Are Center Cities the Engines of Growth for their Suburbs?

—Evidence from Virginia's Metropolitan Areas

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ABSTRACT

For decades, center cities of metropolitan areas were regarded as the growth engines of their suburbs. However, this paradigm has been shifting in the past twenty years in Virginia where suburbs have been growing faster than center cities. Consequently, there is a need in economic development communities to re-evaluate the economic relationship between center cities and their suburbs. This paper develops a statistical test to determine the cause-effect between these two economies and concludes that Virginia's cities are no longer the growth engines of their suburbs. The opposite is almost true: that suburbs are on the verge of becoming the leaders for city economic growth. To further the understanding of what drives city/suburban economy, the study also tests the cause-effect relationship between population growth and employment growth and finds that population growth still exerts a strong influence on employment growth. This knowledge can be useful in designing policies to promote the economic growth of both cities and suburbs.

Introduction

Economists advising economic development officials are often asked the following questions. Where should a region's economic development effort be focused on? Should it be concentrated on center cities or suburbs? Do jobs follow people or do people follow jobs? What options do economic officials have to accelerate the job growth of their regions?

To answer those questions, it is necessary to understand the economic interactions between center cities and their suburbs. For decades, center cities of metropolitan areas were regarded as the growth engines of their suburbs. However, recent data show that suburbs are growing faster in terms of both population and jobs. Take eleven Virginia metropolitan statistical areas (MSA) as an example. From 1990 to 2004, the average annual employment growth rate for center cities was 0.21%, while that of suburbs was 1.76% (BLS, 2005). Do cities still have strong influences on the economic well-being of their suburbs? Has the interaction paradigm between cities and suburbs shifted from city-leading-suburb to suburb-leading-city?

Several academic papers have addressed these questions empirically (Voith, 1992 and 1998; Brooks and Summers, 1997; Soli-Olle and Viladecans-Marsal, 2004). The general conclusion is that the growth of suburbs is positively related to that of center cities. However, a positive correlation does not imply that center cities are the engines of suburban growth. Both city and suburban economies are affected by macroeconomic trends, national policies, and business cycles, thus they can move in the same direction. In addition, even if the positive correlation reflects a causal relationship, it could be that suburban growth leads to city growth. Another possibility is that a positive correlation is the result of a bi-directional cause-effect relationship. In that case, cities can cause suburbs to grow and vise-versa. The purpose of this paper is to develop a statistical causality test to determine the existence and the direction of the cause-effect between center cities and their suburbs. Specifically, using data from 11 Virginia metropolitan areas spanning 15 years, Granger Causality Tests will be performed to reach that goal.

However, determining the economic relationship between center cities and their suburbs is not the only objective of the study. Finding the policy recommendations that can maximize the effect of the regional development effort is. After determining the cause-effect relationship between cities and their suburbs, consequent analysis will suggest how cities and suburbs can do to improve their economic performance.

This paper is organized as follows: The next section will describe the growth experience of Virginia's cities and their suburbs in the past 15 years. A simple correlation analysis will then be performed. Afterward, a series of Granger Causality Tests will be conducted to determine the economic relationships between center cities and their surrounding counties. Finally, this paper will discuss the policy implications of the causality tests and what cities and suburbs can do to promote their economic growth.

