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Multi-regional Input-Output Model for the Dallas and Oklahoma City Metropolitan Areas

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I. Introduction

Understanding regional development has a long history in economics and regional science. Several strands of research in Urban/Regional Economics as well as Public Sector Economics define the nature of development with the early work of von Thünen (1826), Christaller (1933)[1], Losch (1940)[2], and later Krugman (1991) examining the origin of cities and systems of cities. Roback (1982, 1988) and Beeson and Eberts (1989) investigate the relationship between quality of life measures and regional development. A vast literature concerning regional development and urban productivity includes persuasive research by Rauch (1993), Glaeser et al (2001) and Moomaw (1981). All of these topics approach development through a different lens.

For decades, urban economic research focused on individual cities. The Monocentric City Model was often used to describe the density of urban activity. It discussed all city activity in distance gradients from the city's Central Business District (CBD). Activities occurring nearer to the CBD incurred higher land rents which were offset by the productivity gains they experienced by locating nearer to their primary suppliers/clients. As distance from the CBD increased, corresponding land rents decreased owing to decreased productivity. This model was useful in describing the structure of cities in the U.S. until the post world war II period when urban dwellers began flocking to suburbs. This flight from the central metropolis changed the landscape of urban regions and decreased the importance of the Monocentric Model. Even still, Ciccone and Hall (1996) studied the relationship between urban density and productivity and found that increased urban density leads to increased city productivity. This finding seems at odds with the observed sprawling metropolises. Glaeser and Kahn (2001, 2004) pointed to the internal combustion engine as the primary cause of large-scale decentralization. With the decline in commuting times and opportunity cost of travel, workers could choose larger dwellings and suburban amenities while maintaining and potentially increasing their productivity. This sprawling environment continues to lead to systems of city regions that are less distinctly defined. Indeed, Glaser (2007) found that all megaregions he studied continued to decentralize over the seven year period from 1994 to 2001.

While the Monocentric Model is useful for understanding the impact of density on economic activity, it is less useful for describing the current sprawl of economic activity in the U.S. Even still, Mills (1994) opines that the term megalopolis is "unreal" because "metropolitan areas within a megalopolis are not united by the usual criterion of people commuting from one to another." He goes on to observe that the megapolitan areas in the U.S. contain vast amounts of rural land. While these arguments have some validity, certainly metropolitan areas within a megalopolis are linked via economic activity, even if not linked directly by daily commuters. Activity does not take place in a costless plane. One metropolitan

[1] Christaller's work was published in German. An English translation was published by Carlisle W. Baskin in 1966. See *Central Places in Southern Germany* (Englewood Cliffs, N.J: Prentice Hall, 1966)
[2] Losch's work, published in German in 1940 appeared in an English translation by W.H. Woglom and W.F. Stolper as *The Economics of Location* (New Haven, Conn.: Yale University Press, 1954).

area purchases the production of a neighboring metropolitan area because the transportation costs are less than purchasing from a more distant metropolitan area. Consumers are more likely to choose a nearby lake to enjoy recreation than a similar lake in a similar geography many miles away. Lastly, while fewer workers commute between neighboring metropolises than their primary metropolis, the number of commuters is non-zero. And, certainly workers commute from less dense areas to more than one primary metropolis.

Over the last decade there has been an increase in research discussing the need and effectiveness of regional cooperation. While certainly not a new concept, municipalities are driving interest as they are more rigorously competing for business location. Haughwout and Inman (2002) discuss the linkage between central cities and their suburbs suggesting that both benefit from development to the central city. Glaeser (2007) suggests that a mixture of cooperation and competition is prescribed for cities located in megaregions. All this suggesting that some level of cooperation may be optimal for Megapolitan areas.

This study was commissioned to examine the level of economic dependency between north Texas and southern Oklahoma. Due to the defined structure of the U.S. Megalopolis, we chose to use the existing I-35 Corridor Megalopolis as the structural framework to characterize the study region. A description and list of all U.S. megalopolises is given in Section 2. Section 3 discusses the development and characteristics of the I-35 Corridor and the more narrowly defined study region. Section 4 describes the study methodology. Sections 5 and 6 present the results of the study and provide concluding remarks.

II. The U.S. Megalopolis

Coined by French Geographer Jean Gottmann (1961), the term Megalopolis describes a continuous grouping of large urban metropolises.[3] The term is growing in popularity as geographers and economists alike study the interaction and growth of urban areas. While examining the 1950 U.S. Census, Gottmann observed that a group of Metropolitan Statistical Ares (MSAs) formed a continuous area from southern New Hampshire to Northern Virginia. Called the BosWash, this became the first Megalopolis and includes the cities of Boston, New York, Philadelphia, Baltimore and Washington DC.

When Gottman wrote his original work "Megalopolis," he focused only on the northeastern corridor, realizing much later that Megapolitan areas existed throughout the country. The U.S. Census Bureau is considering a new Megapolitan classification to account for these large urban areas. In a 2005 census report, Lang and Dhavale recognized 10 such urban clusters as Megalopolises. Building on previous discussions by Faludi (2002), Yaro and Carbonell (2004), Yaro et al (2004) and Carbonell and Yaro (2005), Lang and Dhavale defined Megapolitan Areas as having the following characteristics:

- Combines at least two, but may include dozens of exiting metropolitan areas.
- Totals more than 10,000,000 projected residents by 2040.
- Derives from contiguous metropolitan and micropolitan areas.
- Constitutes and "organic" cultural region with a distinct history and identity.
- Occupies a roughly similar physical environment.
- Links large centers through major transportation infrastructure.
- Forms a functional urban network via goods and service flows.
- Creates a usable geography that is suitable for large-scale regional planning.
- Lies within the United States.
- Consists of counties as the most basic unit.

The megapolitan areas they described are listed in Table 1.

[3] The Webster Dictionary defines a Megalopolis as a thickly populated region centering in a metropolis or embracing several metropolises.

