Community Resilience through Innovation Networks: An Agent Based Approach

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Abstract. Innovation has been a major focus for economic research on urban areas. Innovation also has the potential to increase prosperity in rural areas. In this paper, we look at the effect of community innovation networks on community resilience using a network simulation model. In our model communities face stochastic labour-reducing technical change, but they also have a stochastic pool of job-creation opportunities which community actors discover and exploit at a rate that depends on community network structure and local information. Drawing on results showing that community networks may innovate more efficiently than the industrial networks typical of industrial forestry, we examine the evolution of a stylized community system consisting of community forests and industrial forestry firms. We conclude that community innovation networks combined with community forestry as a form of tenure may be a powerful mechanism to increase the resilience and economic prosperity of rural communities.

Keywords: community, networks, resource, rural, innovation, forestry, resilience

1 Introduction

In the early part of the 21st century, forestry communities in Canada are threatened by migration, technological change in the forestry industry, declining transportation and communication costs , climate change, competing products and changing markets. Mills have shut down and forest communities are losing jobs and people [1]. If they are to survive these communities must find ways to create new livelihoods, industries, and jobs. They must innovate.

We have shown in previous simulation studies [5, 4, 7, 8] that the network structure of communities influences the capacity to innovate. The network structure sustained by industrial forestry and its accompanying tenure system is less able to exploit local resources, including local talents than the network structure that we argue would be associated with community forestry.

The result of previous work provides the maintained hypothesis for this study. We explore how a small advantage in innovation capacity can affect the survival of individual communities and the evolution of a stylized community system consisting of community forests and industrial forestry firms.[1]

We consider communities distributed on a on a line. This is a time-honoured spatial modelling technique going back at least to Hotelling's 1929 location model of firms on a line [2] that was used to explore the relationship between location and pricing behaviour of firms. Where Hotelling has a uniform fixed population of consumers and allows firms to choose locations on the line, we fix community locations and allow the population to choose locations. Steven Salop [6] introduced a refinement of the Hotelling model that we use here. We make the first and last communities neighbours. Our 20 communities are therefore distributed evenly around a circle. One dimensional models in this family can produce most of the important results found in full 2-dimensional models, but they facilitate visualization of the results.

At the start of the simulations communities are the same size. They are subject to uniform technological change that reduces their labour requirements, plus a normally distributed random population change. The base case is therefore one in which communities decline.

We then introduce a very simple migration model. People are move from smaller communities to larger neighbouring communities at a rate that depends on the difference in community sizes. This formulation generates the well known tendency or population to agglomerate. Several mechanism have been used to account for the observed tendency toward agglomeration in forestry regions. One is that assumed economies of scale lead companies to shut down smaller plants in favour of larger operations. If we begin with his view, migration can be seen a a consequence of technological change.

An alternative explanation is rooted in central place theory - larger centres support a larger variety of services, and these services attract people. Declining transportation costs for consumers may lead them to spend a steadily increasing share of their income in larger communities. Economies of scale also give larger retailers located in larger centres a cost advantage. The larger population base might provide stronger support for existing industries or encourage new businesses to develop. A closely related explanation suggests that the increasing efficient scale of public facilities like schools and hospitals leads to closures and declining amenity level in small communities, making them less able to hold young people and seniors.

Migration and shifting economies of scale are mutually reinforcing. We are not concerned to provide a precise explanation of the intra-community migration process. We focus on the effect of a slight increase in business formation that could result from a shift to community control of local forests. Our previous work suggests that such an increase would occur: we offer a simple model that reveals the likely results at the regional level.

[1] We use R for these simulations. R is a free and open-source statistical package widely used and universally available. The source code is included as an appendix to permit verification of our results and to encourage extensions.

2 The Parameter Space

Any model of this sort represents a dynamical system with a collection of stock variables and laws of motion for the stocks. The ‘parameter space’ for the model is simply the set of numerical values that specify the laws of motion. The results that are derived from a model of this sort are simply characterizations of the typical behaviour of the model for specific parameter settings. A simulation study is map of possible outcomes projected onto the parameter space.