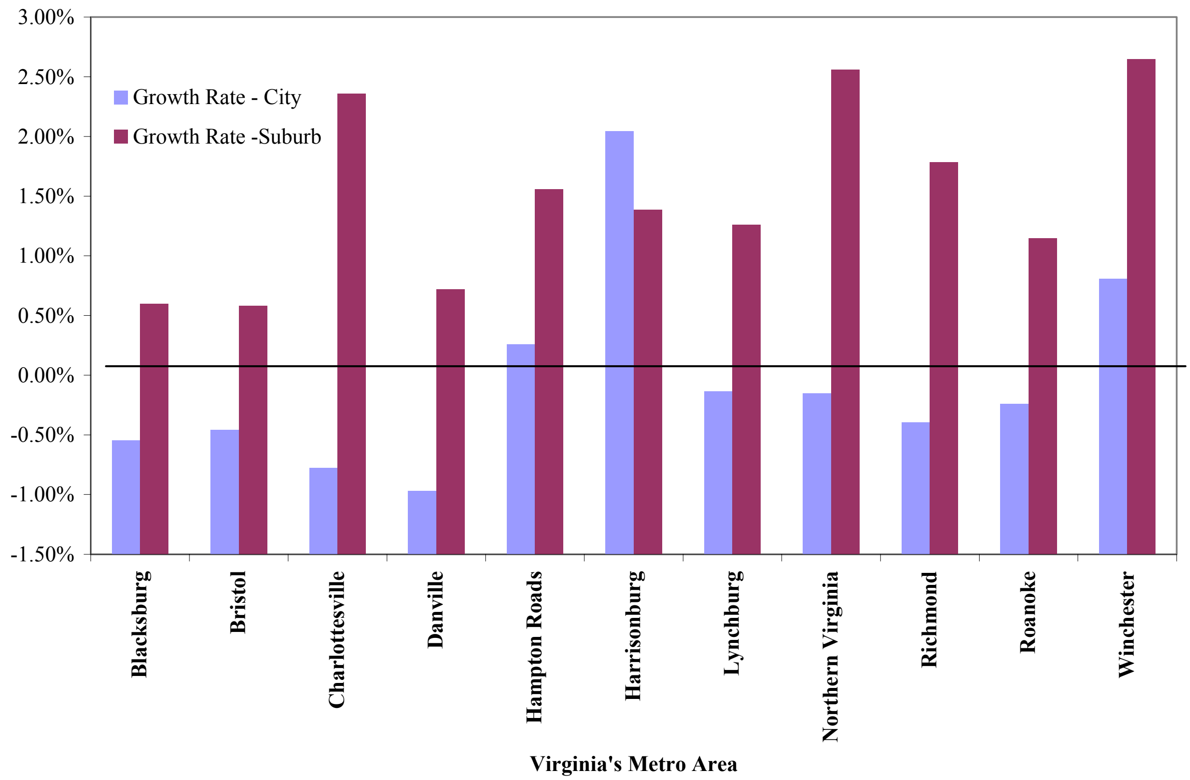
Economic Growth of Virginia Cities and their Suburbs

Virginia has 11 metropolitan statistical areas (MSA)[1]. To study the economic growth of them, the first task is to define a measure of economic activity. Following Soli-Olle and Viladecans-Marsal (2004), economic activity is defined as the size of employment in a locality. Economic growth is measured by the employment growth rate, which is of central interest in this study. This definition is consistent with practice since most economic development practitioners consider job creation their primary goals. But the definition is different from those in several

[1] Those 11 MSAs are: Blacksburg, Bristol, Charlottesville, Danville, Hampton Roads, Harrisonburg, Lynchburg, Northern Virginia, Richmond, Roanoke, and Winchester.

other studies. For example, Voith (1998) used per capita income to measure the economy of a locality. Per capita income is not an accurate indicator of economic activity because a person's place of work and place of residence are disconnected in a modern economy. High personal income of a locality does not translate into high economic activities. An upscale retirement community can boast high per capita income, yet it produces very little economic output. In addition, per capita income also includes transfer income, such as unemployment benefits or social security income, which is less indicative of the performance of a local economy.

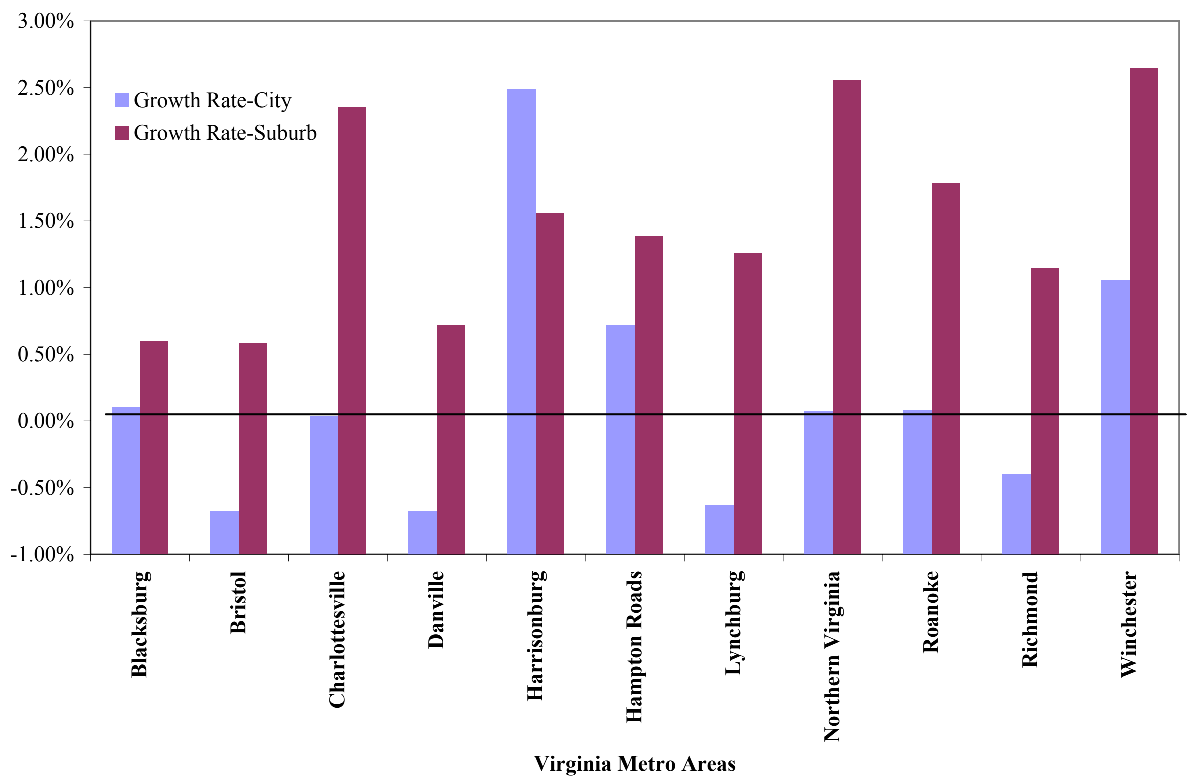
Figure 1: Annual Population Growth Rate of Center City and Suburb (1990-2004)