Table 1: U.S. Megapolitans		
Megapolitan	**Metropolitan Areas Included[4]**	**States Included**
Cascadia	Portland, Seattle, Tacoma	OR, WA
Gulf Coast	Houston, New Orleans, Gulfport, Mobile, Pensacola	AL, FL, LA, MS, TX
I-35 Corridor	**Kansas City, Tulsa, Oklahoma City, Dallas, Austin, San Antonio**	**KS, MO, OK, TX**
Midwest	Milwaukee, Chicago, Detroit, Indianapolis, Cincinnati, Columbus, Cleveland, Pittsburgh	IL, IN, KY, MI, OH, PA, WI, WV
NorCal	San Francisco, Oakland, Sacramento, Reno	CA, NV
Northeast (BosWash)	Boston, New York, Philadelphia, Baltimore, Washington DC	CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VA, WV
Peninsula	Orlando, Tampa, Miami, Fort Lauderdale	FL
Piedmont	Brimingham, Montgomery, Charlotte, Raleigh, Columbia, Chattanooga, Knoxville	AL, GA, NC, SC, TN, VA
Southland	Los Angeles, San Diego, San Bernadino, Las Vegas	CA, NV
Valley of the Sun	Phoenix	AZ

[4] Major metropolitan areas within each geography include but are not limited to those identified.

Table 2 shows the population and growth rates of the U.S. megapolitans in 2003. In 2003, 67.8% of the total U.S. populous lived in the Megapolitan areas. The Northeast and Midwest megapolitans are by far the largest but are growing much more slowly than other regions. The fastest growing megapolitans are the Valley of the Sun (9.5%), Peninsula (6.8%) and I-35 Corridor (5.9%). This change in Megapolitan population is consistent with the larger trend of southern migration throughout the U.S.

Table 2: U.S. Megapolitan Population and Growth

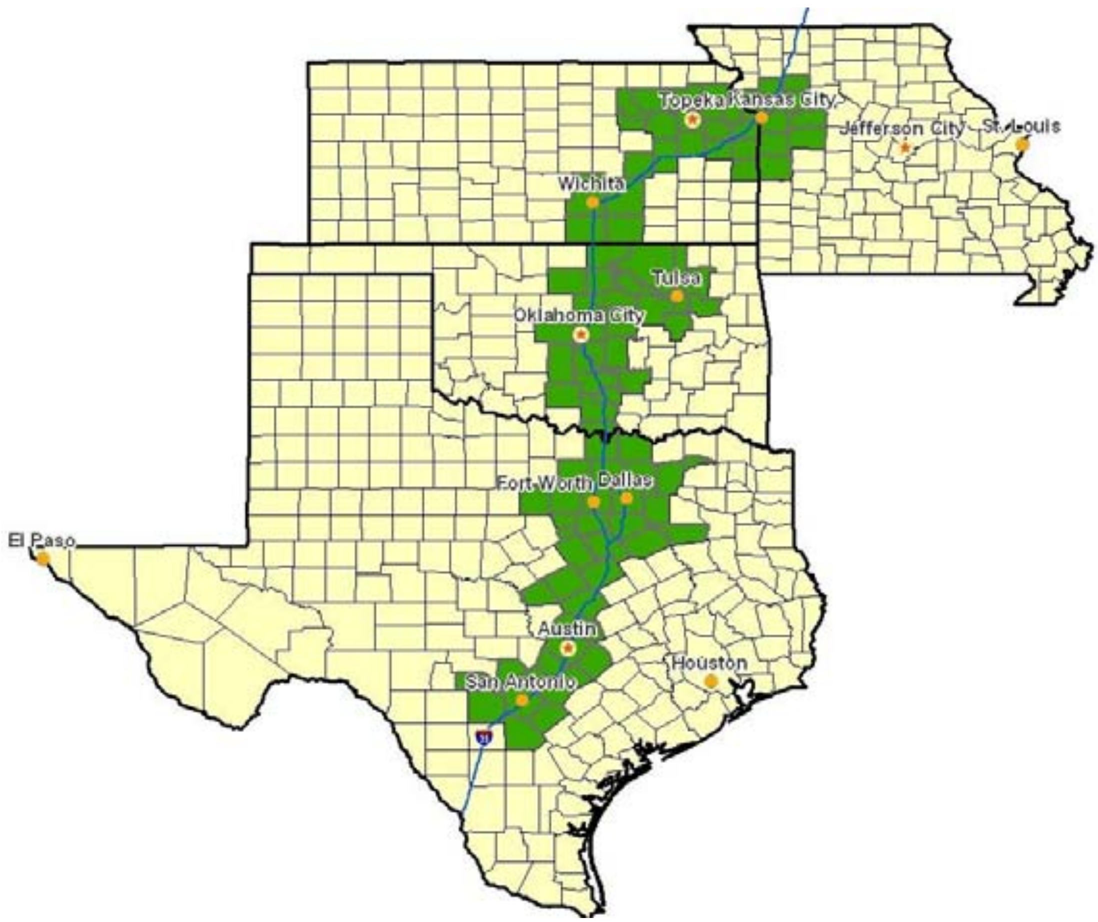
Megapolitan	2003 Population	2003 Population Rank	2000 – 2003 Growth Rate	2000 – 2003 Growth Rank	Percent of 2003 U.S. Population
Northeast	50,427,921	1	2.5 %	9	17.3%
Midwest	40,082,288	2	1.5%	10	13.8%
Southland	22,173,291	3	5.8%	4	7.6%
Piedmont	19,318,992	4	5.0%	5	6.6%
I-35 Corridor	**15,315,317**	**5**	**5.9%**	**3**	**5.3%**
Peninsula	13,708,165	6	6.8%	2	4.7%
Gulf Coast	12,064,600	7	4.6%	6	3.7%
NorCal	12,024,173	8	3.9%	8	4.1%
Cascadia	7,412,248	9	4.2%	7	2.6%
Valley of the Sun	4,486,206	10	9.5%	1	1.5%

Source: Reprinted from Lang and Dhavale (2005)

III. Study Region

The I-35 Corridor extends north from San Antonio, TX to Kansas City, MO along the interstate highway I-35. It incorporates 97 counties (5 rural), 12 Metro areas, 5 of which have populations greater than 1 million, and 18 Micro areas. Centered primarily along interstate 35, Tulsa, OK is the only metro area lying away from I-35. It was the fifth largest and third fastest growing Megalopolis as of 2003 according to Lang and Dhavale (2005) and is presented in Figure 1. All counties included in the corridor are highlighted in green.

