FIRST MICRO-SIMULATION MODEL OF A LEDDA COMMUNITY CURRENCY-DOLLAR ECONOMY

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ABSTRACT

Results are presented for a first-in-class microsimulation model of a local-national currency system. The agent-based, stock-flow consistent model uses US Census income data as a starting point to project the evolution of local currency (community currency) and dollar flows within a simplified county-level economy over a period of 28 years. Changes in the distribution of family income are tracked. The community currency system under investigation is the Token Exchange System (TES), a component of the larger Local Economic Direct Democracy Association (LEDDA) framework under development by the Principled Societies Project. The model captures key design features of a TES, and results suggest parameter ranges under which the simulated TES is capable of achieving stated aims. Median and mean take-home family income more than double during the simulation period, income inequality is nearly eliminated, and the unemployment rate drops to a 1 percent structural level. The need for more sophisticated modeling of a TES, and avenues of future research, are discussed.

ABBREVIATIONS USED

ACE: Agent-based computational economic (model); *AGI*: Adjusted gross income; *CBFS*: Crowd-Based Financial System; *LEDDA*: Local Economic Direct Democracy Association; *LFNJ*: LEDDA-funded new job; *NIWF*: Not in workforce; *SFC*: Stock-flow consistent (model); *T&D*: Tokens plus dollars; *TES*: Token Exchange System; *TSI*: Token share of income.

1. INTRODUCTION

This paper examines characteristics of the Token Exchange System (TES), a novel local-national currency system proposed as one part of the larger Local Economic Direct Democracy Association (LEDDA) framework. The LEDDA framework is under development by the Principled Societies Project [Principled Societies Project 2014], an organization founded by the author. The framework integrates ideas from buy local, invest local, local currency, local food, local sharing, open source, open government, open data, participatory democracy, Internet of Things, smart cities, and related community development, knowledge transfer, data-sharing, and decision-making initiatives. The complete LEDDA framework is described in the book *Economic Direct Democracy* [Boik 2014].

Local currency systems, also known as community or complementary currency systems, are growing in popularity and exhibit a wide range of program designs and characteristics [Martignoni 2012, Schroeder et al. 2011, DeMeulenaere and Flode 2014, Lietaer and Dunne 2013]. Many local currencies are designed to flow in parallel with their respective national currencies.

Throughout this paper, terms specific to the US economy and political geography are used (e.g., "dollar" and "counties"), but this is for convenience only and the framework is intended for a global audience.

The proposed local electronic currency, called the *token*, flows in parallel with the dollar. Together the two currencies define a token-dollar economy. Because of the complexity of the complete LEDDA framework, the TES is not a simple local currency system. It is more akin to an integrated economic—financial—business—social welfare system.

The Token Exchange System is examined through computer simulation modeling. The model presented is illustrative rather than predictive. It is intended to describe currency flows in a TES under simplified, idealized conditions, not to forecast flows in a real setting. The aims of this paper are to: (1) introduce the LEDDA framework and TES; (2) describe some general concepts of token-dollar flow; and (3) demonstrate that a stock-flow consistent illustrative model of token and dollar flow can be parameterized such that every LEDDA-member family receives a direct income gain over baseline in every year, and the membership eventually achieves full income equality and full employment.

Because the model is illustrative, no claim is made that similar results can be produced in a real LEDDA. Nevertheless, the model has value. It conveys broad, low-resolution design intentions for actual TES dynamics. And it serves as a steppingstone toward future, more sophisticated versions. Stock-flow consistency rules out certain flaws in design logic at the modeled resolution and opens the door to higher-resolution studies.

To offer some degree of realism, dollar flows at the start of the simulation resemble those of a real county economy, and conditions evolve from this base. For example, starting income levels resemble real income levels, and tax rates resemble real tax rates. Thus, initial conditions are said to be *semi-realistic*.

1.1. LEDDA, Token Exchange System, and income equality

While the focus of this paper is on the Token Exchange System, some background on the LEDDA framework can provide context. A LEDDA is a membership-based, community development association open to all individuals, businesses, nonprofits, public service agencies, and other organizations in an area (e.g., city, county, or multicounty region). For convenience, and unless otherwise specified, the term *member* refers to an individual who voluntarily joins a LEDDA. That some organizations also choose to become members is implied.

Members manage their local LEDDA framework. The framework implements *LEDDA economic direct democracy*, a system of organization that acts as an overlay to the local economy. The stated purpose of the framework is to maximize member well-being and benefit the global public. In some respects, a LEDDA is akin to a sophisticated smart cities initiative that includes economic democracy as a component. A LEDDA maximizes well-being in part by more efficient use of resources and in part by providing new opportunities for democratic decision-making within the economic sphere. Members engage with the community, aided by new social, economic, and information opportunities.

In LEDDA economic direct democracy, the token and, by extension, the dollar function in part as voting tools. One arena for token-dollar voting is the LEDDA financial system, called the *Crowd-Based Financial System (CBFS)*, a novel type of mandatory crowdfunding system. Because money is viewed as a voting tool, the LEDDA framework is designed to achieve a high degree of income equality over time. In this way, all members gain roughly equal decision-making power over their token-dollar economy.

1.2 Modelling approach

The simulated token-dollar economy (the modeled world) comprises five aggregate agents, termed *Persons, Government, CBFS, Organizations*, and *Rest-of-Counties*. All agents pertain to the county in which the LEDDA exists, except Rest-of-Counties, which represents all other US counties. The Organizations agent represents all for-profit businesses and nonprofit organizations. The Government agent represents local accounts for state and federal governments. The CBFS agent represents the LEDDA financial system. The Persons agent represents the set of all individuals in the county. Each person and family is modeled individually, which allows for changes in income distribution to be tracked over time. In addition, *LEDDA* and *County agents* exist for convenience; they hold summary information about a LEDDA and its county, but are not part of the simulation itself.

All agents together form a closed economic system, meaning that no flows of tokens or dollars cross into or out of the defined system. Accounting equations ensure that flows of tokens and dollars from any one agent are recorded as receipts by others. The stocks of these are also recorded. The model is an abstraction and simplification of a county token-dollar economy. Conditions in a real token-dollar economy would be more complex.

Although the simulation model is simple (abstract, aggregate agents; limited decision-making power by individuals), it nevertheless exhibits core characteristics of both an agent-based computational economic (ACE) microsimulation model and a stock-flow consistent (SFC) economic model. As such, it can be considered an elementary ACE/SFC microsimulation model. (A microsimulation model tracks events at a detailed resolution.)

The ACE approach provides flexibility in modeling complex, real-world economies. Agents (persons, businesses, aggregate businesses, etc.) interact according to a set of predefined rules. ACE microsimulation models can output rich data, including income distribution, making them well suited for income inequality studies. Moreover, because ACE models can capture dynamic, emergent patterns of economic activity, they are suitable for study of non-equilibrium conditions. Seppecher, for example, uses an ACE model to investigate the role of minimum wage on economic stability [Seppecher 2012]. On the down side, ACE models tend to be computationally expensive, both in run time and memory requirements, compared to the more common equilibrium and systems dynamics models. A resource for ACE models is maintained by Tesfatsion [Tesfatsion 2014].

Stock-flow consistent models have two components: (1) an accounting system that ensures currency stocks and flows are internally consistent, and (2) a set of behavioral equations that influence how the flows, and thus the stocks, change over time [Caverzasi and Godin 2013, Lavoie and Godley 2012]. Typically, SFC models are used to study national macroeconomic conditions. In this paper, the approach is applied to a county-level token-dollar economy. Investigators have beneficially combined ACE and SFC approaches. For example, Riccetti, Russo, and Gallegati use a combined ACE/SFC model to examine market interactions [Riccetti et al. 2012].

To the author's best knowledge, this paper describes the first-ever ACE/SFC model of a local-national currency system in which initial conditions are semi-realistic. Several groups study aspects of community currency systems using equilibrium or systems dynamics models. Stodder uses an equilibrium model to assess the counter-cyclical nature of trading activity of the Swiss WIR, a national complementary currency [Stodder 2009]. Peruta and Torre use an equilibrium model to assess the capacity of a Local Exchange Trading System (LETS) to maintain skill levels for the unemployed [Peruta and Torre 2013]. Groppa uses a systems dynamics model to examine the mechanics of money issuance in a generic local-national currency system [Groppa 2013]. Eren explores long-term stability of a generic local-national currency system using a systems dynamics model [Eren 2012].

Two groups study aspects of community currency systems using agent-based simulation models. Kichiji and Nishibe develop a buyer-seller network to examine transaction efficiency within a LETS [Kichiji and Nishibe 2012]. Saito, Morino, and Murai develop a manufacturer-consumer network to examine the effect of free riders (players who strategically fail to repay debts) on the stability of mutual credit systems [Saito et al. 2006]. The networks in both models examine focused, limited characteristics of a community currency system.