In Virginia, most cities and their suburbs took a divergent path in terms of population and economic growth in the past 15 years. As Figure 1 shows, suburban population growth outpaced that of center cities in all metropolitan areas except Harrisonburg. While all suburbs have experienced positive population growth, eight center cities lost population from 1990 to

2004. That leaves only three center cities gaining population during that time frame—Harrisonburg, Winchester, and Hampton Roads. Since Harrisonburg and Winchester are relatively small cities, and Winchester itself can be regarded as an outlying suburb of Washington D.C., the only significant population growth in the center cities occurred in Hampton Roads MSA. A high concentration of stable military establishments in the center cities of the Hampton Roads may prevent them from losing population. On average, the annual population growth rate of all Virginia's central cities was -0.02% from 1990 to 2004, while that of all suburbs was 1.97% (US Census, 2005).

Figure 2: Annual Employment Growth Rate of Center City and Suburb (1990-2004)



Job growth tells a similar story. Figure 2 shows the average employment growth rates of Virginia's center cities and their suburbs from 1990 to 2004. Except for Harrisonburg MSA, employment growth rates in all suburbs were higher than those of their central cities. While all suburbs achieved net job gains, four center cities lost jobs from 1990 to 2004. They are Richmond, Bristol, Lynchburg, and Danville. For example, the employment in the City of Richmond declined by -0.4% annually from 1990 to 2004, while jobs in its suburbs grew by 1.33% per year for the same period. In addition to those four cities with negative job growth, there was virtually no employment growth in the center cities of Blacksburg, Charlottesville, and Roanoke. On average, the annual employment growth rate of all Virginia's central cities was 0.21% from 1990 to 2004, while that of all suburbs was 1.76% (BLS, 2005). The past growth experience makes it difficult to argue that cities are the engines of suburban economic growth while the cities themselves are shrinking or growing slowly.

Correlation between City and Suburban Employment Growth

Table 1 presents the correlation coefficients between the employment growth of Virginia's center cities and their suburbs from 1990 to 2004. Employment growth rates of cities and their suburbs are positively correlated for all metropolitan areas except Danville and Charlottesville. Danville's negative correlation is not significant and only Charlottesville's negative correlation is significant at 95% confidence level. Among 9 metropolitan areas where growth rates of cities and suburbs are positively correlated, 7 of the correlation coefficients are significant at the 95% confidence level. When all areas are pooled together, the correlation coefficient is 0.24, significant at 95% confidence level. The statistics suggest that for most Virginia's metropolitan areas, the employment growth of center cities and their suburbs move in the same direction. These correlation results are consistent with the findings by Voith (1998) and Soli-Olle and Viladecans-Marsal (2004). Both studies found positive and significant correlations between the economies of cities and their suburbs. They concluded that the economic growth of cities and their suburbs are not substitutes, but complement each other.