Figure 1: I-35 Corridor



This study focuses on a smaller portion of the I-35 Corridor extending from Oklahoma City (OKC), OK to Dallas/Ft. Worth (DFW), TX. This geography covers 29 counties, 22,744 square miles and incorporates a population of 7,771,661. Figure 2 maps the display area and table 3 lists the counties. For the purpose of this report, the study region will be denoted OKCDFW.

Figure 2: OKCDFW Region

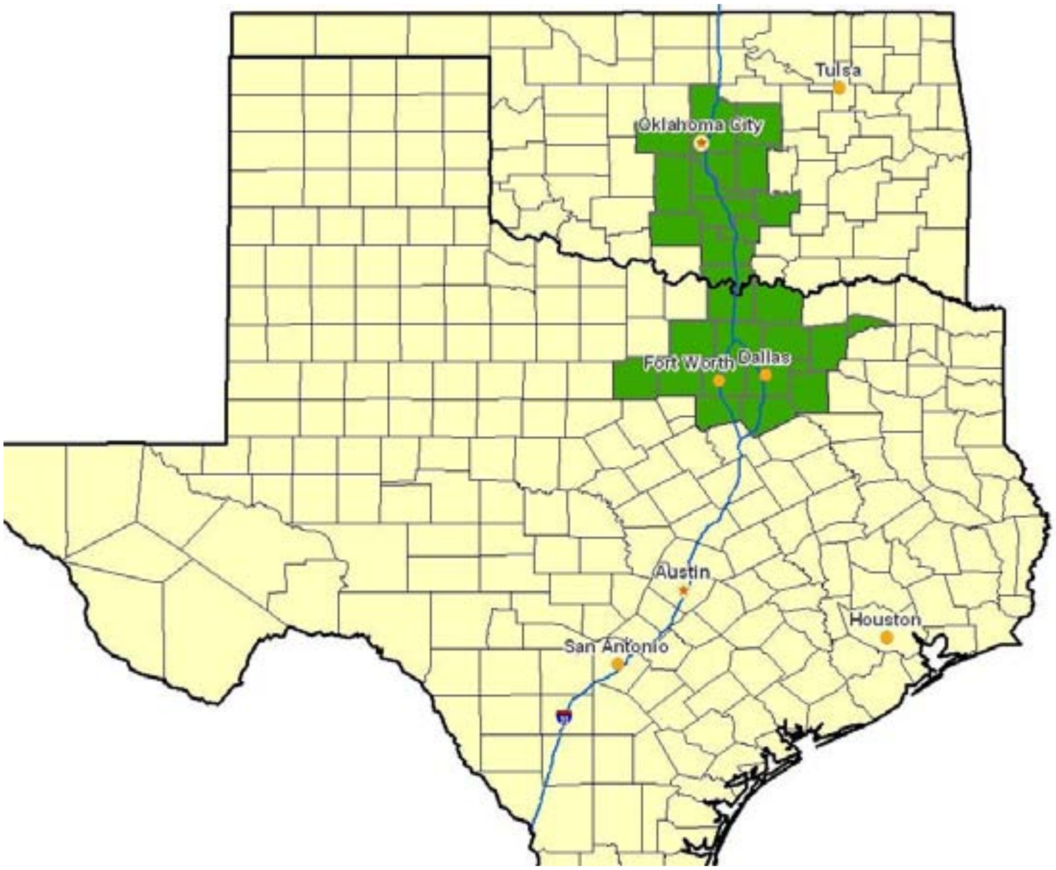


Table 3: OKCDFW Counties	
Oklahoma Counties (14)	**Texas Counties (15)**
- Canadian	- Collin
- Carter	- Cooke
- Cleveland	- Dallas
- Garvin	- Delta
- Grady	- Denton
- Lincoln	- Ellis
- Logan	- Grayson
- Love	- Hunt
- McClain	- Johnson
- Murray	- Kaufman
- Oklahoma	- Palo Pinto
- Pontotoc	- Parker
- Potawatomie	- Rockwall
- Stephens	- Tarrant
	- Wise

Slightly less than one half of the I-35 Corridor population lives in the study area with the study area growing faster than the region as a whole at 15.9% from 2000 – 2007. The portion of the region in Texas is growing at roughly twice the Oklahoma portion. The OKCDFW is only marginally less urban than the entire I-35 region at 87%. Table 4 details the study region demographics. Table 5 details the top 3 industries for the OKC and DFW MSAs.

Table 4: OKCDFW Demographics

	Total Population (2007)	Total Population (2000)	Percent Change Pop 2000-2007	% Urban Population (2000 Census)	Number of Counties	Area (square miles)
I-35 Corridor	16,330,875	14,465,638	14.0%	88%	97	75,125.70
OKCDFW	7,771,661	6,706,801	15.9%	87%	29	22,743.56
Oklahoma Region	1,434,494	1,336,015	7.4%	74%	14	10,595.86
Texas Region	6,337,167	5,370,786	18.0%	90%	15	12,147.70

Source: U.S. Census Bureau

The top 3 industries for both of the primary MSAs are Food Services and Drinking Places, Adminstrative and Support Services and Professional, Scientific and Technical Services with Food Services and Drinking Places leading in OKC and Administrative and Support Services leading in DFW.

Table 5: A Snapshot of Top Industries by Total Employment in the OKCDFW MSAs			
Oklahoma City, MSA	**Avg. Quarterly Employment (2007Q4 - 2008Q3)**	**Hiring (2008Q3)**	**Avg. Monthly Earnings (2007Q4 -2008Q3)**
All NAICS subsectors	456,721	39,415	$3,363
1.Food Services and Drinking Places	44,354	5,434	$1,234
2.Administrative and Support Services	42,531	4,769	$2,518
3.Professional, Scientific, and Technical Services	29,923	2,248	$4,442
Dallas-Fort Worth-Arlington, MSA			
All NAICS subsectors	2,610,288	209,291	$4,500
1. Administrative and Support Services	229,080	26,681	$3,552
2. Food Services and Drinking Places	207,538	25,889	$1,603
3. Professional, Scientific, and Technical Services	198,999	16,034	$6,619

Source: U.S. Bureau of Economic Analysis

Demographic and Industrial Regional Trends

Population in the OKCDFW area has increased by 18.4 percent from 6.71 million in 2000 to 7.94 million in 2008. Table 6 shows population statistics for the OKCDFW region and its two metropolitan areas. The U.S. Census Bureau's cumulative population estimates for MSAs between 2000 and 2008 ranks the Dallas- Fort Worth- Arlington MSA number one on population change during 2000-08 with Oklahoma City at 44. Population in the Dallas-Fort Worth-Arlington MSA increased by 22.1 percent during this time and by 10.1 percent in Oklahoma City MSA, as shown in Table 6 below.