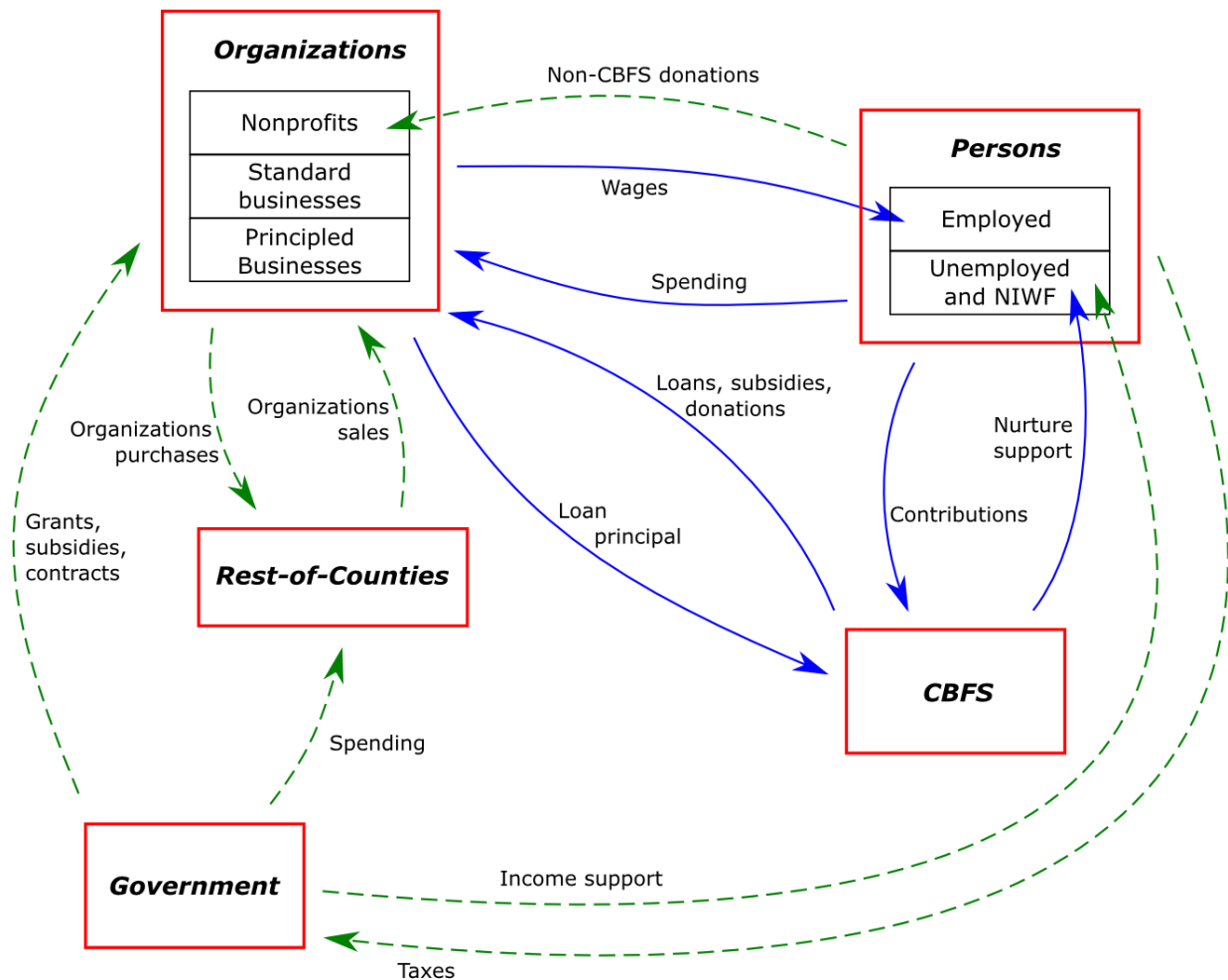## 2 THE SIMULATION MODEL

2.1 Architecture of agents and flows

The simulation tracks stocks and flows of tokens and dollars among five aggregate agents, as illustrated in Figure 1 (below). For simplicity, only a limited set of agents and flows is considered. Thus, the agents and flows depicted in Figure 1 constitute the foundational set of model assumptions. For example, banking, local government, and foreign agents do not exist in the modeled world. Further, individuals do not purchase goods from Rest-of-Counties; all trade with outside counties occurs through Organizations as the intermediary.

Organizations in Figure 1 is divided into three subtypes: nonprofits, standard businesses, and Principled Businesses. Nonprofits can include schools, colleges, public service agencies, and charitable organizations. A Principled Business is formed according to a socially responsible business model, unique to the LEDDA framework, that blends characteristics of nonprofit and for-profit models. A standard business is a for-profit business that is not a Principled Business.

Persons is divided into two subtypes: employed and unemployed/not-in-workforce (NIWF). Unemployed persons are adults in the workforce who do not hold jobs. NIWF persons are those who do not participate in the workforce. These can include elderly and disabled persons, adults who stay home to take care of children, and non-working spouses. Nationally, about 37 percent of the adult population is NIWF [Bureau of Labor Statistics 2014b].

Although not depicted in the figure, Persons can also be divided into LEDDA members and non-members. Likewise, some fraction of Organizations is also in the membership. Only members (individuals and organizations) receive and spend tokens, and interact with the CBFS. Every member who is a person and who receives tokens must contribute a designated amount of dollars and tokens to the CBFS.

The CBFS is not an investment-for-profit system. It is a profit-neutral mechanism used to fund those organizations that members choose to support. Additionally, it funds income assistance for those members who are unemployed or NIWF. Although not modeled here, in a real LEDDA

Figure 1: Flows of tokens and dollars (blue solid lines) and dollars only (green dotted lines) among simulation agents

members would retain substantial power over their CBFS contributions. True to the crowdfunding approach, each member would decide which CBFS applicants (organizations) to support, and at what amount. The four arms of the CBFS—donation, subsidy, loan, and nurture—offer a flexible mechanism by which members shape their token-dollar economy.

Using the CBFS, members provide funding to for-profit organizations in the form of subsidies and interest-free loans, both in tokens and dollars. Similarly, members provide funding to nonprofit organizations in the form of donations and interest-free loans. Thus, the CBFS also acts as a savings mechanism for tokens and dollars; contributions made to the lending arm of the CBFS can later be recovered for personal use, given certain restrictions, and minus any losses caused by loan default. Last, members use the nurture arm of the CBFS to provide income assistance, as previously noted. In actuality, the CBFS would fund nonprofit organizations to administer income assistance programs, rather than providing assistance directly to individuals.

To keep the model simple, numerous other assumptions are made about agents and flows. First, demographics and the dollar economy apart from token-dollar flow serve pri-

marily as a static backdrop. Only flows and conditions directly related to LEDDA activities exist in the modeled world. Thus, for example, inflation, normal economic growth, normal savings and investment, birth and death of individuals, and income and job changes for non-members do not exist. While variables such as inflation, GDP growth, and expansion of the national dollar supply might be important for a model that is intended to make forecasts about the dollar economy, such predictions are not the aim here.

Additional simplifying assumptions include the following:

- The NIWF population is static; people do not switch from NIWF to employed or unemployed status. This is conservative, however, as about 7 percent of NIWF persons desire work [Bureau of Labor Statistics 2014a].

- Residents of County, all of whom are adults, are grouped into two-person families. Household income and family income are synonymous.

- The purchasing power of the token is equal to that of the dollar.

- The structural unemployment rate is assumed to be 1 percent. Full employment occurs when the structural unemployment rate is achieved.

- All employed persons work full time. Normal raises for employees do not exist in the modeled world.

The simulation period is divided into one-year steps. The tracked variables are: (1) income and job changes for individuals who become members; and (2) stocks and flows of tokens and dollars for each aggregate agent. To provide a somewhat higher resolution, certain stocks and flows are tracked for subtypes within the CBFS and Organizations agents.

2.2 Virtuous growth cycle

To achieve Aim (3) of this paper, the model must be designed such that every member family receives a direct income gain over baseline in each year, and a set of parameters must be defined such that full income equality and full employment are eventually achieved for the membership. These requirements, along with the demands of stock-flow consistency, limit the set of admissible rules for governing token-dollar flow. Note that by achieving Aim (3), one can roughly state that a LEDDA pays individuals to become members. Income gain is viewed as one factor that expands the membership over time.

Aim (3) is achieved by defining a virtuous growth cycle, driven largely by a participation function and three model constructs: the income target, token share of income (TSI) target, and Wage Option.

The flows depicted in Figure 1 can be compacted into just four repeating steps, which together form a virtuous cycle: (1) Organizations creates new tokens, as needed, and via a buy local program adjusts the inter-county trade balance to obtain dollars, as needed; (2) the tokens and dollars gained by Organizations are used to increase wages and salaries; (3) individuals share income increases with CBFS; and (4) CBFS funding creates new jobs and provides income assistance for unemployed and NIWF members. This cycle repeats each year, and as it does, more tokens are created and circulate locally, more dollars are retained to circulate longer in the local economy, member incomes rise, member unemployment drops, and a higher fraction of unemployed and NIWF members receives income assistance. Regarding Step 1, existing local currency systems already demonstrate the capacity to inject a substantial volume of money into a local economy, and studies on buy local initiatives suggest a substantial capacity to alter a city's trade balance [Civics Economics 2013, De la Rosa and Stodder 2013].

The virtuous cycle is a simplification of what would occur in a real LEDDA. For example, tokens would not be created (or destroyed) by organizations, but by the LEDDA as a whole acting through its (direct democracy) governance system. A LEDDA can create as many tokens as it can productively use, limited by inflation concerns. Also in a real LEDDA, organizations would not channel 100 percent of token and dollar aggregate gains to employee raises; some

portion would be retained for business expansion and improvement.

The token creation process has similarities to and differences from the usual dollar creation process. Both tokens and dollars are created by fiat. Dollars, however, are created primarily by banks; banks loan dollars into existence via interest-bearing debt [McLeay et al. 2014]. Tokens are created without debt and are distributed to members (individuals and organizations). This centralized mechanism of local currency creation/destruction differs, for example, from the issuance of credit by individuals in mutual credit systems [Greco 2009].

In relation to the CBFS, individuals act as pass-through agents. That is, as token-dollar incomes rise, members keep a portion of their gains and contribute the remainder of gains to the CBFS. Thus, a distinction is made between pre-CBFS income—income prior to CBFS contributions—and post-CBFS income—pretax income after CBFS contributions have been made. One can think of post-CBFS income as pre-tax, take-home income. To clarify Aim (3), income gains and income equality refer to post-CBFS income. For non-members, income and post-CBFS income are synonymous and do not change.

2.3 Model constructs

The first construct, the income target, is a series of annual token-plus-dollar (T&D) pre-CBFS personal incomes, defined by a monotonically increasing (non-decreasing) income function. In a real LEDDA, the form and parameterization of the income function would be chosen by the membership before the first token is issued (and adjusted over time by the membership as needed). It represents a planned income expansion used by member organizations to calculate wages and salaries for certain member employees.

The second construct is the Wage Option. During the simulation, individual members and their families make a limited set of decisions. The primary decision is a family's choice of Wage Option. Two options are available, and at the beginning of each year each member family chooses the one that most increases its post-CBFS income.

In Wage Option 1, the pre-CBFS income of each person in the family matches the current-year income target, and each person's CBFS contribution is based on a percentage of that target. In Wage Option 2, the pre-CBFS income of each person in the family matches his or her *base income* (or baseline, Year 0, initial income) plus an incentive bonus paid in tokens. Each person's CBFS contribution for Wage Option 2 is based on the same percentage used in Wage Option 1, but applied only to the incentive bonus.

To see how this works, consider a member family in which base incomes are $30,000 and $40,000. Suppose that the current-year income target is 40,000 T&D, the bonus is 3,000 tokens, and the CBFS contribution rate for both Wage Options is 0.5 (50 percent). Then this family will choose Wage Option 2. By doing so, its post-CBFS income is 73,000

T&D, a gain of 3,000 T&D over baseline. If it chose Wage Option 1, its post-CBFS family income would be only 40,000 T&D, a loss of 30,000 T&D.

Suppose some years later that the income target has risen to 80,000 T&D. Now the family will choose Wage Option 1. By doing so, its post-CBFS family income is 80,000 T&D, a gain of 10,000 T&D over baseline. If it chose Wage Option 2, its income would remain at 73,000 T&D.