Table 1: Correlation Coefficient of Employment Growth of Center Cities and Suburbs (1990-2004)			
MSA	Correlation	Growth Rate-City	Growth Rate-Suburb
Blacksburg	82.74%*	0.10%	0.93%
Bristol	67.78%*	-0.68%	0.45%
Charlottesville	-60.87%*	0.04%	1.47%
Danville	-27.98%	-0.67%	0.86%
Harrisonburg	30.57%	2.49%	1.67%
Hampton Roads	65.88%*	0.72%	1.87%
Lynchburg	77.16%*	-0.63%	0.65%
Northern Virginia	65.76%*	0.08%	2.19%
Roanoke	70.84%*	0.08%	1.12%
Richmond	67.34%*	-0.40%	1.37%
Winchester	5.72%	1.05%	2.66%
Average	24.80%*	0.21%	1.76%

Note: * Significant at 95% confidence level

Correlation analysis suggests that for most of Virginia's metropolitan areas, the employment growth of cities and suburbs tend to move in the same direction. However, that does not imply that cities are the engines of suburban economic growth. There are several relationship patterns between cities and their suburbs that could result in a positive correlation. For example, the growth of both cities and suburbs can be affected by macroeconomic trends, or federal and state economic policies. Consequently, they tend to have a positive correlation without causing each other to grow. Another scenario is that suburbs can be the growth engines of center cities, which will also result in a positive correlation. The last possibility is that the cause-effect between cities and their suburbs are bi-directional. City growth can affect part of suburban growth and vice versa. In that scenario, there is no leader or follower in a city-suburb relationship, yet they all influence each other, which results in a positive correlation. To determine the exact economic relationship between Virginia's cities and their suburbs, a causality test needs to be performed.

General Approach to Causality Testing

There are several approaches to determine the causality between two variables. Soli-Olle and Viladecans-Marsal (2004) used a Vector Error Correction (VEC) model to determine cause-effect between the economies of Spanish cities and suburbs. Their tests require a longer time frame than the available Virginia data. This analysis uses the Granger Causality Test proposed by Granger (1969) to evaluate the economic relationship between Virginia's cities and their suburbs.

Let superscript *S* indicate suburbs and *C* indicate center cities. Let Y^S be the employment growth rate of suburbs, and Y^C be the employment growth rate of central cities. To determine whether Y^C Granger-causes Y^S involves using an F-test to determine whether the past information of Y^C provides any statistically significant information about Y^S in the presence of lagged Y^S.

Mathematically, assume a particular autoregressive lag length is *p*. To test whether Y^C causes Y^S involves estimating the following two equations, one with lagged Y^C, and one without.

(1) $$Y_t^S = c_1 + \sum_{i=1}^{p} \alpha_i Y_{t-i}^S + \sum_{i=1}^{p} \beta_i Y_{t-i}^C + u_t$$

(2) $$Y_t^S = c_2 + \sum_{i=1}^{p} \gamma_i Y_{t-i}^S + e_t$$

where c_1 and c_2 are constant terms, and μ_t and e_t are error terms. The null hypothesis can be written as:

(3) $$H_0 : \beta_1 = \beta_2 = ... = \beta_p = 0; \ \Rightarrow \ Y^C \text{ does not cause } Y^S$$

The F statistics can be calculated as:

(4) $$f = \frac{(RSS_0 - RSS_1)/p}{RSS_1} \sim F_{p,T-2p-1}$$

where $RSS_1 = \sum_{t=1}^{T} u_t^2 \qquad RSS_0 = \sum_{t=1}^{T} e_t^2$

If the calculated F-test score is greater than the specified critical value of an F distribution with *(p, T-2p-1)* degrees of freedom, the null hypothesis is rejected and it should be accepted that that Y^C Granger-causes Y^S.

Model Specification

This section addresses the issues of model specification and justifies the specific model forms used in Granger Causality Tests.

Specifically, to test whether city employment growth causes suburban employment growth, the following two equations are estimated in this study:

(5) $$Y_t^S = c_1 + \alpha_1 Y_{t-1}^S + \beta_1 Y_{t-1}^C + u_t$$

(6) $$Y_t^S = c_0 + \alpha_0 Y_{t-1}^S + e_t$$

In addition to test whether center cities cause the suburban economies to grow, a test is also performed to determine whether the reverse relationship is true. That is whether suburban employment growth causes that of city centers. To test that hypothesis, the following two equations are estimated:

(7) $$Y_t^C = c_1 + \alpha_1 Y_{t-1}^C + \beta_1 Y_{t-1}^S + u_t$$

(8) $$Y_t^C = c_0 + \alpha_0 Y_{t-1}^C + e_t$$

Due to the relatively short time frame, when causality tests are repeated for Virginia's individual metropolitan area, none of those tests yields conclusive results with respect to the economic relationship between a specific center city and its suburbs. As a result, only pooled models are estimated.

When all metropolitan areas are pooled together, it is possible that the heterogeneity among different regions may warrant panel data treatment, such as using a fixed effect model or a random model. However, if those metropolitan areas are proved to be similar, several regions can be pooled together without a panel data specification (Soli-Olle and Viladecans-Marsal, 2004). As a result, a specification test of heteroscedasticity is performed with null hypothesis being that error terms are homogenous. The resulting χ^2 -test score for Equation (5) is 1.5 with a P-value of 0.91, indicating that there is little heteroscedasticity among error terms[2]. Consequently, the study pools all Virginia metros together in estimating the model and performing the causality tests without panel data techniques.