Table 6: Population Statistics[i] (2000-08)

Area	Ranking by population change (2000-08)	Total population (2000)	Total population (2008)	Population change (2000-08)
OKCDFW	N/A	6,706,801	7,938,123	18.4%
DFW MSA	1	5,161,530	6,300,006	22.1%
OKC MSA	44	1,095,422	1,206,142	10.1%

Source: U.S. Census Bureau

Table 7 shows annual population for Texas counties for 2000 and 2008. Dallas County had the largest population at 2.41 million, followed by Tarrant County with 1.75 million in 2008. The three fastest growing counties were Rockwall, Collin and Denton demonstrating the significant growth occurring north of Dallas.

Table 7: Population – TX Counties (2000, 2008)

County	2000	2008	Population Change
Dallas	2,218,899	2,412,827	8.74%
Tarrant	1,446,219	1,750,091	21.01%
Collin	491,675	762,010	54.98%
Denton	432,976	636,557	47.02%
Johnson	126,811	153,630	21.15%
Ellis	111,360	148,186	33.07%
Grayson	110,595	118,804	7.42%
Parker	88,495	111,776	26.31%
Kaufman	71,313	100,527	40.97%
Hunt	76,596	82,805	8.11%
Rockwall	43,080	77,633	80.21%
Wise	48,793	58,506	19.91%
Cooke	36,363	38,407	5.62%
Palo Pinto	27,026	27,486	1.70%
Delta	5,327	5,458	2.46%
Total TX Counties	**5,335,528**	**6,484,703**	**21.54%**

Source: U.S. Census Bureau

Table 8 reports annual population for Oklahoma counties for 2000 and 2008. Among all the counties, Oklahoma County had the largest population of 706,617 in 2008, followed by Cleveland County with 239,760. . Growth rates were not as regionally concentrated in the Oklahoma Region as they were in the Texas Region. Canadian County experienced the largest increase in population during this timeframe followed by Cleveland and Logan Counties

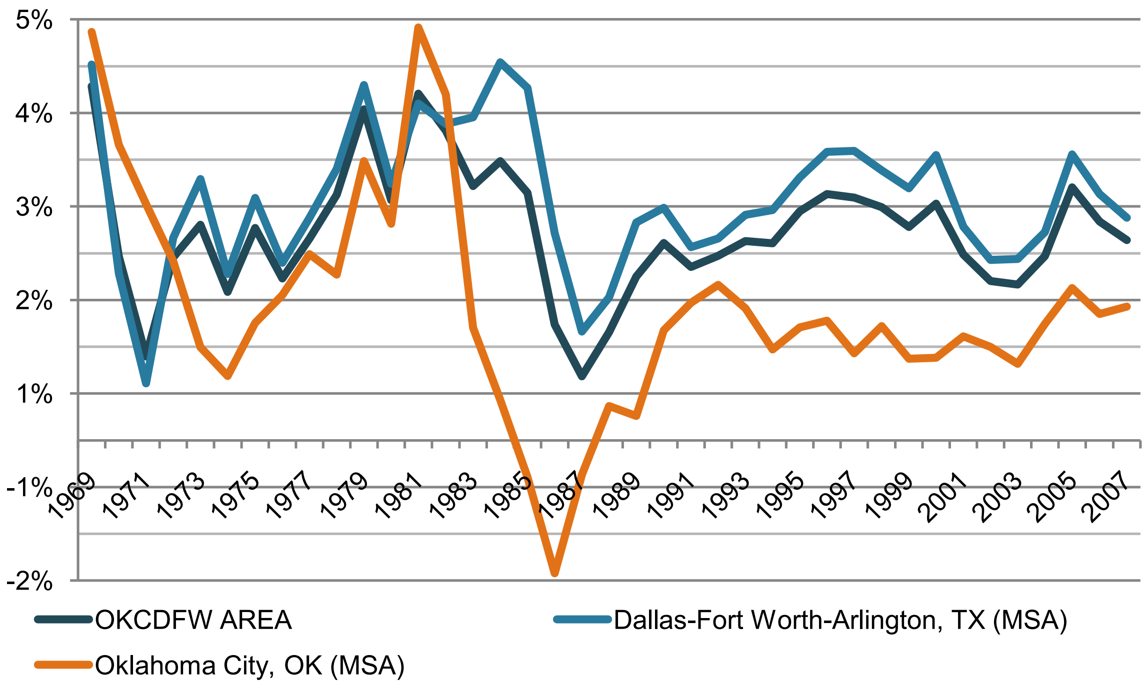
Table 8: Population – OK Counties (2000, 2008)

County	2000	2008	Population Change
Oklahoma	660,448	706,617	6.99%
Cleveland	208,016	239,760	15.26%
Canadian	87,697	106,079	20.96%
Potawatomie	65,521	69,616	6.25%
Grady	45,516	51,066	12.19%
Carter	45,621	47,979	5.17%
Stephens	43,182	43,498	0.73%
Logan	33,924	38,102	12.32%
Pontotoc	35,143	36,999	5.28%
McClain	27,740	32,365	16.67%
Lincoln	32,080	32,153	0.23%
Garvin	27,210	27,247	0.14%
Murray	12,623	12,784	1.28%
Love	8,831	9,155	3.67%
Total OK Counties	**1,333,552**	**1,453,420**	**8.99%**

Source: U.S. Census Bureau

Historically, the population of the OKCDFW region and Dallas-Fort Worth-Arlington MSAs have grown along a similar path as seen in Figure 3. From 1969 through 2008, the Dallas-Fort Worth-Arlington MSA had consistently higher annual population growth rates in comparison to the OKCDFW region while Oklahoma City MSA generally experienced lower growth rates. The only period of higher growth for the Oklahoma City MSA coincided with the so-called "oil boom" of the early 1980s. With much of the local economy dependent on the energy sector, growth plummeted with plunging oil prices that left the Oklahoma City economy reeling for much of the remainder of the decade. Steady Oklahoma City growth ensued in the 1990s, yet, at a lower rate than the rest of the region.