In the case where only one person in a family is a member, Option 2 is required. This is to prevent the situation where a family benefits most by having only one person join a LEDDA. If the current-year income target is high, and if one person in a family has a very low base income while the other has a very high base income, then the family might benefit most by keeping the high-earner out of membership and having the low-earner join and choose Wage Option 1. Said another way, if the low-earner joins first and chooses Wage Option 1, and in a later year the high-earner joins, then the family might experience an unacceptable year-to-year income loss through participation.

The Wage Option system provides a direct gain in post-CBFS income over base for every member family in every year. Even a family whose base income is extremely high could receive an income gain via the incentive bonus, as per Wage Option 2. However, in the case of a high-earning family, the bonus might be minor relative to its base income. It is assumed for the simulation that relative income gain acts as a determinant of participation. Specifically, a family post-CBFS income gain of at least 3 percent over base is needed to provide sufficient motivation for membership. As will be seen, the income function is chosen such that families at the 90th percentile of base income see a 3 percent income gain via Wage Option 1. The set of families at or below the 90th percentile of base income is called the *target population*; eventually all families in this set join the LEDDA and choose Wage Option 1 because they have motivation to do so.

The third construct is the TSI target. Token share of income is the fraction of income paid as tokens, with the rest paid in dollars. The TSI target is a series of annual TSI values defined by a monotonically increasing TSI function. Like the income function, the form and parameterization of the TSI function for a real LEDDA would be chosen by the membership before the first token is issued. The TSI target is used by member organizations to calculate the token-to-dollar ratio for wages and salaries that it will pay to those employees who choose Wage Option 1. Also, the TSI target is used (with some modification) to calculate the token-to-dollar ratio for CBFS contributions for both Wage Options.

For simplicity, the income, TSI, and participation functions are defined here as piecewise linear functions of time. The first 15 years of the simulation are termed the *growth period*. During this period the three functions increase. The subsequent 13 years are called the *post-growth period*. During this period the three functions are constant. In total, the simulation period spans 28 years. By Year 28, most vari-

ables tracked have reached an asymptote and are essentially static.

A real LEDDA could choose any monotonic form for the income and TSI functions, within reason. For example, it could choose a sigmoidal form, where fastest growth occurs in the middle years. The meaning of the simulation results shown here would not change appreciably, however, if a nonlinear form had been used. Further, it is quite reasonable that a LEDDA would choose linear forms. Whatever the choice, it is not made in a vacuum. By the time a real LEDDA is ready to choose income and TSI functions, simulation models more sophisticated than the current one would be available to provide assistance.

In a real LEDDA, the participation function might depend on multiple variables. One could be the rate of income rise (due to the income function). Another could be base income distribution; in the United States there are far more people in lower income brackets than in higher brackets. Another factor could be the reach of the public relations and education campaigns that encourage membership. Yet another factor could be the characteristics of existing social networks; a person might be more likely to join if a close friend, spouse, or colleague has already joined. Still another factor could be the degree of civil interest within the community; persons who are civic-minded might be more inclined to join a LEDDA compared to those who are not. In the current model, a simple piecewise linear participation function of time is assumed. One could think of this as a crude approximation to the multivariate function that would in reality drive participation.

It is important to understand that the virtuous cycle described in Section 2.2 is not dependent on the goodwill of employers to give raises, or on the goodwill of employees to share gains with the CBFS. Steps (2) and (3) of the cycle are contractual in nature, aided by the transparency of currency flow and framework function, and dependent upon pre-defined income and TSI functions and Wage Options. In a real LEDDA, any employer having difficulty meeting its obligations could apply to the CBFS for funding assistance. Further, CBFS contributions would be paid automatically as members receive wages and salaries; contributions would not be made at the end of year.

2.4 Generation of base incomes

Income data for Year 0, the year before tokens are introduced, are generated by sampling 2011 US Census microdata files for Lane County, Oregon [Ruggles et al. 2010]. In 2011, Lane County mean and median household incomes were $53,049 and $40,584, respectively [U.S. Census 2014]. The average household size was two adults. National mean and median 2011 household incomes were higher, at $65,253 and $47,198, respectively, when adjusted to a two-adult household [U.S. Census 2014]. Mean Lane County household income is also lower than the mean of all US county means. In this respect, Lane County is typical. Just as income inequality exists between households, viewed na-

tionally, inequality also exists between counties (see appendix).

The preliminary step in the simulation is to generate a population of individuals and families. This is done by specifying an adult population size (10,000, 20,000, and 100,000 persons); a labor participation rate (65 percent); an initial unemployment rate (7 percent); and a fraction of employees who work for nonprofit organizations (7 percent). A virtual individual is generated and binomial probability functions are used to randomly assign workforce/NIWF status, employed/unemployed status (for those in the workforce), and nonprofit/standard business employer status (for those who are employed).

An income for each employed individual is generated by randomly sampling the set of Lane County income data above a certain threshold ($10,050 annually). Similarly, an income for each unemployed and NIWF individual is generated by sampling the set of income data below the threshold.

Finally, individuals are grouped into families. For simplicity, assignments are random. This means that incomes of family members are unrelated, a condition not likely to be met in real life. If assignment had produced a positive association between spouse incomes, the generated family income distribution would have had thicker tails—somewhat more families would have very low incomes because both individuals would be low earners. Likewise, somewhat more families would have very high incomes because both individuals would be high earners.

But such an association would not substantially alter the meaning of results produced. First, the generated population is representative, by some measure. The threshold income value mentioned previously was chosen so that family mean and median incomes in the generated population closely match those published for Lane County. Second, initial unemployment and NIWF rates are realistic. Third, regardless of the shape of the income distribution, 90 percent of families will fall into the target population and eventually become members. Fourth, in the simulation, job creation and membership growth occurs independent of families who have base incomes above the 90th percentile.

As previously mentioned, the dollar economy apart from token-dollar flow is held at a snapshot. Prior to the introduction of tokens in Year 1, all agents are in equilibrium and all variables are static; no agent accumulates dollars, and incomes of individuals do not change. This is verified by running the simulation for a three-year burn-in period prior to Year 1.

2.5 Token and dollar stocks and flows

Numerous model parameters influence the stocks and flows of tokens and dollars. It is useful to divide these into "general" and "TES-specific" parameter sets, as listed in Tables 1 and 2 of the appendix. Values for general parameters are chosen only to create semi-realistic conditions. The simulation model is not particularly sensitive to these pa-

rameters, and the meaning of simulation results would not markedly change if one or more were altered (but still kept within somewhat realistic bounds). General parameters include, for example, those used to generate base incomes, mentioned previously. They also include government spending rates, tax rates, the risk of job loss, the cost of new jobs, and the rate of donations to nonprofits apart from CBFS contributions.

In contrast, TES-specific parameters can potentially have a large and meaningful impact on token and dollar flows. The most important of these are parameters for the piecewise linear income, TSI, and participation functions, and the CBFS *earmarks*, fractions of income or incentive bonus that must be contributed to the different arms of the CBFS. TES-specific parameters were fine-tuned by trial and error so that Aim (3) of the paper is achieved.

Other choices for TES-specific parameters might have resulted in substantially different results. The fine-tuning process was easy, however. Only a few trial-and-error attempts were needed to achieve Aim (3), and the trials suggested a small number of almost obvious rules of thumb, discussed later. Thus, the model was not particularly sensitive even to the TES-specific parameters, as long as some simple rules of thumb were followed.

The simulation model is also not sensitive to certain structural modifications. For example, results of similar meaning could be obtained using only three agents: Persons, Organizations, and CBFS. Further, flows could be simplified by eliminating donations to nonprofits apart from the CBFS. If such a "bare bones" structure were used (only the solid blue lines in Figure 1), Organizations, rather than Rest-of-Counties, would run a dollar deficit. But the meaning of simulation results would not appreciably change. The structure illustrated in Figure 1 is employed to offer a more realistic picture of a county economy.

2.6 Agents

The CBFS agent has four arms: loan, subsidy, donation, and nurture. One or more earmarks exist for each. The nurture arm provides income support for some (and by Year 28, all) NIWF and unemployed members. Such support is called a *nurture engagement.* Each year, a growing percentage of the NIWF member population receives nurture support, as CBFS funds allow. Once support is given, it is maintained for the duration of the simulation. Members who lose a LEDDA-funded new job (LFNJ)—a job created through CBFS funding—receive nurture support until they obtain another LFNJ.

The Persons agent holds summary information from the generated population. Individuals donate dollars to local nonprofits at a fixed rate (2 percent of dollar income), apart from the CBFS. These are called *non-CBFS dollar donations* to distinguish them from CBFS contributions.

The Organizations agent interacts with Rest-of-Counties via trade. Organizations spends dollars by purchasing goods and services from Rest-of-Counties, and receives dollars by

selling goods and services to Rest-of-Counties. As the simulation proceeds, Organizations alters the trade balance by enacting a buy local program, which is facilitated by the token. For simplicity, the import rate of dollars is held constant at 70 percent of total revenue. Prior to Year 1, trade is balanced and the export rate of dollars is equal to the import rate. But starting in Year 1, the export rate is flexible; Organizations adjusts the export of dollars such that it retains enough to pay dollar wages owed to employees. That is, Organizations uses a buy local program to increase the percentage of goods and supplies purchased from local vendors, holding sales to outside customers at a steady rate. Since fewer dollars flow out than flow in, one can say that Organizations "extracts" dollars from Rest-of-Counties.

For simplicity, the Government agent has no local employees of its own. One can imagine County as having no Government facilities; all facilities that might employ Government workers, such as military bases, are located in Rest-of-Counties. The base income of each NIWF and unemployed individual is assumed to derive from Government income support. The average annual amount, determined by querying the population, is about $5,000. Note that in a real economy, many NIWF individuals would receive no direct government assistance and others would receive assistance far above the mean. For example, the nonworking spouse of a middle-class earner might receive no government assistance.

Government also collects tax payments from individuals, who pay at a rate of about 19 percent of adjusted gross income (AGI). The AGI is calculated for each individual by subtracting from pre-CBFS T&D income either a standard deduction of $2,500, or by subtracting non-CBFS dollar donations plus non-loan CBFS contributions that support nonprofit organizations (this includes contributions for nurture support). Whichever method that results in the lowest taxes for an individual is chosen.

The absolute amount of Government spending on grants, subsidies, and contracts within County does not change over time. This is a conservative assumption; in a real county, government spending would tend to rise with economic growth. As a result, Government actually spends less money in County each year because the unemployment rate falls and fewer individuals require support. Moreover, tax receipts rise as T&D incomes rise. Government would run a substantial surplus of dollars in later years, except that it spends all its surplus in Rest-of-Counties.

