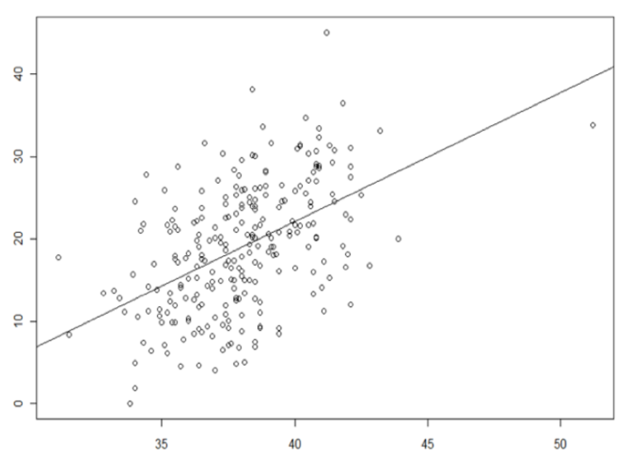
REMEMBER to use the Costume Stock that CoW has and then we will BORROW OR BUY costume pieces.

TRY your costumes in the piece.
Do they work? Or is it not what you thought it would be?
EDIT costumes as needed.

SDW COSTUME THOUGHTS

- ✓ **P**oint**O**f**V**iew (POV) STATEMENT

1. What is your piece about, what is the concept? What are you trying to accomplish? Are you using a particular movement style/pedagogy? What does your piece make you feel? What do you want your audience to take from your piece?
   My piece explores how one can make use of an econometric tool, specifically a regression equation, as a source for choreography. The structure of the dance will partially follow the numerical structure and relationships of the regression equation. My dance explores how dancers can affect a dance in the way that independent variables affect the dependent variable.
2. What is the music or sound for the piece?
   COPYCAT by Billie Ellish
3. Who are the dancers in your piece?
   Elyse Evans, Karabella Hernandez, Ella Lang, Kathlyn MacDonald, and Reyka VanSickle



Source:
http://sphweb.bumc.bu.edu/otlt/MPH-Modules/BS/R/R5_Correlation-Regression/R5_Correlation-Regression5.html

- ✓ Find and attach a PICTURE/PAINTING/VISUAL INSPRIRATION.

  Color thoughts: Black and white to capture the non-discriminating and plain nature of regression equations. However, a different color could potentially be used on each dancer since they are each representing a different variable.

- ✓ Please attach 2 complete looks for your piece.

1. LITERAL (PEDESTRIAN, DANCE CATALOGUE, KOHLS/TARGET/WALMART)

Source: https://www.trendhunter.com/trends/cream-dress

2. ABSTRACT (HAUTE COUTURE, AVANT GARDE, ABSTRACT FASHION, EDITORIAL)

Source: https://www.news.com.au/lifestyle/fashion/fashion-trends/shoppers-slam-hideous-jeans-made-from-laces/news-story/8888f57d01543e65b339958b46130299

Appendix E: Spring Dance Concert Publicity Poster

Appendix F: The Wooster Voice Article About the Spring Dance Concert

6 APRIL 12 Arts&Entertainmen

Spring Dance Concert displays collaborative artistry

Claire Wineman
Senior Staff Writer

As much as we invoke the phrase "Independent Minds, Working Together" here at Wooster — both seriously and ironically — there's never a shortage of ways for us to experience it at work around campus. We are constantly in cooperation with one another to achieve end results that would be incomplete without all the perspectives involved, not only for our classes and student groups, but also for our performances and presentations.

The Spring Dance Concert is the epitome of such collaboration: 75 students, as well as staff members and visiting artist Talise Campbell, have worked together to put on this weekend's production. "The concert contains the work of creative and talented students and staff who have invested hundreds of hours in this process," says Kim Tritt, director of the show and professor of theatre and dance at the College. "It's wonderful to have the opportunity to put that much work into it and to share with an audience."

The show includes pieces from over six student choreographers, including Claire Smrekar '19 and Rachel Lau '19. Smrekar, who has participated in the dance show during all four of her years at the College, has seen her experiences in the arts as a valuable source of balance to her busy academic life, especially while finishing her I.S. "Having such a rigorous dance schedule only allows me so much time to do my academic work, so it really helps me focus and provides me with a place to decompress," she said. "Previously, I've choreographed pieces about the heart and lungs, and my dance this time is a conglomerate of those two — pathways between the heart and the lungs as well as your emotions, and how we interact with ourselves and with others."