Figure 3: OKCDFW Annual Population Growth (1969-2008)



OKCDFW Employment

Table 9 contains industrial employment statistics for the OKCDFW region. According to the U.S. Census Bureau, the largest sector in terms of employment in the OKCDFW region is retail trade, employing 675,892 regional workers in 2007. Manufacturing is the second largest employer, with a 2007 total employment of 506,892. Between 2001 and 2007, the most significant employment growth occurred in the Management of Companies and Enterprises sector (64.2%) followed by Real Estate and Rental/Leasing (39.9%) and Mining (38.2%).

Table 9: Industrial Employment in OKCDFW region (2001-07)

Industry/Sector	2001	2007	Employment Growth (2001-07)
Management of companies and enterprises	30,881	50,705	64.2%
Real estate and rental and leasing	212,350	297,005	39.9%
Mining	102,832	142,134	38.2%
Educational services	69,476	89,421	28.7%
Arts, entertainment, and recreation	85,926	107,444	25.0%
Administrative and waste services	389,961	473,729	21.5%
Health care and social assistance	446,917	538,675	20.5%
Finance and insurance	301,435	354,643	17.7%
Professional, scientific, and technical services	348,610	408,984	17.3%
Construction	361,915	420,680	16.2%
Other services, except public administration	327,508	373,533	14.1%
Accommodation and food services	377,729	428,928	13.6%
Transportation and warehousing	227,442	245,781	8.1%
Wholesale trade	260,852	277,860	6.5%
Forestry, fishing, related activities, and other	12,487	13,184	5.6%
Retail trade	669,125	675,892	1.0%
Utilities	22,408	21,430	-4.4%
Manufacturing	565,250	506,892	-10.3%
Information	178,117	141,494	-20.6%

Source: U.S. Census Bureau

IV. Study Purpose and Methodology

With the growth of the I-35 Corridor there has been much interest in identifying the linkages that exist within the region between the northern Texas and Southern Oklahoma areas. As would be expected from a regional economic area that crosses state boundaries, a healthy rivalry exists between the states of Oklahoma and Texas and certainly between Dallas/Ft. Worth and Oklahoma City. Oklahomans often discuss the "brain drain" of Oklahoma educated young persons who choose to migrate to Texas, and more specifically DFW to work after college graduation. Texans often bemoan the migration of Texas high school athletes to Oklahoma colleges. While the competition is healthy there are many things that the two regions share. The language and culture are similar and both regions have a healthy energy industrial base.

This study analyzes the industrial linkages and trade flows between Oklahoma and Texas along the I-35 Corridor from Oklahoma City, OK to Dallas/Ft. Worth, TX to estimate the level of economic dependency that exists between the two regions. We report the impact that development in the Texas region has on the Oklahoma region, and vice versa. To analyze these linkages, we constructed a Multi-Regional Input-Output (MRIO) model to estimate the level of economic interdependency that exists. The subsequent paragraphs detail the study methodology.

Regional Economic Models

Regional economic models are used for a variety of purposes by a large subset of decision makers. Governments use regional models for forecasting budgets, planning urban development, estimating policy impacts and determining appropriate economic incentive packages to attract local developers. Firms use regional economic models to forecast production and to drive location decisions. Governments and firms find models provide necessary information for planning purposes.

The range of use is vast requiring a multitude of models to meet a variety of planning needs. Beginning in the early 20th century, planners began to see the need for models to explain regional growth. Economic Base theory was born to explain the duality of local production for both export and local support activities. Krikelas (1992) describes the beginning of EB theory as an attempt to describe the relationship between primary city founders who derived their income from activities outside the city and the secondary city founders whose livelihood depended on the activities of the primary city founders. He discusses how this concept was born of sociologist Werner Sombart in the early part of the twentieth century.

Economic base models are simple to use and moderately informative for understanding local growth amongst diverse industries. However, their use is limited due to their lack of real underlying structure. Therefore they tend to be used for simple development planning or regional growth analysis.

Regional econometric models are often used for economic forecasting, revenue forecasting and policy analysis. With current computing power, they are relatively easy to implement and very flexible to use. They use statistical techniques to derive parameter estimates for regional or national short-run models. Because they are empirical models, however, they often lack the structure of more sophisticated regional models and may perform poorly for some implementations. It is for this reason that they are not as useful for analyzing policy alternatives relative to economic structure such as the project at hand.

Input-Output Models

Input-Output (I-O) models have a long history in regional science. The I-O framework was developed by Wassily Leontief in the late 1920s and early 1930s[5]. Isard (1960) contributed an early detailed discussion of regional and interregional I-O models. Other detailed discussions can be found in Miernyk (1965) and Bulmer-Thomas (1982). I-O models are used frequently for impact analysis because of their underlying structure that captures the interdependencies between industries and regions. As such, it will be used to estimate the dependency between areas within the study region.

I-O models use a fixed coefficient expenditure matrix to approximate dollar flows through a local economy. The expenditure matrix is estimated from economic flows at a given period in time. By effectively stopping the economy in time, I-O models allow the researcher to observe the magnitude of industry and institutional linkages within an economy. Specifically, I-O models begin with estimated dollar flows from industries to households and government sectors and vice versa. These frozen flows between industries and institutions (households, government, and foreign trade) provide a quantifiable measure of the inter-industry linkages in the economy. Finally, production is assumed to occur in fixed proportions, so that an increase in the final demand from any industry requires a proportional increase in the final demand of all supporting industries.

With the linkages modeled, prices assumed constant, and production assumed to occur in fixed proportions, impact analysis proceeds by tracing the initial effect of a change in the demand for a specific industry's output through the system of inter-industry relationships. For example, a new office park construction presents itself in the model as a change to the final demand for construction output. The "snapshot" of the economy reveals that increasing the output from the construction sector requires construction firms to increase their demand for materials and labor used in construction. Thus the total impact to the economy is the direct increase in construction activity plus the indirect increase in supporting activities. Finally, note that workers in the construction and supporting industries have increased income as a result of the original project, and spend that income in accordance with personal consumption expenditure data. Thus the aggregate impact of the original project is the direct increase in construction activity plus the indirect increase in supporting activities plus the induced increase in consumption by households. For any project, I-O models measure the total impact as the sum of direct, indirect, and induced effects.