By construction, only two agents can accumulate a surplus or deficit of tokens or dollars in any given year. These are CBFS and Rest-of-Counties. But an attempt is made to keep the annual CBFS balance near zero so that all available funds are used rather than stored. This leaves Rest-of-Counties as the only agent that runs a meaningful surplus or deficit, and it runs a deficit during the growth period. In this period, when the LEDDA needs more dollars to increase incomes, Organizations extracts a large amount from Rest-of-Counties, more than Government spends there. In the post-growth years of the simulation, when member

income is no longer rising, the amount of dollars extracted from Rest-of-Counties is roughly equal to Government spending there.

2.7 Order of events

In each year, the simulation proceeds according to the following sequence of steps:

1.   New members are added. While all employed members receive tokens upon joining (as part of wages and salaries), not all NIWF and unemployed members receive tokens. It might take some time before they are offered a LFNJ or nurture support. Those members who do not immediately receive tokens could be considered as members-in-waiting. Their incomes do not change.

2.   A group of randomly selected members who hold LFNJs lose their jobs. The job loss rate is set so that a member loses a LFNJ or switches jobs about once every five years. This is similar to the rate seen in the national economy [Bureau of Labor Statistics 2014c].

3.   CBFS uses its previous year's receipts to make nurture payments to unemployed and NIWF members, subtracting any Government support they receive. And it creates jobs for unemployed and employed members by funding Organizations.

4.   Government uses its previous year's receipts to make grant, subsidy, and contract payments to Organizations. It also makes support payments to all unemployed and NIWF individuals. Lastly, Government transfers any surplus it might have to Rest-of-Counties.

5.   Organizations adjusts the trade balance with Rest-of-Counties to retain any dollars needed to pay employee wages. Organizations also creates new tokens as necessary to pay wages, and destroys tokens if it has an excess. These two tasks are conducted by member organizations within the Organizations agent.

6.   Each year, families who receive tokens (from employment or nurture engagements) choose a Wage Option. Then Organizations pays wages to employees.

7.   Individuals pay taxes to Government, make dollar donations to nonprofits, and members make contributions to CBFS. Finally, individuals spend all remaining income at Organizations.

For Step 1, no members are added after the growth period ends. For Step 3, it is assumed that 60 percent of funding received by Organizations is used for job creation and that the remainder is used to help cover operational costs. Further, it is assumed that the cost of a new job is equal to the current income target times a multiplier of 2.0. Thus the cost of job creation rises over time. Costs for new nonprofit jobs are the same as those for new for-profit jobs, but in years subsequent to a hire, wages for nonprofit LFNJ employees are paid in full by the CBFS donation arm. Base incomes change only slightly during the simulation, and do

not change at all for people who do not receive tokens. More details on Step 3 are provided in the appendix.

3 RESULTS

All results pertain to the population size 100,000 simulation, unless noted. Token and dollar results for population sizes 10,000 and 20,000 were similar in pattern and timing to the 100,000-sized population, but approximately one-tenth and one-fifth the magnitude, respectively. Ratio variables were similar for all population sizes. Thus, the results scaled approximately linearly with population size, holding all other parameters equal.

Animations of some results are posted at http://www.PrincipledSocietiesProject.org. A Python package that contains code needed to run the simulation is also available, released under a GNU General Public License.

Some TES-specific parameters used in the simulation are listed in Table 1. By construction, the income, TSI, and participation functions are piecewise linear, and constant during the post-growth period.

Table 1: Selected TES-specific parameters

Parameter	Starting value	Ending value	Year growth starts	Year growth ends
Income target	$25,000 T&D	107,239 T&D	1	15
Incentive bonus	0 T	3,000 T	0	3
TSI target	0.05	0.35	1	15
Participation rate	0.05	0.90	1	15

Earmarks are listed in Table 2. The non-lending total approximates the long-term CBFS contribution rate; contributions to the lending arm are assumed to end when an accumulated threshold of 30,000 T&D per member is reached (see appendix).

3.1 LEDDA agent

Figure 2, top panel, shows the participation rate and the fraction of individuals in County who receive tokens. By Year 28, both are equal to 90 percent. That is, 100 percent of the target population has joined the membership, and essentially all members receive tokens. Also shown is the fraction of County NIWF and unemployed individuals who receive nurture support. By Year 28, essentially 100 percent of this population is covered. The bottom panel shows the per-person, pre-CBFS income target in T&D, tokens, and dollars. The peak is 107,239 T&D.

Table 2: CBFS earmarks

Earmark	Fraction of income or incentive bonus
Lending, standard business	0.01
Lending, Principled Business	0.02
Lending, nonprofit	0.01
Subsidy, standard business	0.01
Subsidy, Principled Business	0.02
Nurture	0.39
Donation, nonprofit	0.11
Non-Lending Total	0.53

Figure 3 shows the mean TSI, TSI target, and mean token share of spending. Between Years 4 and 14, the mean TSI and mean token share of spending are lower than the TSI target. This is because a substantial number of families choose Wage Option 2. Toward the end of the simulation, however, essentially all families choose Wage Option 1, and the mean TSI increases to the target.
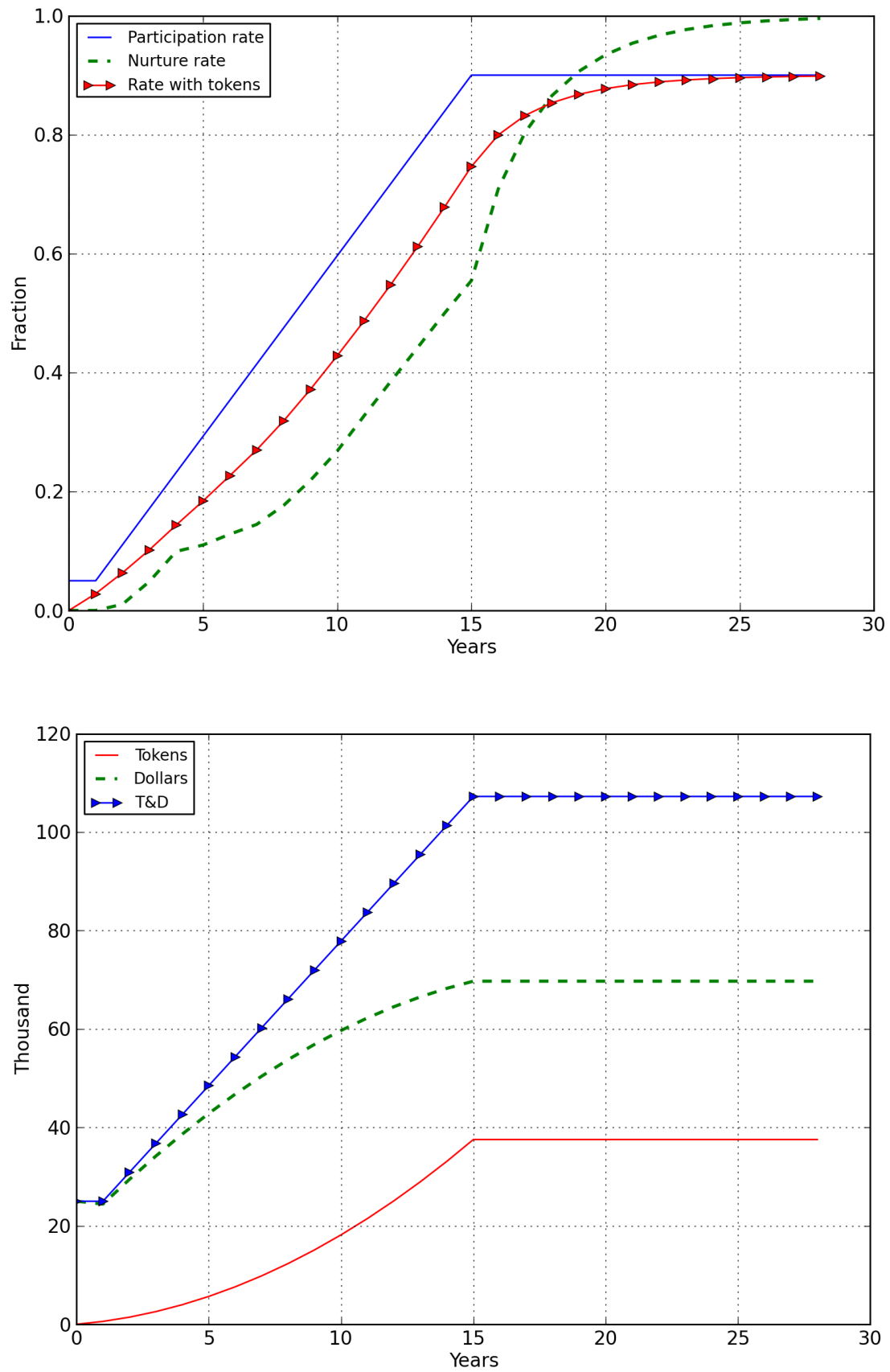
The mean token share of spending rises higher than the TSI target in the later years because taxes are paid in dollars, leaving a higher percentage of discretionary spending in tokens. Also, in later years the mean token share of CBFS contributions falls to the mean TSI; in earlier years, it is slightly above the mean TSI (see appendix).

The change in mean post-CBFS family income for members is shown in Figure 4, both with and without T&D savings accumulated in the CBFS lending arm. Mean family income increases from $39,800 in Year 0 to 104,100 T&D in Year 28. By Year 28, each member family has about 60,000 T&D "saved" in the CBFS lending arm. Median family income of members increases from $36,300 to 104,800 T&D.

LEDDA and County unemployment rates (as fractions) are shown in Figure 5. Full employment is reached in Year 10 for members and in Year 15 for County as a whole. That is, unemployment rates have dropped to the structural unemployment rate, which is assumed to be 1 percent.

3.2 County agent

Mean and median family incomes for Year 0 in the generated population closely match published values. These are $52,948 and $40,700 for the generated population, respectively, and $53,049 and $40,584 for Lane County, respectively [U.S. Census 2014].