This Spring Dance Concert contains a mix of themes, dance styles and creative visions (Photo from The College of Wooster Theatre and Dance Facebook).

Lau's dance, on the other hand, was choreographed in partial fulfillment of her I.S. — and in the true spirit of the liberal arts, seeks a connection between her two majors in dance and economics. "My I.S. asks how one can make use of an econometric tool, specifically the regression model, as a source for choreography. In other words, it tries to physicalize concepts from a mathematical branch of economics, or econometrics. There was a lot of uncertainty involved with such an experimental and unconventional piece, and I honestly had no idea what to expect. I tried to strike a healthy balance between my artistic choices and accuracy of my conceptual ideas.," she said.

Tritt's retirement is imminent after directing over 65 dance shows at the College for 34 years and says this uncertainty is all part of the process. "I'm always really excited about seeing how the dances have progressed from the original idea and how they've been fulfilled at the conclusion of the concert. This year's show has such an incredible sense of pure joy. It's very thoughtful but very fun. There's more of that than ever," Tritt said.

The Spring Dance Concert is one of many excellent opportunities to support our fellow students and has performances Friday, April 12 and Saturday, April 13 at 7:30 p.m. in Freedlander Theatre. Tickets, which can be purchased at the Freedlander Box Office, are $9 for general admission and $6 for senior citizens as well as faculty, staff and non-College of Wooster students.

Appendix G: Spring Dance Concert Tech Schedule

Thursday, April 4
4:00-6:00pm – 1st Tech for Kim
*any crew available.
6:00-10:00pm – SM Coordinated Schedule

Friday, April 5
SM Coordinated Schedule

Saturday, April 6
1:00pm - Crew Call
1:30pm - Reyka Call
2:00pm - Reyka Go (60mins)
2:30pm – Crystal Call
3:00pm- Crystal Go (45mins)
3:15pm – Madigan Call
3:45pm -Madigan Go (45mins)
4:00pm -Rachel Call
4:30pm - Rachel Go (60mins)

Sunday, April 7
1:00pm - Crew Call
1:30pm – Claire Call
1:45pm - Rachel Video Go (15mins)
2:00pm - Claire Go (45mins)
2:15pm - Teagan Call
2:45pm - Teagan Go – (45mins)
3:00pm - Kim Call
3:30pm - Kim Go (90 mins)

Monday, April 8
6:00pm Crew Call
6:15pm Dancers Call
7:30pm Go Dress Rehearsal 1
*Full Costume & Makeup
*Crew in all black
*Dancers Dismissed with Kim's permission

Tuesday, April 9
5:45pm Crew Call
6:00pm Dancers Called
7:00pm Photo Call
7:30pm Go Dress Rehearsal 2