In this case the stocks are simply 20 communities with initial populations set arbitrarily at 10. Changes are all specified as proportions. The distribution of forest community sizes in Northern Ontario seems to centre near 1000, so it is convenient to think of each unit as 100 people.

Table 1. default

parameter	value	description
x	10	initial community size
b	-0.15	bias of random population change
v	0.15	rate of innovation in community forests
sd	.15	standard deviation for Gaussian population change
m1	0.05	influence of nearest neighbour on migration
m2	0.01	influence neighbour’s neighbour on migration
MIN	2	minimum community size
innovate	0.15	rate of innovation in community forests

We assume that the migration process has a constant absolute negative bias, b, consistent with Canadian research by Polése and Shearmur [3] We imagine a period as a census period of 5 years. We assume that there is a random component to the regional population change. In the base model this component is normally distributed with a standard deviation of sd=0.15. The communities lose b=0.1 or 10% of their population in each period.[2]

We explicitly model inter-community intra-regional migration, assuming that if a neighbouring community is larger, then a fraction of the population of the reference community will move to the larger community. We put an arbitrary but small minimum on community size on the assumption that every area has some features to keep some people in place. We assume that more distant communities do not affect the local outmigration.[3] We make the rate of migration depend on the difference in community size. A signed community-specific attraction factor,

[2] This rate is probably too high, but the effect is simply to speed up the simulation. It is likely that larger communities lose population more slowly than smaller ones, but the stability threshold appears to be near 100,000 and the communities we are considering have populations around 1,000. so we ignore this effect.

[3] A general rate of outmigration is built into the downward bias of the random changes.

α, ranges from minus one to one as as the difference in size between communities increases. Inter-community migration is then $\alpha m1$ times the population above the minimum size for nearest neighbours and $\alpha m2$ of the second nearest neighbour. regionsl structure is affected by the choice of m1 and m2

3 Results

1. With no negative bias and no difference in innovation capacity there is a long period during which a hierarchy of communities resembles the pattern predicted by central place theory emerges. The model eventually results in one quarter to one third of the communities absorbing almost all the population. After a number of cycles of random movement the larger communities basically eat their neighbours. The result is driven entirely by inter-community migration.
2. With a negative bias and no difference in innovation capacity ($v = 0$) the model generates a hierarchy of community sizes with a declining overall population. Successful communities survive longer by eating their neighbours, but eventually decline.
3. With a negative bias and an innovation rate half the size of the downward bias only the innovating communities survive. Non-innovating communities decline rapidly. In the middle term a hierarchy of community sizes emerges. In the long run even innovating communities decline to the minimum population level. This represents what might be seen as moderate success for community forests if our maintained hypothesis is correct,
4. With a negative bias and an innovation rate equal to the downward bias, most innovating communities grow as long as they can continue to cannibalize neighbours. Depending on the strength of the inter-community attraction, non-innovating communities may also grow at first by cannibalizing neighbours, including unlucky innovators, but they eventually decline. With m2 positive, Successful innovators eventually devour nearby innovators as well.
5. With an negative bias and and innovation rate greater than the downward bias, innovating communities grow indefinitely after consuming non-innovating neighbours. The growth rate is the difference between the technologically given downward bias and the innovation rate.

4 Conclusions

This model has illustrated how local innovation networks may affect not just the network structure, but ultimately the survival of communities. The model uses population distribution within communities distributed on a line, and subject to stochastic labour-reducing technical change. It begins with the established tendency of populations to consolidate into larger centres, and identifies the level of innovation required for sustaining communities given these pressures. The result is at once simple and robust. With an innovation mechanism that

Table 2. Major regimes

	$b > 0$		$b = 0$
$v = 0$	**2** population declines		**1** hierarchy emerges, small communities are eaten, population steady
$v < b$	**3** population declines innovators dominate and survive longest		
$v = b$	**4** Population declines initially then stabillizes innovators grow and dominate. Some are eventually eaten.		
$v > b$	**5** innovating communities grow indefinitely after consuming non- innovating neighbours.		

exceeds the regional rate of population loss, communities not only survive but thrive.