Figure 2: Fraction of County population that participates, fraction of County population that receives tokens, and fraction of County unemployed and NIWF individuals that receives nurture support (top panel). Income target in tokens, dollars, and T&D (bottom panel).
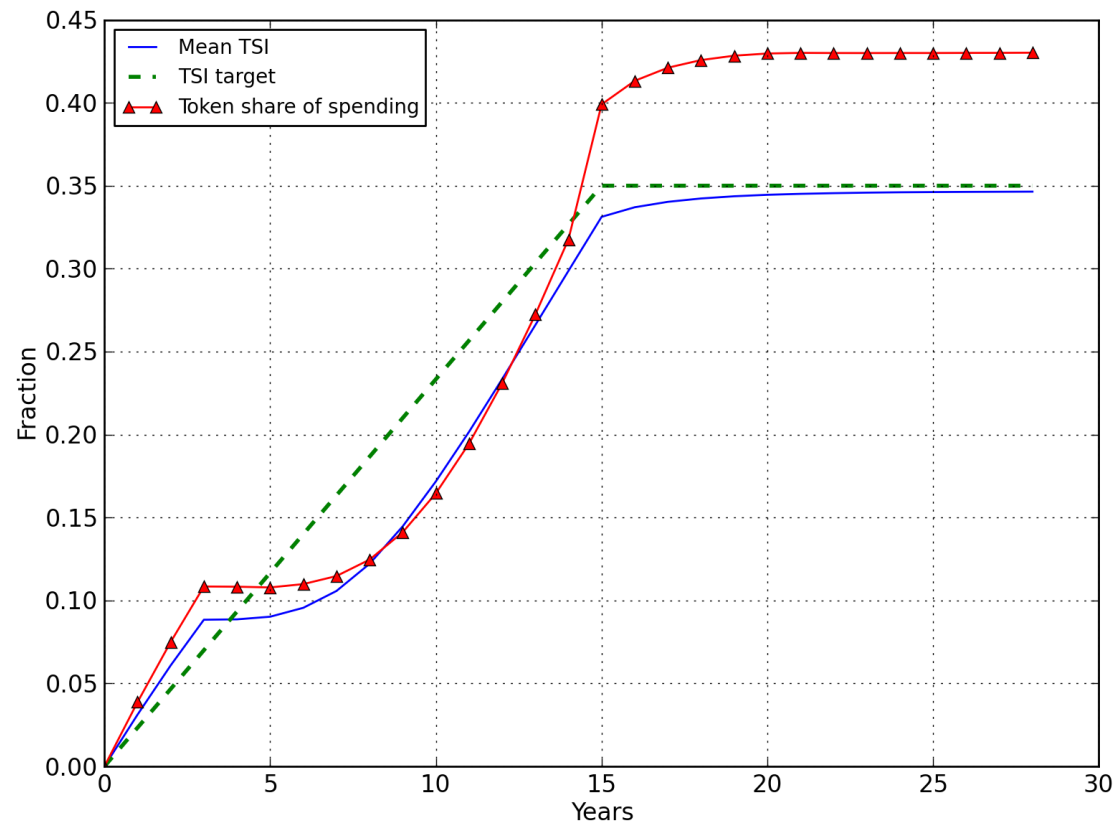
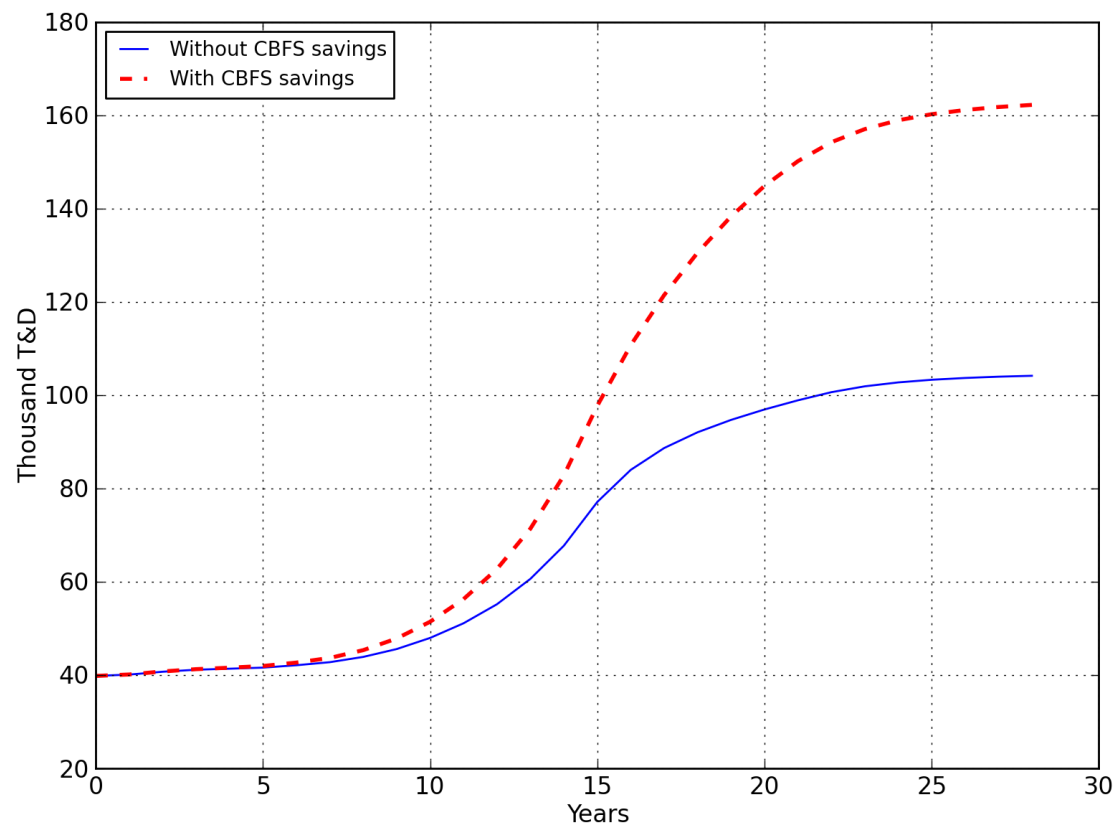**Figure 3:** Mean TSI, TSI target, and mean token share of spending

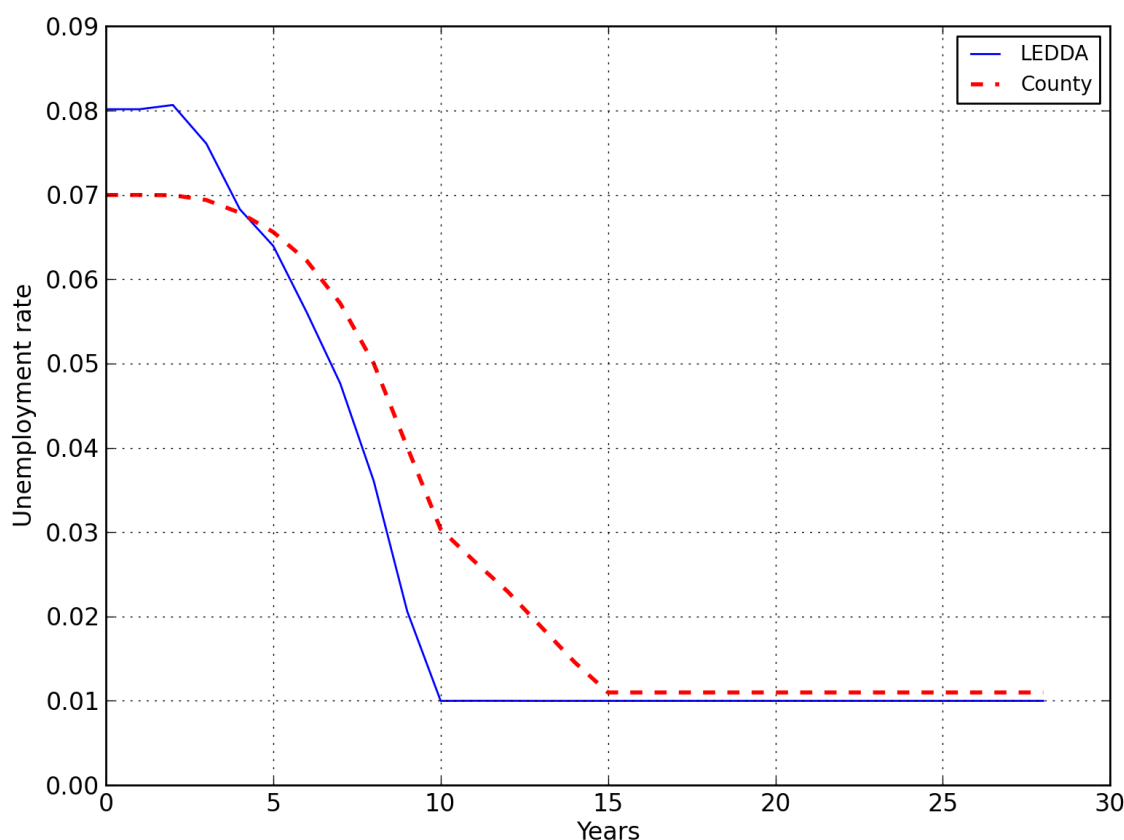**Figure 4:** Post-CBFS member mean family income both with and without accumulated CBFS savings

Figure 5: LEDDA and County unemployment rates, as fractions

The 90th percentile of family base income is $101,182. Given the parameter values in Tables 1 and 2, member families at the 90th percentile gain a 3 percent income rise over base. Higher relative gains are achieved for families with lower base incomes.

The distribution of Year 0, post-CBFS family income for County is shown in the top panel of Figure 6. The bottom panel shows the distribution at Year 28.

3.3 CFBS agent

The volume of CBFS funding is shown in Figure 7. Because CBFS arms do not experience a substantial deficit or surplus, the amount of CBFS contributions by members is essentially equal to the amount of CBFS funding (see appendix).

3.4 Organizational agent

Figure 8 shows the fraction of employees in each of the three Organizations subtypes. The percentage of nonprofit employees in the workforce approximately doubles, from about 7 percent in Year 0 to about 14 percent in Year 15.