*Full Costume & Makeup
*Dancers Dismissed with Kim's permission

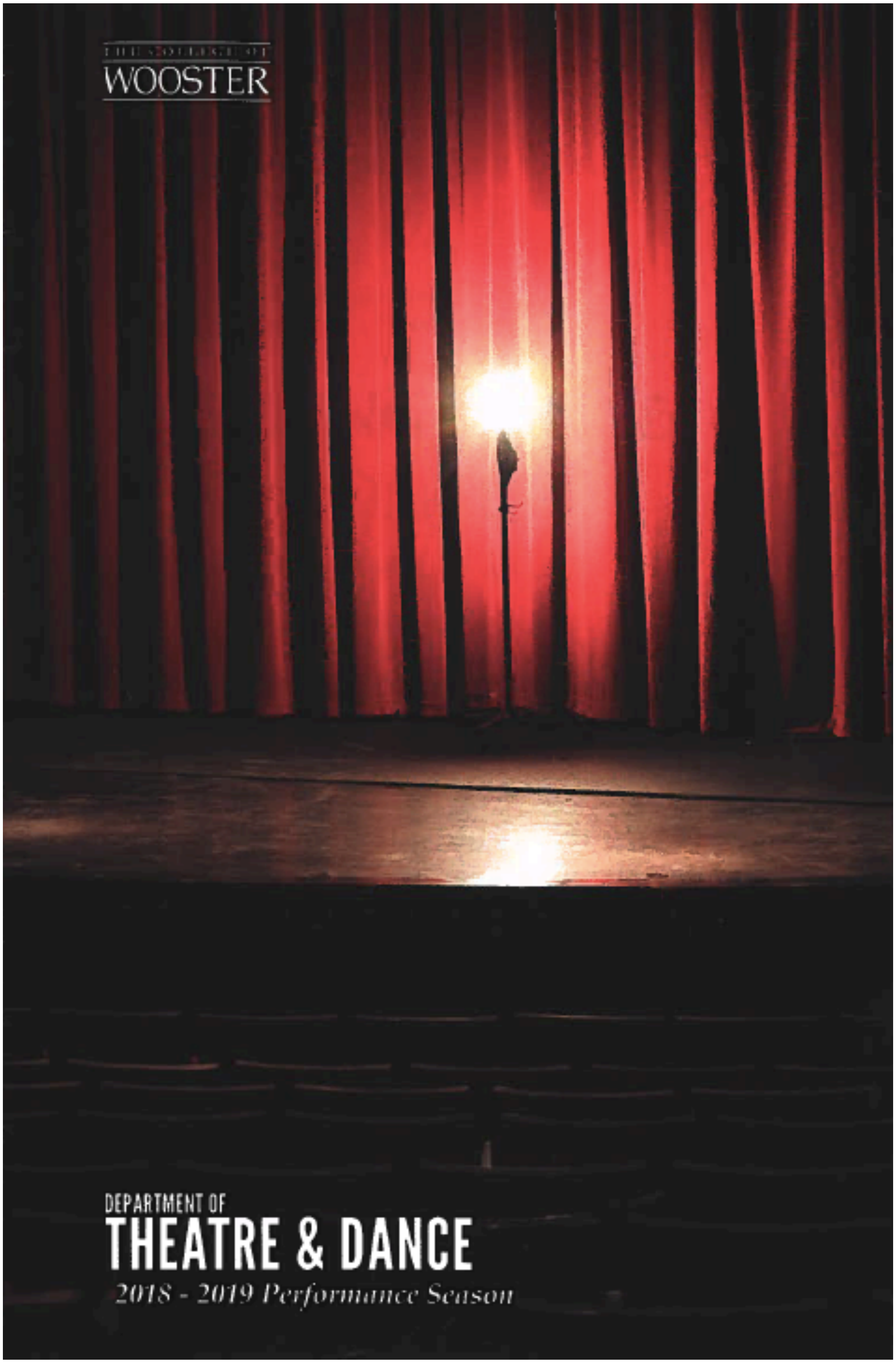
Wednesday, April 10
2:00-5:00pm – Tech/Spacing Rehearsal – Talise
3:00pm – SM/Crew Call, as needed.
5:00-6:00pm – SM/Crew Dinner Break
6:00pm Crew Call
6:15pm Dancers Called
7:30pm Go Dress Rehearsal 3 & Video
*Full Costume & Makeup
*Immediately following the rehearsal, all dancers must report to the stage for final notes.

Thursday, April 11
5:30pm Crew Call
5:45pm Dancers Call
6:00pm Warm Up
7:30pm Go Opening Night

Friday, April 12
5:30pm Crew Call
5:45pm Dancers Call
6:00pm Warm Up
7:30pm Go Performance 2

Saturday, April 13
5:30pm Crew Call
5:45pm Dancers Call
6:00pm Warm Up
7:30pm Go Performance 3

Appendix H: Spring Dance Concert Program



FREEDLANDER THEATRE, APRIL 11, 12 AND 13, 2019

THE COLLEGE OF WOOSTER

DEPARTMENT OF THEATRE AND DANCE
PRESENTS

SPRING DANCE CONCERT

Artistic Direction by KIM TRITT

Lighting Design by DALE E. SEEDS

Costume Design by REBECCA R. CALLAN

Sound Design by CHUCK FINDLEY

Technical Direction by MIKE SCHAFER

Production Stage Managment by CLEO POTTER

There will be a ten-minute intermission.

Photographs, videos, and sound recordings are strictly prohibited.

Please turn off all cell phones and pagers before the performance.