The following example demonstrates the direct linkages between industries in an I-O model that are used to estimate indirect impacts to changes in final demand. An I-O model estimates the

[5] Leontief published a seminal work in *The Review of Economics and Statistics* in 1936.

dependencies between industries using historical accounting transactions. For each output from an industry, inputs from other industries are tracked by monetary payment to estimate the dollar amount of each industry input required to produce one dollar of the study industry output. For example, suppose industry X produces $10,000 worth of output. An expenditure matrix for industry X is given in Table 10 below.

Table 10: Example I-O Expenditure Table for Industry X

	Industry X
Industry X	$2,000
Industry Y	$1,000
Industry Z	$1,500

According to Table 10, industry X requires $2,000 worth of industry X production as primary inputs to produce $10,000 worth of industry X output. Likewise, $1,000 of industry Y and $1,500 worth of industry Z are required to produce $10,000 worth of industry X output. Using simple algebra, it is determined that for every $1 of industry X production, $0.20 of industry X, $0.10 of industry Y and $0.15 of industry Z are required as production inputs. This places a fixed dependency between industries X, Y and Z.

Of course, this is only the beginning of the story. Industries Y and Z also require inputs for production. Table 11 shows a fully populated industry-by-industry production expenditure matrix. From this matrix one can develop the industrial dependencies for all three local industries. Suppose that industry Y produces $5,000 of output and industry Z produces $15,000 of output.

Table 11: Example I-O Expenditure Table for all Local Industries

	Industry X	Industry Y	Industry Z
Industry X	$2,000	$500	$700
Industry Y	$1,000	$800	$300
Industry Z	$1,500	$1,000	$900

Table 12, called the direct input requirements matrix, reports the dollar for dollar linkage between all local industries. It is derived directly from Table 11. This direct input requirements matrix reports the direct dependencies between local industries. When creating a local model, an analyst must also incorporate other local institutions such as households and local governments. The I-O table would be expanded to include all local household and government expenditure and production to mirror the local economy. This expanded table (and thus expanded requirements matrix) would yield all local dependencies between industries, consumers and governments, allowing for the derivation of multipliers and the analysis of impacts from an initial change in final demand.

Table 12: Example I-O Direct Input requirements Matrix

	Industry X	Industry Y	Industry Z
Industry X	0.2	0.1	0.047
Industry Y	0.1	0.16	0.02
Industry Z	0.15	0.2	0.06

Early renditions of single region input-output models suffered criticisms for failing to consider inter regional feedbacks. Consider two distinct economies, engaged either directly or indirectly in regional trade. Suppose an exogenous change in final demand in region 1 requires purchases of intermediate inputs from region 2. Single-region I-O models treat these expenditure flows as leakages, dropping out of the system with no residual effects on the region. If however, production of the inputs in region 2, or resulting labor income expenditures from region 2 include purchases from region 1, aggregate region 1 impacts will be understated. This criticism is especially likely to hold in regions with considerable economic interdependencies.

Multi-regional I-O models are designed to more thoroughly gauge economic impacts of final demand changes within and between economies with significant interdependencies.[6] Their infrequent use can be attributed to the sparse availability of inter-regional trade flow data. However, recently, the Minnesota Implan Group (MIG) has developed a methodology that to generate inter-county trade flow estimates by incorporating county-to-county distances by transportation mode, ton-miles data by commodity and county imports and exports into a sophisticated gravity model[7]. We use their estimates of inter-regional trade flows given in Implan Version 3 to estimate inter-regional interdependency. Once the two regions are developed the trade flows are used to estimate impacts.

The level of inter-regional dependency is estimated by observing the impact that 1% Texas Region growth has on the Oklahoma Region. One model for each region is created and connected using the Implan trade flows. Extending the I-O linear technology to commodity imports, Texas Region commodity imports from Oklahoma are increased by 1%. This increase is introduced into the Oklahoma Region I-O model as a change to final demand for those commodities. Changes to production, employment and income occur as increased commodity demand leads to increased demand for inputs to production through multiple rounds of change. Additionally, feedback effects from the Texas region are incorporated as increased demand for Texas goods and services which then create increased income for Texas residents. This increased income leads to additional rounds of change to Oklahoma exports which creates additional local demand. This process continues until all changes are exhausted. This methodology is repeated to estimate similar impacts for the Texas region using a 1% Oklahoma Region growth assumption. Results from these scenarios are reported in Section 5.

[6] Interregional Input Output models are also referred to as multi regional input output (MRIO) models and can encompass any number of related regions.
[7] See Lindall et al (2006).

V. Study Results

The results are reported for 2 primary and 2 expanded regions and are detailed in 2 sections for simplicity. The first section discusses the impacts of Texas growth on Oklahoma based on a 1% increase in Texas imports of Oklahoma commodities due to a 1% increase in Texas production. The second section discusses the opposite case. In the second section the impact of 1% Oklahoma growth is estimated for Texas by implementing a 1% increase in Oklahoma imports from Texas. Both of these sections examine the primary OKCDFW regions as outlined in the previous sections of this document. Once these primary region impacts are derived, the regions are expanded to include a larger section of the I-35 Corridor in both Oklahoma and Texas. Impacts are then derived for the expanded regions.

Primary Region Initial Production

Initial primary region production values are listed in Table 13 for both OKCDFW regions. Based on Implan data, the Gross Regional Product of the TX Region is roughly 5.6 times more than the OK Region. The trade flow data indicate that the OK Region imports from the TX Region equal nearly 14% of it's Gross Regional Product while the TX Region imports from OK equal only 0.1% of it's Gross Regional Product. There are likely two reasons for the disparity between OK and TX region imports. First, as the TX Region has a larger population and GRP, it also has a greater variety of products and services and thus will naturally draw more purchases than the OK Region than vice versa. Second, the TX Region is surrounded by more large metropolises than the OK Region. Nearby the Dallas/Ft. Worth MSA has no less than 3 metropolitan trading partners (Austin, San Antonio and Houston) while the OKC MSA has only much smaller MSAs with which to trade.