County nonprofits also gain from an increased volume of non-CBFS dollar donations, as shown in Figure 9. Donations rise by 265 percent secondary to an aggregate rise in dollar income.
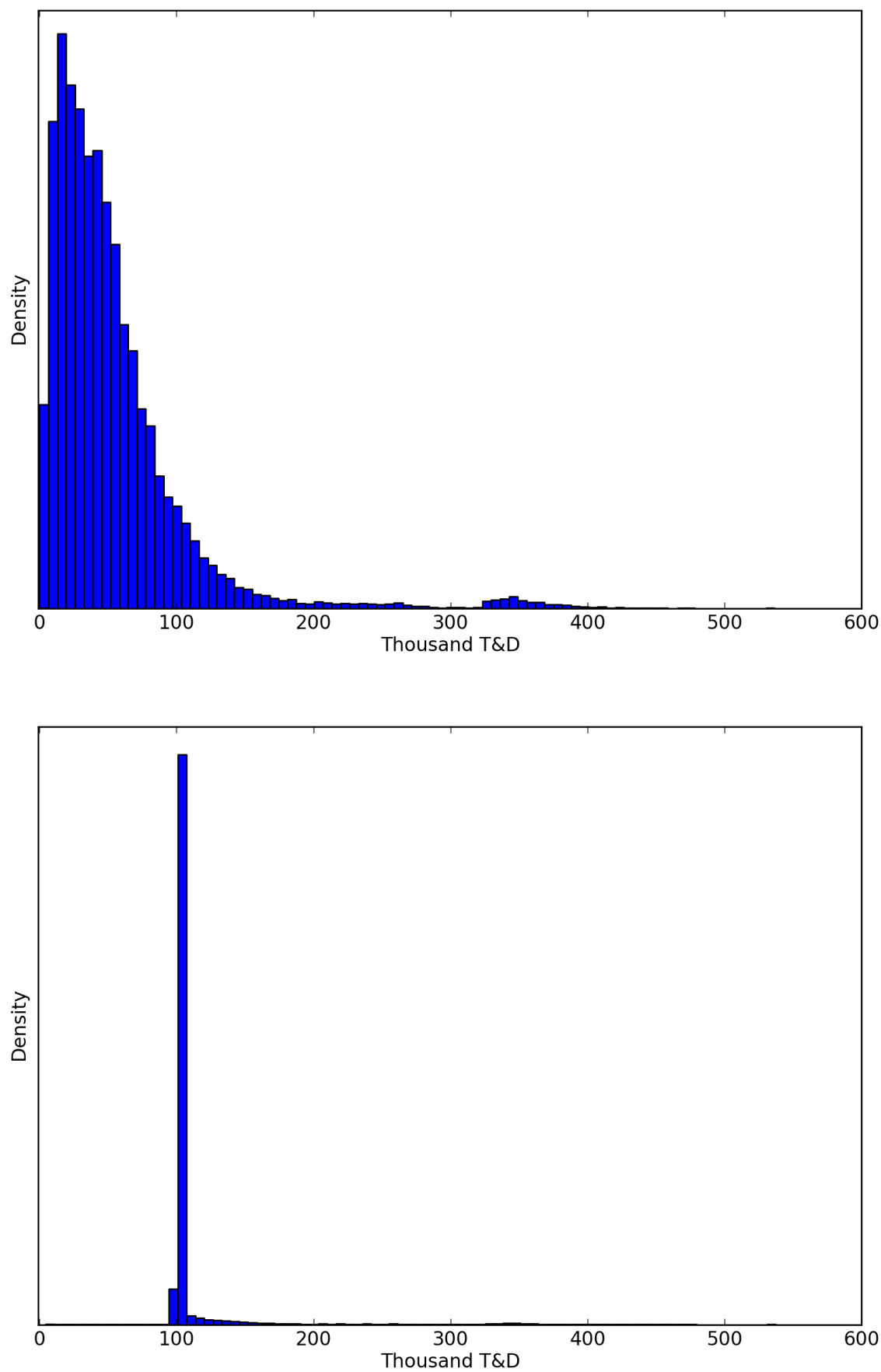
Figure 10 shows token creation by Organizations and dollar deficit of Organizations prior to trade adjustment (top panel). After reaching a peak near Year 15, values of both variables fall, with token creation approaching zero near Year 28. The bottom panel shows the ratio between the dollar deficit and total receipts of all member Organizations (as opposed to all Organizations). The receipts of member Organizations are approximated by multiplying the receipts of Organizations by the fraction of individuals in County who receive tokens (Figure 2). A peak occurs around Year 15, when just over 30 percent of revenues for member Organizations stem from adjustments to the trade balance.

3.5 Government agent

The surplus of dollars extracted from County by Government is shown in Figure 11. The figure also shows Government tax receipts. Any surplus is immediately spent in Rest-of-Counties. The surplus in Year 28 of $666 million is approximately equal to the $678 million extracted from Rest-of-Counties by Organizations in that year (Figure 10, top panel).

3.6 Rest-of-Counties agent

Figure 12 shows the accumulated dollar deficit experienced by Rest-of-Counties. In total, just over $5 billion is extracted from Rest-of-Counties over all years.

Figure 6: Distributions of post-CBFS family income for County: Year 0 (top panel), Year 28 (bottom panel)
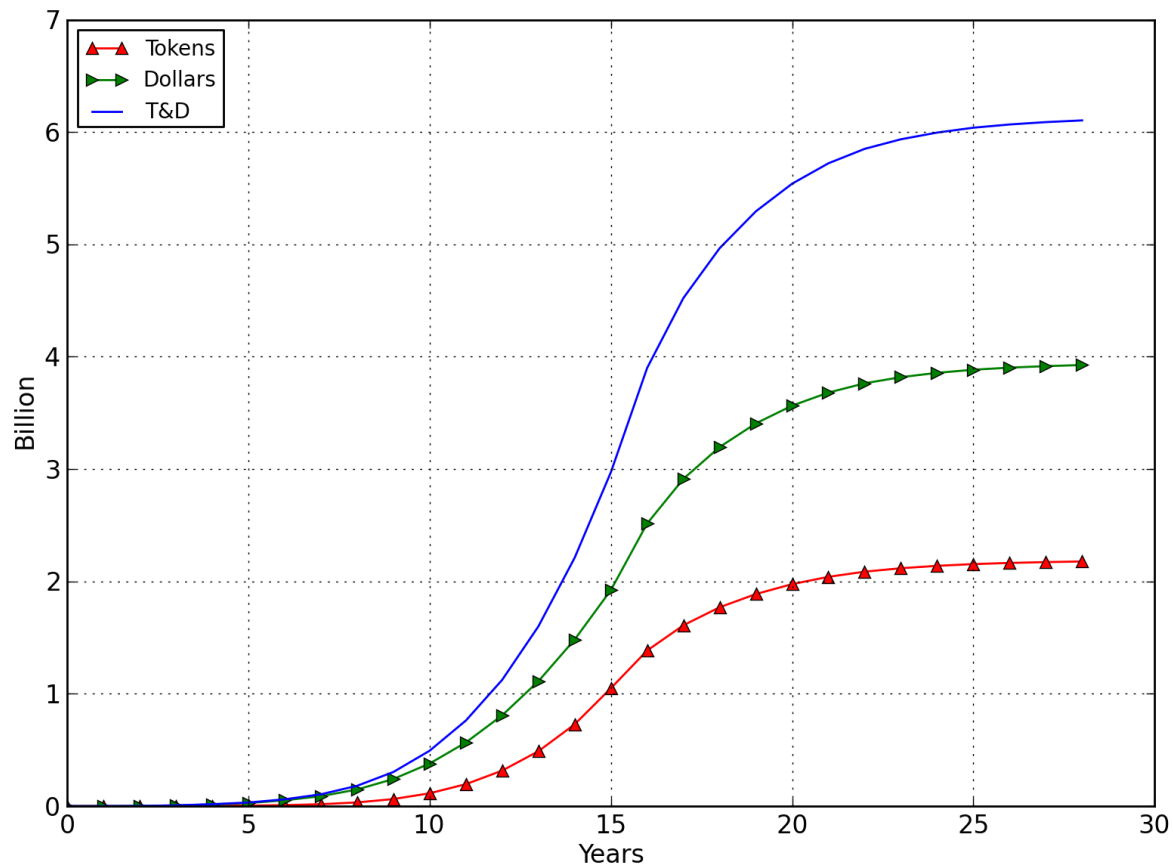
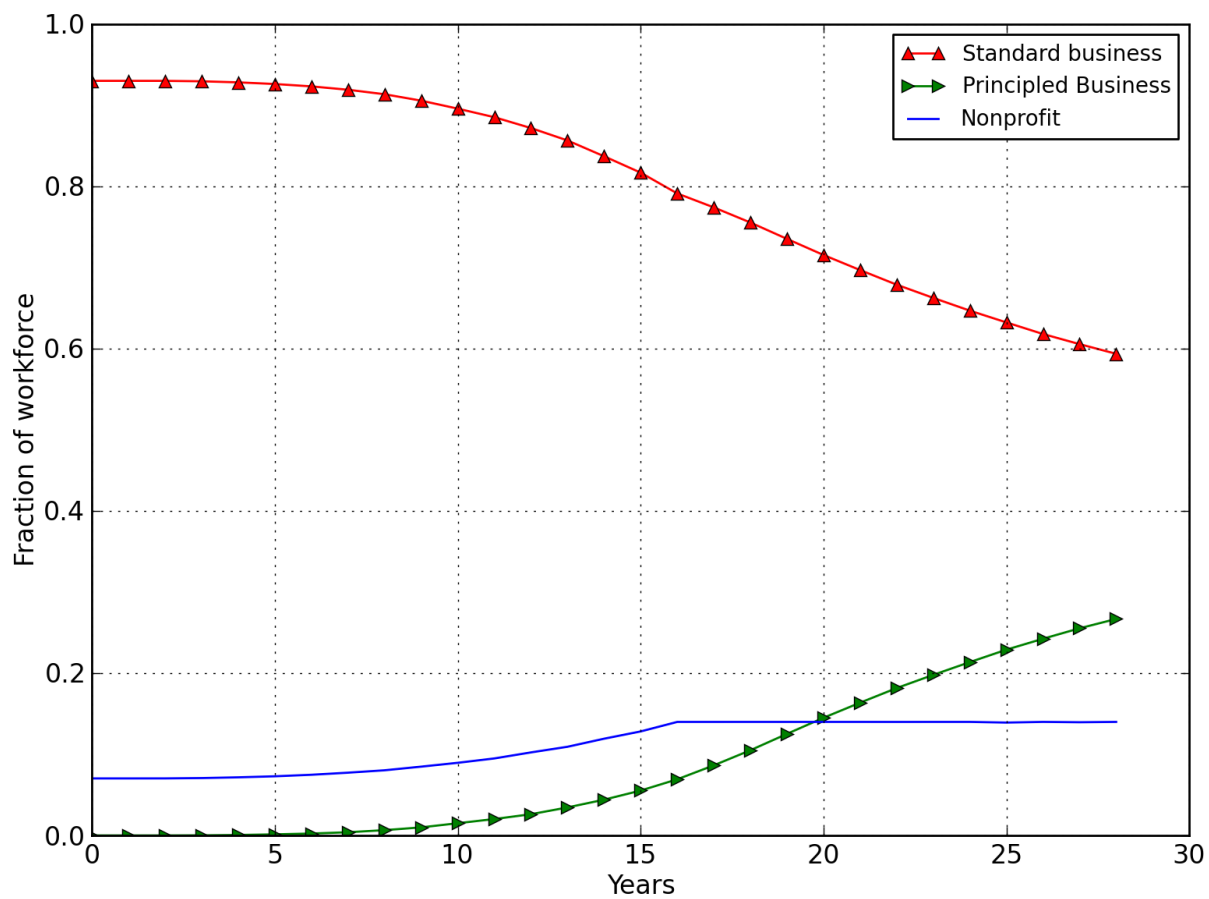**Figure 7:** Annual payments by CBFS in tokens, dollars, and T&D