A Humbling Oasis

Choreographer	Reyka VanSickle
Dancers	Ivan Akiri, Sarah Brunot, Estelle Dowling, Minjoo Kang, Olivia Kline, Nikki Preucil, Crystal Sermon, Claire Smrekar
Music	Shades of Gold
Lighting Designer	Darian Harvey

INTERMISSION

Can't Is a Four-Letter Word

Choreographer	Teagan Robinson
Dancers	Emily Anderson, Cloud Chang, Morgan Day, Manasi Desai, Olivia Kline, Sarah Renaker, Teagan Robinson, Madigan Strange
Music	H. Jon Benjamin and Jazz Daredevil
Lighting Designer	Juliet Merillat

Kaleidoscopic

Choreographer	Madigan Strange
Dancers	Ivan Akiri, Magia Karagianni, Kathlyn MacDonald, Sophie Schoenle, Crystal Sermon, Kate Yordy
Music	Scott Perkins
Lighting Designer	Juliet Perkins

Physicalizing Econometrics

Choreographer	Rachel Lau
SR IS Advisor	Kim Tritt
Dancers	Elyse Evans, Karabella Hernandez, Ella Lang, Kathlyn MacDonald, Reyka VanSickle
Music	Billie Eilish
Lighting Designer	Mike Schafer

Just Something to Wear? Fashion Week; White T-Shirt; Little Black Dress

Choreographer	Kim Tritt
Dancers	Sarah Brunot, Estelle Dowling, Elyse Evans, Olivia Kline, Joelle Lau, Rachel Lau, Hannah Lane-Davies, Claire Smrekar, Reyka VanSickle
Music	Overture from *The Marriage of Figaro* by Wolfgang Amadeus Mozart (arr. Laurel Seeds), Piano Sonata No. 14 in C# Minor Op. 27 No. 2 by Ludwig van Beethoven, Robert Palmer
Scenic and Lighting Designer	Dale Seeds

Living Pathways

Choreographer	Claire Smrekar
Dancers	Mallory Crane, Elyse Evans, Teagan Robinson, Sophie Schoenle
Music	Vox Freaks and Fleet Foxes
Lighting Designer	Rachel Lau

Happiness Is Just An Elevator Ride Away

Choreographer	Cystal Sermon
Dancers	Cloud Chang, Manasi Desai, Sky Gill, Riya Joshi, Sarah Renaker, Madigan Strange
Music	Usher and June's Diary
Lighting Designer	Cleo Potter
Scenic Designers	Dale E. Seeds, Cleo Potter

Physicalizing Econometrics: Physicalizing Econometrics is in partial fulfillment of my Senior Independent Study. My research aims to physicalize a mathematical branch of economics called econometrics. The piece is separated into three sections, each exploring a different econometric concept. Section one illustrates a simplified regression equation that establishes the impact of four independent variables on one dependent variable. Each dancer represents one of these independent variables, with the exception of one dancer who represents the remaining factors affecting the dependent variable, or the "error term." Just as independent variables affect the dependent variable, the dancers affect the dance. Section two explores multicollinearity, or the interactions among independent variables. Thus, this section explores dancers' relationships with each other through contact. Section three contrasts the simplified regression equation performed in section one with a more accurate version of the same regression equation.

Choreo-ception

Choreographer	Rachel Lau
Dancers	Isabel Bonhomme, Rachel Lau, etc.
Music	Osmo

TOUKII - Journey (A look into the past as we continue to move forward.)

Choreographer	Talise Campbell
Musical Director	Weedie Braimah
Dancers	Malana Broome, Talise Campbell, Inaya Carrington, Farah Emeka, Sauriika Lockett, Yaisha Lockett, Maiya Jones, Stephanie Hill, Shalonda Davis, Jordyn Edwards, Samantha Ray, Chinnarra McCants, Layla Jones, Brooklyn Davis
Drummers	Weedie Braimah, Durotimi Troy, Chitunda Josh Jamal, Shamba Muhammed
Lighting Designer	Dale E. Seeds

Just Something to Wear? by Kim Tritt

The New York Museum of Modern Art recently presented the exhibit, *Items; Is Fashion Modern?* which included over 350 garments, accessories, photos, design sketches, and videos from other museums and private collections. The focus of the exhibition examined these articles in the context of how clothing and accessories represent who we once were, who we are now and might be in the future. Garments are often designed with the intent to integrate form with function. However, fashion, as in dance, is also conditioned within understandings in how we view identity, symbols of power, gender, sexuality, race, social dynamics, diversity, physical and cultural migration, global engagement, appropriation, stereotypes, and technology. Like fashion, dance is also centered on aesthetics and presentations of the body that are concealed and revealed. Both share important interrelationships in significant ways that inspire, collaborate and contribute to one another. My research in the *Items* exhibit served as a conceptual starting point for my dance, *Just Something to Wear?* specifically investigating shifts in identity as affected by cultural and social associations throughout time.