The advice to policy makers based on this model is that for the survival of northern communities, they must find an innovation strategy that generates employment faster than technological change removes jobs. In the case of northern communities, the natural place to look is community forestry, which increases the scope for innovation and gives communities the power to innovate with the primary regional resource [4, 7]. Community forestry should be considered as part of any strategy for regional resilience and prosperity.

References

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Appendix: Code for simulation

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# # # # # # # # # # # # # # # # # # # # # # # # # # # Community Resilience through Innovation Networks: An Agent Based Approach
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# # # # # # # # # # # # # # # # # # # # # # # # #
# PARAMETERS
T<- 100; # Number of periods (ROWS)
v<- 0.1; # 0.15;# Rate of innovation in community forests. If zero all communities are identical
b<- -.1 # bias of random population change
sd<- .15 # standard deviation for random change
m1<- 0.05;# influence of neighbours on migration. nearest .25
m2<- 0.025 # influence of neighbours on migration. Next nearest. People flow from larger to smaller .1
MIN<- 2; # minimum community size
MAX<- 20; # maximum community size
# GRAPH FORMAT
sleep<- .5 ; # delay in presenting bargraphs. in seconds
loggraph<- ”y”;# the vertical axis in logs
ymax=50 # Maximum population for the graph
MIN<- 2; # minimum community size
MAX<- 20; # maximum community size
CF<- as.numeric(c(rep(c(0,1),10))); # Designate Community Forests. Any N vector of zeros and 1s will do.
N<- 20 # number of communities (Columns in the data matrix D)
x<- as.numeric(rep(10,N));# Initial values of community size
A<- c(N-1,N,1:N,1,2); # Neighbour list. This creates a ring that allows us to identify 2 neighbours on either side.
# # # # # # INITIALIZE MATRIX
D = data.frame(matrix(vector(), T, N)); # Sets up data matrix for communities over time
D[1,]<- x; # initializes the matrix
# # # # # PLOTTING
colors<- vector(mode=”character”, length=N);
colors<- c(”red”,”green”, # Colors ”red”,”green”,”red”,”green”, ”red”,”green”,”red”,”green”, ”red”,”green”,”red”,”green”, ”red”,”green”,”red”,”green”, ”red”,”green”)
J<- 1# initialilze image to step through the sequence
# # # # # Core code
# We can add a term to make innovation depend on size for (t in 2:T)
D[t,]<- (D[t-1,]+rnorm(N,b,sd)+v*CF); for(i in 1:N)
forced2<- (D[t-1,i]-D[t-1,A[i+0]]) /(MAX-MIN) ;
forced1<- (D[t-1,i]-D[t-1,A[i+1]]) /(MAX-MIN) ;
forceu1<- (D[t-1,i]-D[t-1,A[i+3]])/(MAX-MIN) ;
forceu2<- (D[t-1,i]-D[ t-1,A[i+4]]) /(MAX-MIN) ;
```

signed fraction representing the ratio of difference in community size to hypothetical maximum difference

d1 refers to the first neighbour on the downside, u on the upside

D[t,i]<- D[t,i]+m1*forceu1*(min(D[t-1,i],D[t-1,A[i+3]])-MIN) + m2*forceu2*(min(D[t-1,i],D[t-1,A[i+4]])-MIN) +

m1*forced1*(min(D[t-1,i],D[t-1,A[i+1]])-MIN)+

m2*forced2*(min(D[t-1,i],D[t-1,A[i+0]])-MIN);

if (D[t-1,i]¡=MIN) D[t,i] <- MIN ; # effect of differences

PLOT

for (t in 1:T)

barplot(as.numeric(D[t,]), log=loggraph, space=2, col=colors, ylim=c(1,ymax), main=paste("Evolution of Community Size: t=",t,sep=""),

sub=paste("Community Forest Towns green and Industrial Forest Towns red:
n Innovation rate= ", v,", bias =",b, "
n, immediate neighbour attraction =", m1, ", second neighhbour attraction =", m2,sep=""),

cex.main=1.5, ylab="population proportional to export value"); abline(h=10, lty="dashed");

J<- J+1; Sys.sleep(sleep);#

END