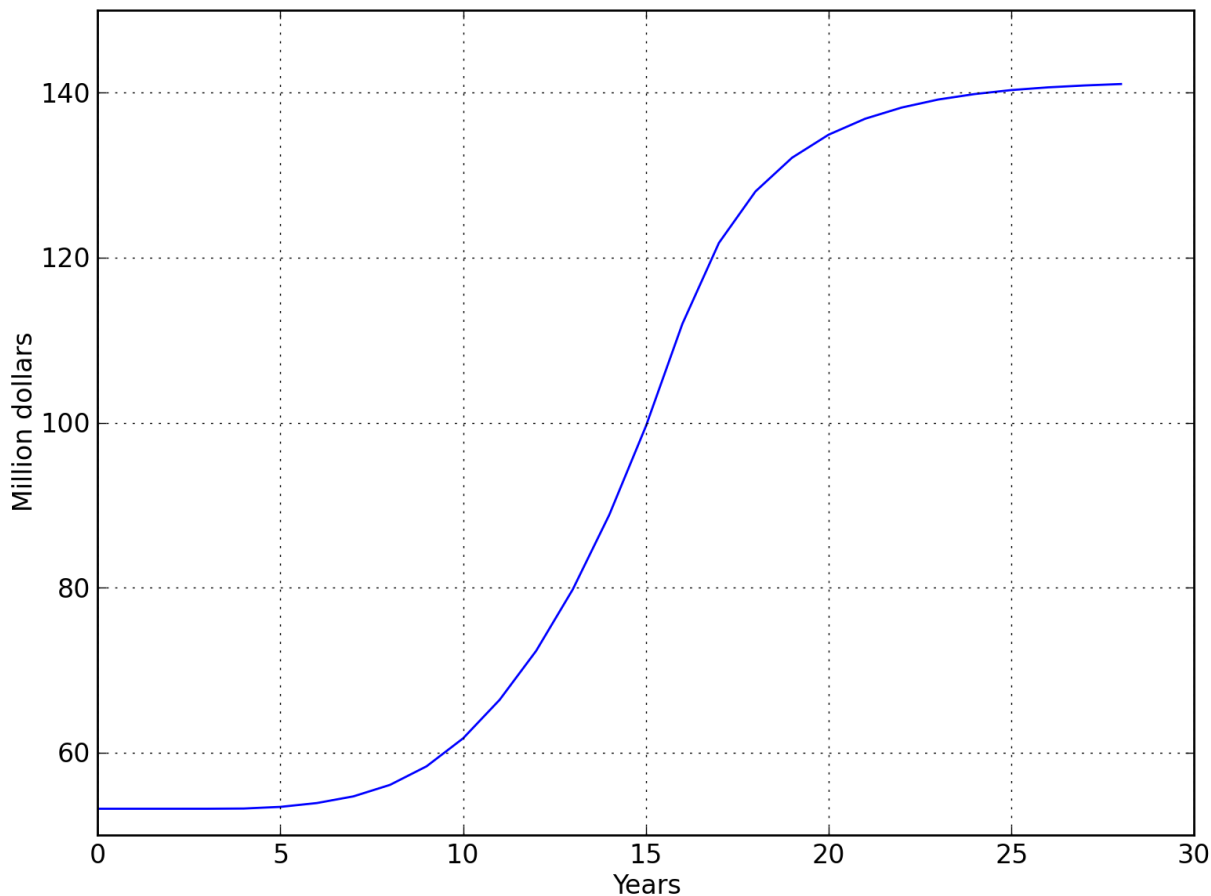**Figure 8:** Fraction of workforce: standard business, Principled Business, and nonprofit sectors

Figure 9: Annual non-CBFS dollar donations to nonprofits

4 DISCUSSION

4.1 Rest-of-Counties as a source of dollars

Achieving income gain, income equality, and full employment for members rests on the capacity of a LEDDA to increase the local volume of tokens and dollars. Ostensibly, increasing the token supply is not difficult, as this is done by fiat. But obtaining enough dollars for wage and salary increases is more challenging.

In the simulation, the LEDDA obtains dollars by reducing the outflow of dollars to other counties. It is implied, but not modeled, that the ultimate source for these dollars is the top 10 percent of base income families, in all counties. After all, families below the 90th percentile of base income in any county could start their own LEDDA. For example, one can speculate that national chains, and thus their wealthy investors, might lose revenue as more consumers shop at locally owned businesses, and as more businesses source locally. Thus, by implication, a LEDDA acts to equalize incomes nationally. Indeed, the amount of dollars extracted from Rest-of-Counties, although large, brings the dollar portion of post-CBFS member-family incomes only up to roughly the national average (recall that income distribution is initially skewed).
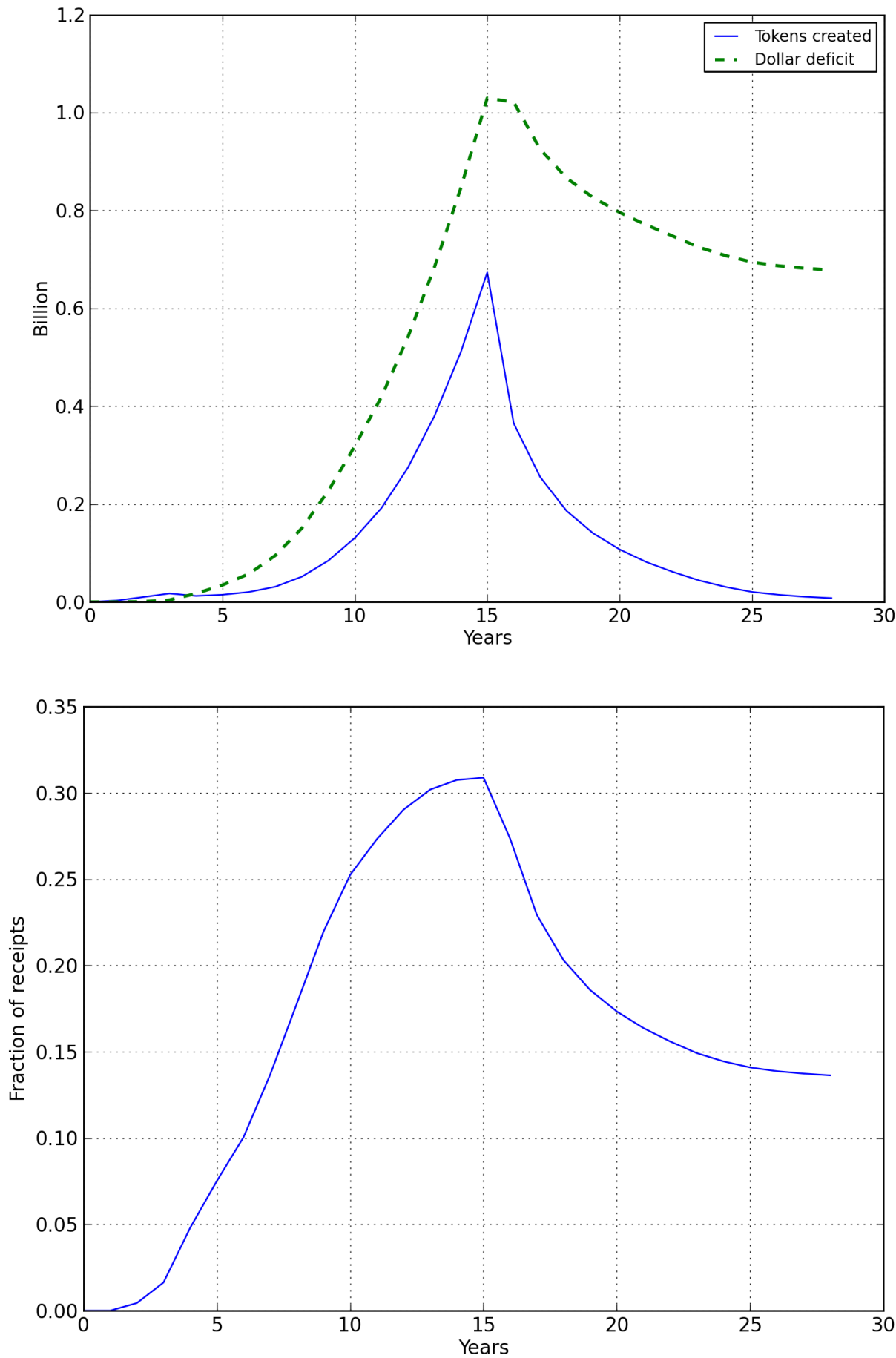
Having said this, the model is simple and other sources of dollars would exist for a real LEDDA. In this sense, Rest-of-Counties serves as a type of catch-all agent to represent multiple sources. One source is Government spending. It is assumed that the absolute amount of Government spending in County does not increase as its economy grows. This assumption might be overly conservative. If Government spending did increase, then fewer dollars would need to be extracted from Rest-of-Counties.

Another source is normal economic growth, which does not exist in the modeled world. In particular, bank lending—the primary source of new dollars in a real economy—does not exist. In a real token-dollar economy, bank lending would likely increase, leading to a larger local dollar supply. For example, a profitable member business might want a loan from a bank or credit union to help it grow faster. If the local dollar supply were to increase due to bank lending, then fewer dollars would need to be extracted from Rest-of-Counties.

The velocity of currency could also affect dollar needs. Local currencies can circulate as much as five times faster than corresponding national currencies [De la Rosa and Stodder 2013]. If the velocity of the token is high relative to the dollar, nationally, then the velocity of the local dollar is also likely to be high; a LEDDA strategically uses a combination of tokens and dollars. An increase in the local velocity of the dollar would, in effect, be akin to an increase in the local dollar supply.