Since testing the economic relationship between cities and their suburbs is the major objective of this study, the models in this study do not include an exhaustive set of variables that could impact the employment growth of a city or its suburbs. Those factors can include climate, demographic structure, regional policies, and infrastructure (Carlino and Mills, 1987). The omission of those variables will not bias the estimates of β, since the lagged value of Y^S is included in Equation (5). If any of the location specific variables mentioned above are important in determining the employment growth of suburbs, the effects of those variables should be captured to a certain degree by the lagged Y^S_{t-1}. The coefficient β only captures the additional effect of city employment growth (Y^C) on suburban employment growth.

Before settling on the final model specification as in Equation (5) and (6), the study experimented with two and three order of auto-regressive lags. More lagged terms did not improve model performance while causing the model to lose a significant amount of degrees of freedom. For example, when 2 auto-regressive lags were included in Equation (5), R^2 only

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[2] The χ^2 -test score s for Equation (5, 6, 7, 8) are listed in Appendix 1.

improves from 0.02 and 0.03, yet the model lost 11 degrees of freedom. The loss of degree of freedom tends to render the model less effective. As a result, only one order of auto-regressive lag is selected.

Many studies have argued that city and suburban employment are determined simultaneously (Soli-Olle and Viladecans-Marsal, 2004). As a result, any model specification needs to be mindful of the simultaneity issue. Voith (1998) used an instrument variable method to solve this problem. The difficulty in instrument variable methodology is that it is hard to find a variable that only affects the growth of one part of a metropolitan area, but not the other. Using lagged city employment growth in Equation (5) solves the simultaneity issue, because Y^S_t and Y^C_{t-1} cannot be simultaneously determined.

Since time series data are used, another concern in model estimation is the auto-correlation among error terms. The Durbin-Watson tests are performed to detect the magnitude of any auto-correlation. For example, the Durbin-Watson test score for Equation (5) is 1.717, indicating that there is little auto-correlation among error terms[3].

In summary, those specification tests indicate that error terms in Equation (5) and (6) are well behaved, with little auto-correlation and heteroscedasticity. Those tests justify using Ordinary Least Square (OLS) method throughout this study.

Causality between City and Suburban Employment Growth

The coefficient estimates of Equation (5, 6, 7, and 8) are listed in Table 4 in Appendix 1. For suburban employment growth models (Equation 5 and 6), the only significant variable is intercept. The lagged city employment growth (Y^C_{t-1}) has virtually no effect on the employment growth of suburbs. For city employment growth models (Equation 7 and 8), however, the results

[3] The complete test scores for Equation (5,6,7,8) are listed in Appendix 1, Table 4.

are different. Lagged employment growth of suburbs (Y^S_{t-1}) has a positive effect on the city employment growth. The coefficient estimate is 0.2147, with a t-value being 1.51. This estimate is marginally significant, indicating that if employment growth rate increases by 1 percentage point in suburbs, the job growth in cities will increase by 0.2 percentage point one year later.

However, R^2 for each of the four equations is very small, suggesting that there are other factors influencing the employment growth of both center cities and suburbs. Compared with some other studies, the small R^2 is not surprising, as employment growth is very difficult to model. For example, in a study of economic growth of over 3000 US counties, Calino and Mills (1987) utilized an extensive set of variables, and only achieved an R^2 of 0.05 in their model of employment growth rate, and 0.13 in their model of population growth rate.

The F-test scores for the Granger Causality Test are listed in Table 2. In terms of whether city employment growth causes that of suburbs, the F-test score is only 0.34, with a P-value of 0.56, implying that the null hypothesis cannot be rejected. It can be concluded that city employment growth does not cause suburban employment growth.

Table 2: Causality Test on Employment Growth Among Center City and Suburbs

			Effects on	
			Y^S	Y^C
Effects From	Y^S	F-Test P-Value		2.28 (0.13)
	Y^C	F-Test P-Value	0.342 (0.56)	

For the hypothesis that whether suburban employment growth causes that of center cities, the F-test score is 2.28, with a P-value of 0.13. This result is not conclusive. If 95% confidence level is used as a criterion for acceptance or rejection, the null hypothesis should be accepted. However, the F-test score is close to being significant. If the confidence level is relaxed to 85%, the null hypothesis can be rejected, and the conclusion should be that suburban employment growth causes city employment growth. Even though we cannot reach the conclusion that suburban growth is a cause of city growth with a high level of confidence, it is safe to say that suburban economic growth has a bigger impact on that of center cities than the other way around.