Table 13: Initial Regional Production (Estimated)[8]

	Output	Imports from Other Region
OK Primary Region	$71,840,187,775	$9,915,598,130
TX Primary Region	$398,820,902,215	$3,933,414,583

Source: Implan

Expanded OK and TX Regions

The OKCDFW region provides a baseline for interdependency between the MSA poles of Oklahoma City and Dallas/Fort Worth. In this section these regions are expanded to provide a sense of the broader interdependency between Oklahoma and Texas along the I-35 Corridor. The OK region is

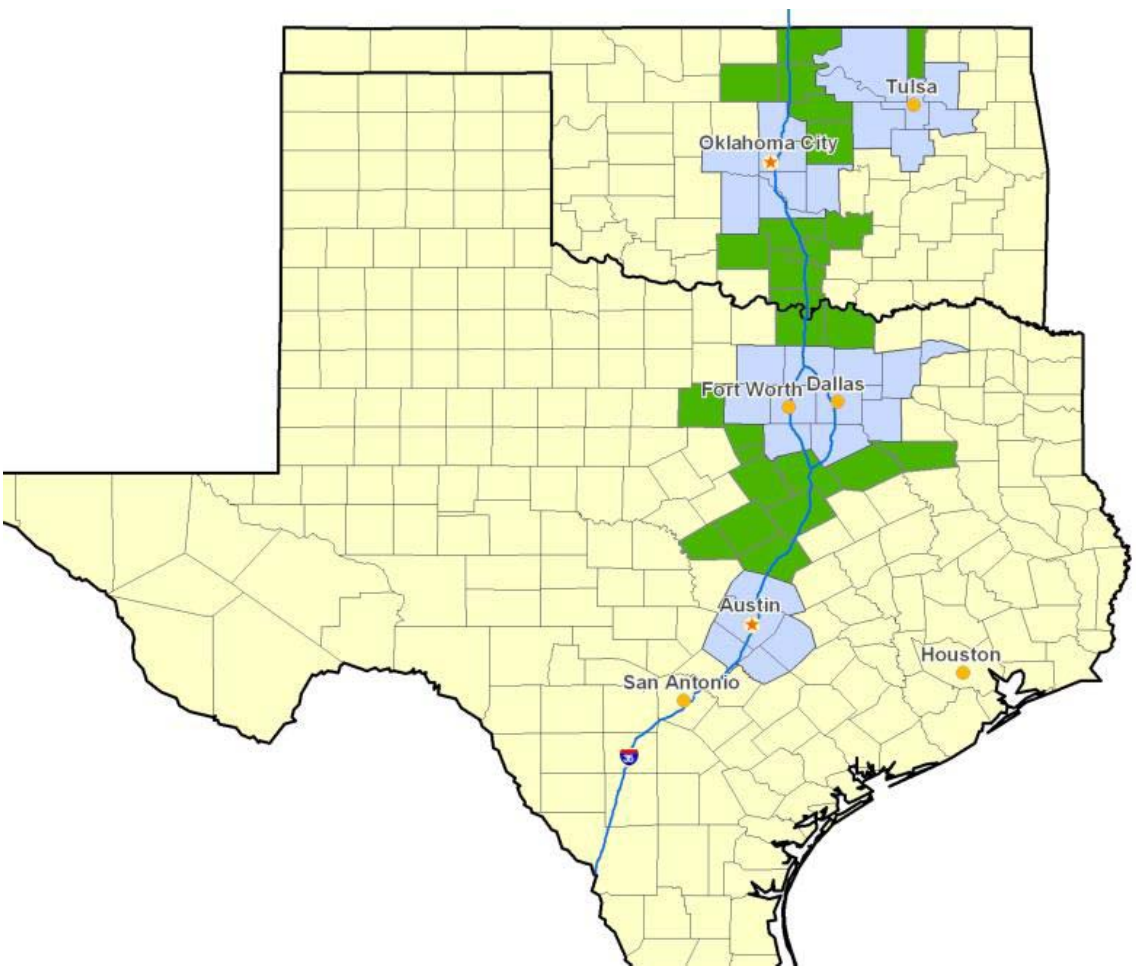
[8] Trade flow and Gross Regional Product (output) data for these regions do not exist. Production and trade flow data are estimates from Implan based on reported regional production and regional distance by method of travel.

increased to include all I-35 Corridor counties all the way to the Kansas border. This expansion brings the Tulsa MSA and a few other northern counties into the discussion. The TX region is expanded southward to include the Austin MSA.

By including these expanded regions, we can observe the broader interdependencies as growth occurs and impacts are disseminated away from the core/primary regions. These will be estimated first by expanding the region of growth and estimating the growth impact on the interdependent primary region. A number of experiments are implemented to estimate the impacts of each primary and expanded region combination. This provides a greater understanding of the nature of the regional interdependencies.

A graphical representation of the expanded experiment is given in Figure 4 and a detailed list of all included counties is given in Table 14.

Figure 4: Expanded OK and TX Regions



The light blue counties belong to the official Metropolitan Statistical Areas (MSAs) while the green counties are rural counties within the region. The expanded experimental region includes both the light blue and green counties.

Table 14: Primary and Expanded Region Counties	
Oklahoma Counties (26)	**Texas Counties (30)**
Primary OK Counties (14)	**Primary TX Counties (15)**
- Canadian	- Collin
- Carter	- Cooke
- Cleveland	- Dallas
- Garvin	- Delta
- Grady	- Denton
- Lincoln	- Ellis
- Logan	- Grayson
- Love	- Hunt
- McClain	- Johnson
- Murray	- Kaufman
- Oklahoma	- Palo Pinto
- Pontotoc	- Parker
- Potawatomie	- Rockwall
- Stephens	- Tarrant
	- Wise
Expanded OK Counties (12)	**Expanded TX Counties (15)**
- Creek	- Bastrop
- Garfield	- Bell
- Kay	- Bosque
- Noble	- Caldwell
- Okmulgee	- Coryell
- Osage	- Hays
- Pawnee	- Henderson
- Payne	- Hill
- Rogers	- Hood
- Tulsa	- Lampasas
- Wagoner	- McLennan
- Washington	- Navarro
	- Somervell
	- Travis
	- Williamson

Expanded Region Production

The OK Expanded Region produces 81% more goods and services than the primary region alone. Even still it produces only 1/3 of the goods and services that the TX Primary Region produces. It exports 41% and imports 32% more goods and services from the TX Primary Region than does the OK Primary Region.

The value of production for the TX Expanded Region exceeds that of the TX Primary Region by 29%. It exports 19% and imports 7% more goods and services from the OK Primary region than does the TX Primary Region. Total regional production characteristics are detailed in Table 15.