Figure 10: Annual token creation and dollar deficit of Organizations prior to trade adjustment (top panel). Dollar deficit prior to trade adjustment as a fraction of member Organizations receipts (bottom panel).
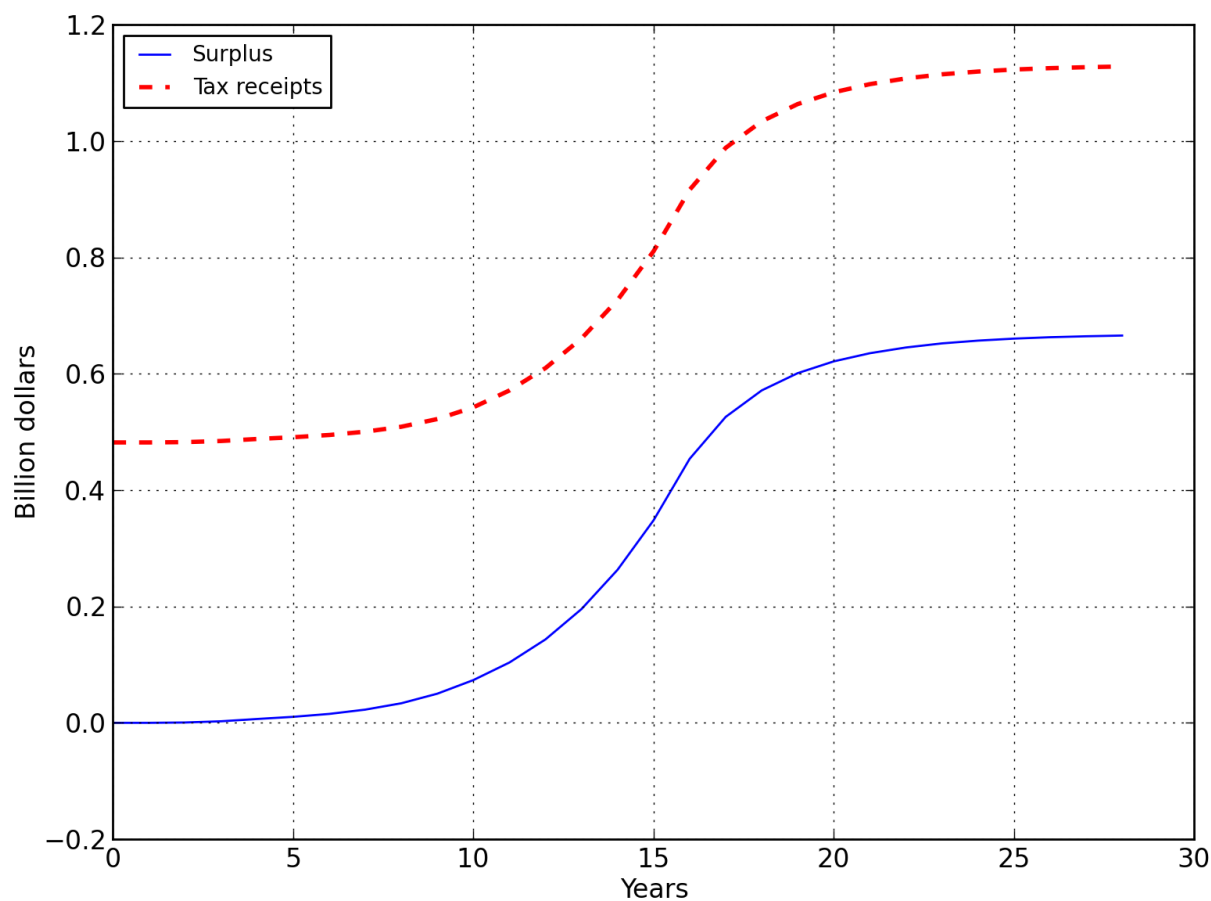
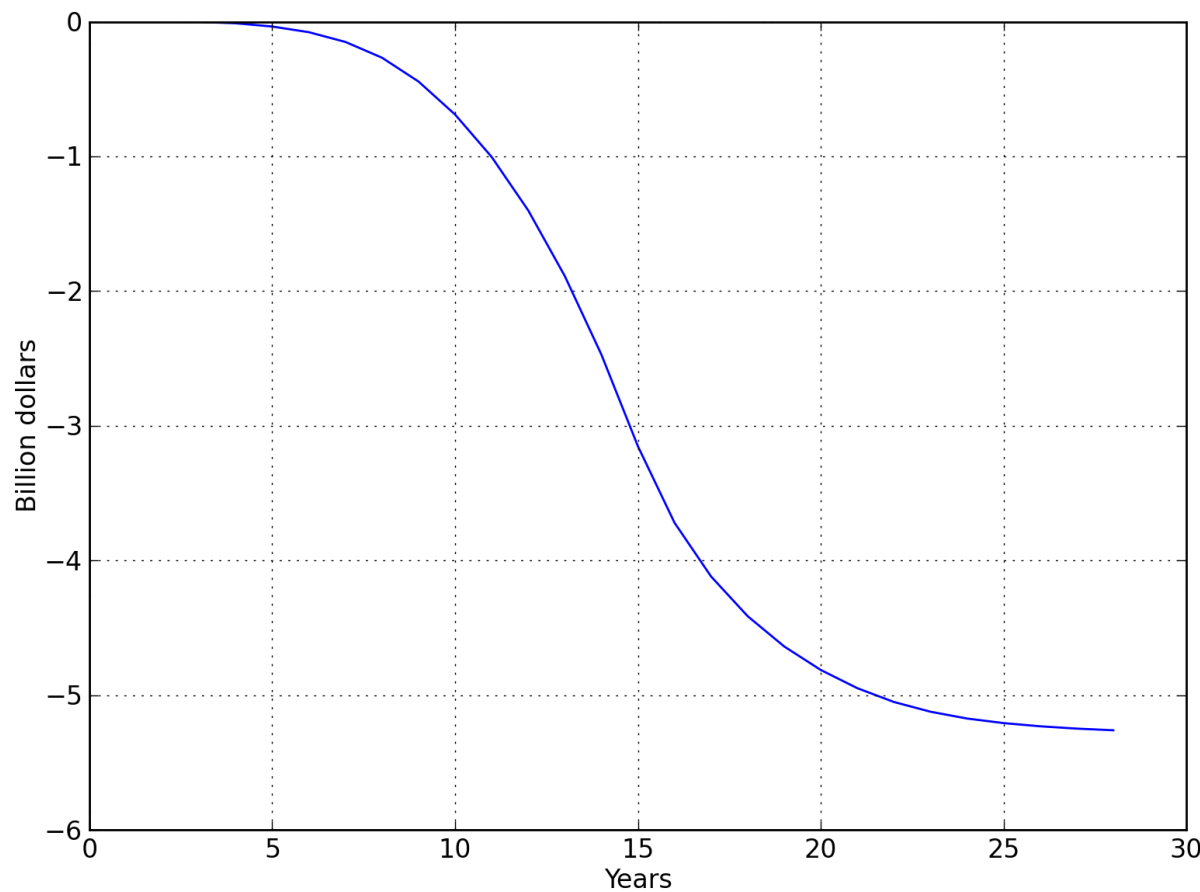**Figure 11:** Annual Government surplus (before Rest-of-Counties spending) and Government tax receipts

Figure 12: Accumulated dollar deficit of Rest-of-Counties

One might wonder if large adjustments to the trade balance, such as used in the simulation, are possible. Studies by the consultancy group Civics Economics suggest that independent businesses in the restaurant and retail shopping sectors tend to locally recirculate about 46 percent of revenue on average, compared to 18 percent for national chains [Civics Economics 2013]. This 2.5-fold gap suggests that substantial adjustments to the trade balance could be achieved if most CBFS funding went toward locally owned, independent businesses.

4.2 Reshaping the local economy

By the end of the simulation, CBFS channels about 2.6 billion T&D annually to Organizations, enough to reach full employment. If similar results were seen in a real LEDDA, conceivably it would be enough to reshape the county economy into one that residents most want. An annual funding pool of 2.6 billion T&D is a large amount of currency for a county of population 100,000 (roughly, the average size US county). It is on par with total outstanding loans at US commercial banks, averaged over all counties.

In reshaping the local economy, the absolute and relative sizes of earmarks would play a role. For example, earmarks that fund nonprofits are relatively high in the simulation, and as a result the size of the nonprofit sector nearly doubles (Figure 8). Further, the chosen earmarks cause the Principled Businesses sector to increase in size from zero employees in Year 0 to about 27 percent of the workforce in Year 28.

Of note here, the LEDDA framework provides 100 percent ongoing wage support for LFNJ nonprofit employees. Further, it offers loans and donations to nonprofits for operational expenses, and (in the simulation) increases non-CBFS dollar donations to nonprofits by about 265 percent. Thus, it is reasonable to expect that a substantial percentage of nonprofits would have motivation to become members.

4.3 Rules of thumb

Two rules of thumb for setting earmarks can be identified. First, to achieve income equality, nurture support must eventually be offered to almost all NIWF and unemployed individuals in County (almost all such individuals would be motivated to join, by assumption). Thus, the nurture earmark should be set to about 39 percent—the final unemployment rate plus the NIWF rate, in the membership (1 percent and 38 percent, respectively). Second, the donations earmark must be set high enough—about 11 percent—so that the CBFS can fund 100 percent of ongoing wages for all LFNJ nonprofit employees. All subsidy and lending earmarks are set low, between 1 percent and 2 percent, to reflect the reasonable needs of organizations.

Regarding length of the growth period, a membership cannot expand faster than new employees and entrepreneurs are trained, than CBFS funding can be issued and new facilities constructed, and than the population accepts the LEDDA framework. But if the growth period is too long,

then members might feel that too little progress is being made, and motivation might suffer. The 15-year growth period used here is selected as a compromise.

Regarding the income function, if peak income is set too low, then too high a percentage of the population might fail to join, or join but choose Wage Option 2. In either case, the LEDDA would not have the capacity to achieve income equality for all members, especially unemployed and NIWF members. On the other hand, if the peak is set too high, too large a volume of dollars would need to be acquired from Rest-of-Counties, and/or the TSI target would need to be set too high. Also, the higher the income target, the greater the risk of inflation. In the simulation, the peak income target is set just high enough so that families at the 90th percentile of base income are motivated to join and eventually choose Wage Option 1. Similarly, the peak TSI target is set at 0.35, a compromise between too small an increase in the token supply and too large an increase relative to assumed outlets for token spending.

4.4 Future directions for research

Much work remains to address the economic, social, political, legal, and psychological questions raised by the LEDDA framework. Further, the model could be improved and expanded so that it can describe realistic stocks and flows, and forecast future conditions. The following is a partial list of efforts awaiting attention, which also highlights weaknesses in the current model:

- Model agents at a more refined level. This could include modeling birth and death of individual organizations.

- Increase the number of flows.

- Increase the number of decisions made by individuals and organizations. For example, individuals might decide to marry or divorce, or to start or sell a business. Also model normal raises for employees, apart from the income target.

- Model demographic changes, as well as inflation, banking, investment, and other normal processes in the population and dollar economy.

- Model the impacts of rising income, income equality, and nurture engagements on motivation and behavior of employees and entrepreneurs.

- Make the tax structure more realistic. Corporations could pay taxes, in addition to individuals. Expand the Government agent to include local, state, and national divisions, with in-county employees at each division.

- Model wealth, in addition to income.

- Model a well-being index that includes non-economic variables.

- Extend the framework to a global audience, including developed and developing regions.

Some of these efforts would require modest work effort, while others might require years of effort. To this end, it is envisioned that model improvement and expansion will be ongoing, as long as interest in the LEDDA framework exists and funding is secured.

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