The borderline significance of this F-test score is consistent with the pattern of paradigm shift. Hypothetically, as the relationship of city/suburban economic growth is evolving from city-leading-suburb to suburb-leading-city, the effect of cities on suburbs is gradually weakened, and the effect of suburbs on cities becomes stronger. Yet the transition is not complete and a causality test is not able to detect a definite leadership role for suburbs. If the trend continues in the near future, the impact of suburbs will be more pronounced and suburbs may become the undisputable economic leaders of center cities.

The Virginia results are slightly different from previous studies by Voith (1998) and Soli-Olle and Viladecans-Marsal (2004). Voith found that center cities had positive effect on the growth of suburban income, population, and housing values. As mentioned before, his measure of economic activity is per capita income, which is not an accurate indicator of the economic activity of a locality. In addition, his sampling frame is from 1970 to 1990, when suburbs have not experienced the explosive growth such as that in Virginia in the 1990s. These reasons may contribute to the fact that he reached a different conclusion.

In a study of economic relationships between Spanish cities and their suburbs, Soli-Olle and Viladecans-Marsal (2004) found a bi-directional cause-effect pattern. They found out that the employment growth of both center cities and suburbs are caused by that of their counterparts. Due to their excellent public transit systems and high population density, unlike many American cities, European cities still maintain their roles as population centers. It is not surprising that European cities have strong influence on the economic well-being of their suburbs. Even their study has acknowledged the fast suburbanization process in Europe and the possible paradigm change, because their model detects that suburbs are having significant impacts on the economy of center cities in Europe.

Policy Implications

The Virginia data show that center cities are no longer the engines of suburban growth. There is significant evidence that suburbs are on the verge of becoming the economic leaders of center cities. The paradigm has shifted in terms of the economic relationship between cities and their suburbs.

What are the practical implications of this paradigm shift? What can cities do to reverse the declining trend in their population and jobs? It is simply not practical to recommend city economic officials to wait for their suburbs to grow, and to enjoy the effect afterwards. It is necessary to find causes for city economic growth other than suburban employment growth and derive policy actions around those causes.

The reasons that center cities lost their growth engine status are due to the population losses and the suburbanization process starting in the 1950s. Many studies have found convincing evidence supporting the "jobs-follow- people" hypothesis (Hoogstra et al, 2005). To verify that point, a Granger Causality Test is performed to test the cause-effect relationship between economic growth and population growth for Virginia's metropolitan areas. The model specification and coefficient estimates are listed in Appendix 2. The models show that suburban population growth has a positive and significant effect on the employment growth of suburbs. For example, a one percentage point increase in suburban population growth can lead to 0.4

percentage point increase in suburban employment growth. Similarly, city population growth also has a strong impact on the employment growth of cities. One percentage point of population growth can lead to 0.7 percentage point increase in the employment growth of cities.

Table 3: Causality Test on Employment Growth and their Populations Growth

			Effects on	
			Y^S	Y^C
Effects From	P^S	F-Test P-Value	6.08 (0.014)	0.86 (0.358)
	P^C	F-Test P-Value	3.94 (0.048)	30.4 (<0.005)

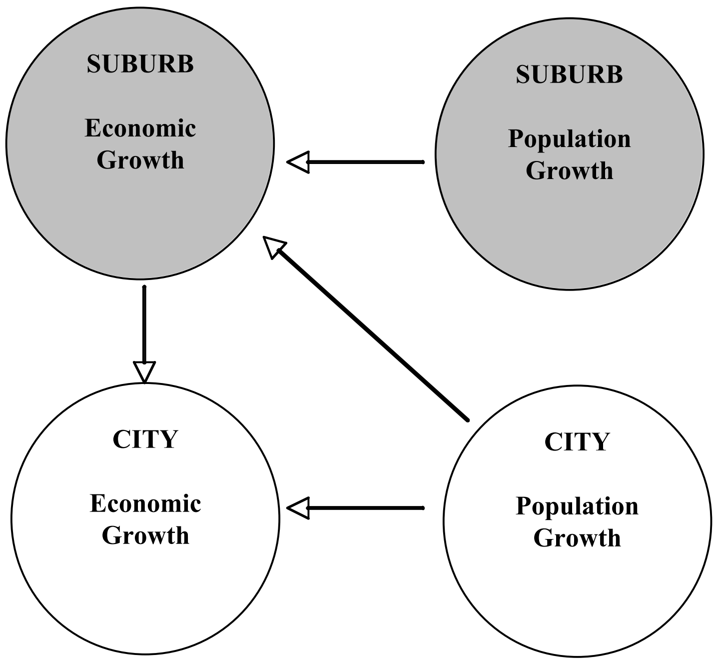
The F-test scores for Granger Causality Tests (Table 3) confirmed that population growth causes the employment growth for both center cities and their suburbs. Suburban population growth can cause suburban employment growth, with an F-test score of 6.08. Similarly, population growth of center cities also causes city employment growth, with an F-score of 30.4. In both tests, the null hypothesis is rejected at the 95% confidence level. Those results indicate that for Virginia's cities and their suburbs, jobs follow people.