James Dean brought the white T-shirt from a functional undergarment for men to a symbol of rebellion. Graphic artists used it as a blank canvas for personal expression. Ballet choreographer George Balanchine used the white T-shirt as his signature costuming bringing focus to movement rather than decoration. The hoodie has evolved from the cloaks of medieval monks to Rocky Balboa's iconic stair-leaping cinematic feat and political statements of today. Updated versions of the Run-DMC track suit can be seen in the latest editions of *Vogue* while the traditional women's black dress remains the perfect silhouette for every occasion. Artists of fashion have created a multitude of masterpieces. Do those who wear them magnify the world in which they are worn? What might happen when these images are brought to life though movement and a dancer's body?

Talise Campbell, Guest Artist

Ms. Campbell is the Artistic Director of Djapo Cultural Arts Institute where her mission is to preserve traditional music, dance, and history through her Community Dance & Drum outreach programs. Ms. Campbell was the 2012 Creative Workforce Fellow and recipient of the Ohio Outstanding Educator Award. She has been afforded the opportunity to travel to various countries in Africa to assist with bringing traditional dance and music back to the states. She plans to receive her Doctoral Degree researching the effects of the integration of the arts comparing students in Dakar, Senegal with students in urban settings in America.

THE COLLEGE OF WOOSTER DANCE COMPANY

The Dance Company is a chartered organization open to all students on campus. Dance Company productions are housed under the umbrella of the Department of Theatre and Dance and the company is grateful for the department's collaboration and endless contributive efforts. Dance concerts provide an opportunity for students at Wooster to explore the art of choreography and performance working under the supervision of Kim Tritt. Choreographers pursue a process in the making of their dances that resembles other forms of research endeavors; first forming a concept or idea for the dance, then through the body as instrument, developing and organizing movement materials that reinforce the idea. Last, choreographers work with the talents of dancers to creatively shape, fame, and articulate the movement with clarity. Through weekly "sharings," the choreographers show their work and are critiqued by other dance company members and Tritt. Together, the Company works through the semester long rehearsal process.

Staff

Production Stage Manager
Cleo Potter
Assistant Stage Managers
Jaz Nappier
Anthony Cisneros
Assistant Lighting Designer
Cleo Potter
Light Board Operator
Darian Harvey
Sound Board Operator
Gustavo Duran
Deck Crew
Carlos DeSantiago
Dante King
Daniel Myers
Hayden Nolan
Kat Tackett
Master Electrician
Mike Schafer
Assistant Master Electrician
Olivia Hall
Scene Shop Assistants
Margaret Attwood
Andrea Brown
Michael Dean
Gustavo Duran
Hannah Grachen
Darian Harvey
Erin Joseph
Nasua Labi
Casey Lohman
Zack Martin
Mercer McLennan
Juliet Merillat
Cleo Potter
Emma Strickert
Patrick Wellman
M'Kinsy Wixson
Wardrobe
Nicole Heusner-Wilkinson
Linnea Kedziora
Keetrone Singleton, Jr.
Costume Shop Crew
Chantel Akuffo
Abby Bateson
Amelia Burke
Lesley Chinery
Isadora Hetrick
Nicole Heusner-Wilkinson
Linnea Kedziora
Aaron Risch
Keetron Singleton, Jr.
Hannah Smith
Riley Smith
Alexis Valente
Dance Company Coordinators
Rachel Lau
Kathlyn MacDonald
Claire Smrekar
Costume Shop Manager
Rebecca Callan
House Manager
Abbey Martin
Box Office Staff
Lizbeth Acevedo
Carlos DeSantiago
Hayley Hardcastle
Nicole Heusner-Wilkinson
Rachel Lau
Michelle Lee
Marco Peticca
Reyka VanSickle
Ushers
Lizbeth Acevedo
Lauren Brown
Heather Foust
Elizabeth Suarez
Photographer
Jacob Lautman
Season Poster Design
Becca Snedeker-Meier
Public Relations
Lesley Chinery
Laney Zuver
Program Design
Patrice Smith
Scene Shop Manager
Mike Schafer
Costume Shop Manager
Rebecca Callan
Faculty
Jimmy A. Noriega, Chairperson
Shirley Huston-Findley
Daniel Hobbs
Kim Tritt