Table 15: Initial Expanded Region Production (Estimated)

		Imports from Other Region			
	Output	OK Primary	OK Expanded	TX Primary	TX Expanded
OK Primary	$71,840,187,775	n/a	n/a	$9,915,598,130	$10,647,503,037
OK Expanded	$130,145,875,335	n/a	n/a	$13,177,544,380	$14,215,024,613
TX Primary	$398,820,902,215	$3,933,414,583	$5,485,303,438	n/a	n/a
TX Expanded	$513,535,909,289	$4,678,814,305	$6,637,323,919	n/a	n/a

Source: Implan

OK Dependency on TX Growth

This section reports the estimated impacts of 1% Texas growth on Oklahoma. There are 4 experiments that are used to reveal the level of Oklahoma dependency on the Texas economy. For the first experiment the impact of TX Primary growth on the OK Primary Region is estimated by increasing the level of OK Primary Region exports to the TX Primary Region. This methodology continues the linearity assumption of the input-output structure by requiring that 1% TX production increases lead to 1% commodity imports from the OK Region.

There are 3 additional scenarios that are included in this section. The second experiment attempts to discover the level of dependency between the TX Primary Region and the OK Expanded Region. The 3rd and 4th experiments find the impacts of growth in the TX Expanded Region on the OK Primary and Expanded Regions. All results are given in Table 16 below.

Table 16: Impact of 1% TX Growth on OK			
1% TX Primary Region Growth	Output (GRP)	Employment	Labor Income
OK Primary Region	$56,348,672	281.73	$37,177,344
OK Expanded Region	$84,619,776	414.44	$47,200,512
1% TX Expanded Region Growth			
OK Primary Region	$66,597,760	327.79	$44,019,584
OK Expanded Region	$101,821,440	492.58	$56,702,464

According to the results, there is a significant regional linkage that exists between Oklahoma and Texas. The OK Primary Region receives an estimated $56 million worth of additional output when the TX Primary Region grows by 1%. This additional $56 million produces an extra 0.08% for the OK Primary Region's Gross Revenue Product. It also supports an additional 281.73 Full Time Equivalent (FTE) jobs with an added payroll of $37 million.

TX Primary Region growth effects extend further into Oklahoma as evidenced by the greater production increase in the OK Expanded Region. The effects of growth to the northern addition, while diminished are significant. This expanded region yields a 50% increase in GRP to $84.6 million, 414.44 FTE jobs and increases the payroll expansion to $47 million.

When the TX region is enlarged to the TX Expanded Region the results are more pronounced for both the OK Primary and Expanded Regions. The total GRP impact of the entire region is $101.8 million.

Upon further observation an interesting point appears. The TX Primary Region has a greater influence on the OK Expanded Region than the TX Expanded Region has on the OK Primary Region. When taken from a purely MSA perspective, one might conclude that there is a more significant linkage between Dallas/Ft. Worth and Tulsa than there is between Austin and Oklahoma City. There are three possible explanations. First is the simple fact that the there is a greater distance from Austin to Oklahoma City. Second, Dallas may have more significant trade with all nearby cities because of it's size and thus influence through a variety of industries. Third, Dallas and Tulsa may have a significant industry linkage that doesn't exist between Austin and Oklahoma City (i.e. perhaps Oklahoma City and Austin specialize in less related industries and therefore have less trade). Further research in this area is required.

TX Dependency on OK Growth

This section looks at the opposite case from the previous section. In the experiments that follow, TX regional exports to the OK regions are increased by 1% to estimate the impacts of 1% Oklahoma growth on Texas. The results from these experiments are reported in Table 17.

Table 17: Impact of 1% OK Growth on TX

1% OK Primary Region Growth	Output (GRP)	Employment	Labor Income
TX Primary Region	$173,652,992	877.17	$120,094,464
TX Expanded Region	$180,435,456	910.01	$121,052,928
1% OK Expanded Region Growth			
TX Primary Region	$233,034,240	1193.77	$151,707,136
TX Expanded Region	$243,331,072	1245.81	$153,245,184

As Table 17 details, the interdependency between Oklahoma and Texas flows in both directions. As the OK Primary Region grows by 1%, the TX Primary Region output increases by $173.7 million. This large dollar increase is likely due to both increased intermediate goods purchases as well as increased Oklahoma consumer demand for Texas goods. The increase is equal to approximately 0.04% of TX Primary Region GRP. It also leads to an employment increase of 877.17 FTE jobs and an additional $120 million in payroll.

As expected, the reach of OK Primary Region growth is diminished the further south the region is defined. Total TX Expanded Region production increases to only $180.4 million or 0.0035% of GRP.

Once again it appears that the linkage between Tulsa and Dallas is stronger than the interdependence between Oklahoma City and Austin as the increase in growth of the TX Primary Region due to growth in the OK Expanded Region is greater than the growth of the TX Expanded Region due to growth in the OK Primary Region. This result is to be expected given the results from the previous section. Again, this result is based on either the closer proximity of Tulsa to Dallas (rather than Oklahoma City and Austin) or the gravity effects of the large, diversified Dallas economy or the specific industry relationships that may exist between the two MSAs or perhaps some combination of all of these.

VI: Concluding Remarks

The states of Texas and Oklahoma share more than a common border – their economic fates are linked via undeniable trade flows. Significant trade imports from TX to OK indicate the value that OK residents place on goods and services from their neighbors and vice versa. With the increase in global economic activity, these two regions should look for areas of cooperation that will increase the productivity of the larger "mega-region" that they create. As Glaeser (2007) points out, there are areas for cooperation and competition between these two regions. As the U.S. population continues to migrate south and west, infrastructure projects that increase the competitiveness of the entire mega-region will increase the ability of the region to assimilate the growth and increase it's competitiveness.

This subject would benefit greatly from further study. Expanding the study region would provide a greater appreciation of the level of interdependency between these and other sub regions. Additionally, a deeper understanding of the multi-regional industry linkages would be helpful to explain the nature of the interdependencies which would provide insight into the viability and benefits of regional cooperation.

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[i] Data source: *Table 7. Cumulative Estimates of Population Change for Metropolitan Statistical Areas and Rankings: April 1, 2000 to July 1, 2008 (CBSA-EST2008-07)*, U.S. Census Bureau, Population Division