These results are associated with the structural change of the U.S. economy. At the same time of suburbanization, the U.S. economy has also transformed from a manufacture-dominated economy to a service-dominated economy (Vias, 1999). Based on 2004 data, the largest sector in Virginia economy in terms of employment is retail, accounting for 12% of the total workforce. In addition, 8% of total workers are in accommodation and food service industries, 9% are in healthcare, and 9% are in construction. However, only 9% of Virginia's total employments are in manufacturing (BLS, 2005). Service jobs such as retail, healthcare, and construction tend to locate close consumers, while manufacturing jobs are located close to suppliers, highways or available lands (Wu, 2000). That is why more and more jobs are following people.

Granger Causality Tests also show that city population growth has a significant impact on suburban employment growth, with an F-test score of 3.94, significant at 95% confidence level. These findings reflect the lifecycles of city residents. Many young city residents will move to suburbs after they are married and have children. As city population grows, so is the out-migration to suburbs, which can bring more jobs to suburbs. The result is that city population growth becomes a cause for suburban employment growth. However, the reverse is not true. Suburban population growth has no effect on city employment growth, with an F-test score of only 0.86. The reason is that there is no significant population migration from suburbs to cities. Even though recent demographic trends have shown that empty-nesters and retirees are moving back to cities, the numbers are not big enough for suburban population growth to become a driver for city job growth. The overall interaction patterns between cities and their suburbs are illustrated in Figure 3, where arrows represent the causality directions.

For cities, the findings point to an economic development strategy that is to make cities more livable. If cities cannot attract and retain their residents, current retail and service jobs eventually will leave. What makes cities more appealing to potential residents? It is generally accepted that younger and more educated people prefer cities (Feridhanusetyawan and Kilkenny, 1996). In addition, people with fewer children also like city residence, while married people probably have higher preference to suburban areas. Previous research has also shown that people care about education and property tax when choosing their residence (Feridhanusetyawan and Kilkenny, 1996). To retain their residents, cities can increase their investment in education without raising property tax rates, which should help prevent married couples from leaving cities. This is a tough position since this means cities have to seek increased education funding somewhere else other than from property tax revenues. In addition, investing in cultural and entertainment establishments can speed up the process of active adults returning to cities.

Figure 3: Interaction Patterns Between Cities and Suburbs



Another direction for city economic development is to be more discriminating in bringing businesses to center cities. They should target industries that do not closely follow consumers, such as business services and consulting, business management, and corporate headquarters. Incentives should not be given to retailers or consumer service businesses in cities. Those funds can be invested in education or urban revitalization projects.

For suburbs, the priority should not be attracting retails or consumer services industries either, because those jobs will come as long as population continues to grow, which seems to be the case in the near future. However, spending on highways provide a significant effect to draw people to more rural areas, rather than cities (Feridhanusetyawan and Kilkenny, 1996). That is one way to promote more job creation in suburbs by investment in transportation networks. Just because suburbs are growing faster than cities does not mean that suburbs should not care about city growth because city population growth does have a spill-over effect on suburbs.

Conclusion

This paper finds that Virginia's center cities are no longer the engines of growth of metropolitan areas. The job growth of center cities lags behind suburbs, and has no significant effect on suburban employment growth. However, the causality test indicates that suburban economy is on the verge of becoming the leader of city economy. This is a significant paradigm shift in regional economic development. Since Virginia is rather typical state, these results can be replicated for other states.

The study also discovers that population growth of both cities and suburbs have strong influence on their employment growth. The study supports the "jobs-follow-people" hypothesis in regional development due to the continuous transition of the U.S. economy to a service-dominated one. Moreover, city population growth has a significant effect not only on city employment growth, but also on suburban employment growth. One key initiative for cities to improve their economies is to attract and retain residents by investing in education. Another recommendation is to focus on targeting industries that do not follow residents closely, such as corporate headquarters and business services.

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Appendix 1: Coefficient Estimates of Equation (5,6,7,8)

Table 4: Coefficient Estimates of Equation (5, 6, 7, 8)				
	Equation (5)	Equation (6)	Equation (7)	Equation (8)
Explanatory Variable	Y^S	Y^S	Y^C	Y^C
Intercept	0.01263 (6.46)*	0.01251 (6.45)*	-0.0002 (0.08)	0.00276 (1.08)
$Y^S_{(t-1)}$	0.10148 (1.18)	0.11389 (1.37)	0.21469 (1.51)***	
$Y^C_{(t-1)}$	0.03029 (0.58)		-0.02752 (0.32)	0.00449 (0.05)
Number of Observation	143	143	143	143
R^2	0.016	0.013	0.016	0
χ^2 Test for Heteroscedasticity	1.50	0.04	5.47	3.78
P-value of χ^2	(0.91)	(0.98)	(0.36)	(0.15)
D-W Test Score	1.717	1.745	1.689	1.709
Note: number in paramphasise indicates t-value *, **, *** Indicates significance at 95%, 90% and 85% Confidence Level				

Appendix 2: Model Specification for Granger Causality between Employment Growth and Population Growth

To test whether city population growth causes city employment growth, the following two equations are estimated:

(9) $$Y_t^C = c_1 + \alpha_1 Y_{t-1}^C + \beta_1 P_{t-1}^C + u_t$$

(6) $$Y_t^C = c_0 + \alpha_0 Y_{t-1}^C + e_t$$

To test whether suburban population growth causes suburban employment growth, the following two equations are estimated:

(10) $$Y_t^S = c_1 + \alpha_1 Y_{t-1}^S + \beta_1 P_{t-1}^S + u_t$$

(8) $$Y_t^S = c_0 + \alpha_0 Y_{t-1}^S + e_t$$

To test whether city population growth causes suburban employment growth, the following two equations are estimated:

(11) $$Y_t^C = c_1 + \alpha_1 Y_{t-1}^C + \beta_1 P_{t-1}^S + u_t$$

(6) $$Y_t^C = c_0 + \alpha_0 Y_{t-1}^C + e_t$$

To test whether suburban population growth causes city employment growth, the following two equations are estimated:

(12) $$Y_t^S = c_1 + \alpha_1 Y_{t-1}^S + \beta_1 P_{t-1}^C + u_t$$

(8) $$Y_t^S = c_0 + \alpha_0 Y_{t-1}^S + e_t$$

The estimations of Equation (9), (6), (10), and (8) are listed in Table 5. The estimation of Equation (11), (6), (12), (8) are listed in Table 6.

Table 5: Coefficient Estimates of Equation (9,6,10,8)				
Explanatory Variable	Equation (9)	Equation (6)	Equation (10)	Equation (8)
	Y^S	Y^S	Y^C	Y^C
Intercept	0.00695	0.01251	0.00286	0.00276
	(2.35)*	(6.45)*	(1.23)	(1.08)
$Y^S_{(t-1)}$	0.05598	0.11389		
	(0.66)	(1.37)		
$P^S_{(t-1)}$	0.4179			
	(2.47)*			
$Y^C_{(t-1)}$			-0.01394	0.00449
			(0.18)	(0.05)
$P^C_{(t-1)}$			0.78106	
			(5.52)*	
Number of Observation	143	143	143	143
R^2	0.05	0.0132	0.1786	0
χ^2 Test for Heteroscedasticity	1.26	0.04	13.26	3.78
P-value of χ^2	(0.94)	(0.98)	(0.02)	(0.15)
D-W Test	1.64	1.745	1.745	
Note: number in parentheses is t-value				
*, **, *** indicates significance at 95%, 90% and 85% Confidence Level				

Table 6: Coefficient Estimates of Equation (11,6,12,8)				
	Equation (11)	Equation (6)	Equation (12)	Equation (8)
Explanatory Variable	Y^S	Y^S	Y^C	Y^C
Intercept	0.0132	0.0125	0.00676	0.00276
	(6.77)*	(6.45)*	(1.35)	(1.08)
$Y^S_{(t-1)}$	0.0661	0.11389		
	(0.77)	(1.37)		
$P^S_{(t-1)}$			-0.26405	
			(0.93)	
$Y^C_{(t-1)}$			0.02426	0.00449
			(0.28)	(0.05)
$P^C_{(t-1)}$	0.1910			
	(1.99)*			
Number of Observation	143	143	143	143
R^2	0.0402	0.0132	0.1786	0
χ^2 Test for Heteroscedasticity	2.19	0.04	7.71	3.78
P-value of χ^2	(0.82)	(0.98)	(0.17	(0.15)
D-W Test	1.824	1.745	1.753	1.709
Note: number in parentheses is t-value				
*, **, *** indicates significance at 95%, 90% and 85% Confidence Level				