Chapter 13
FPGA Speedup for Financial Network Models

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ABSTRACT

We propose to use FPGA (Field Programmable Gate Arrays) to solve the nearly insurmountable computational challenges of Financial Network Models. Flow of funds models have been discussed for decades, but recently, the research activity has picked up due to international financial crises and the increased power of computers, mathematics, and economic models to address these crises. We survey many of these developments and discuss how FPGA can provide the critical technology to provide answers fast enough to be useable by managers in banks and regulatory agencies.

FINANCIAL TRADING NETWORK MODELS

Motivation

The random walk of asset prices has been a popular topic in the financial literature since Bachelier (1900) presented the first mathematical exposition of Brownian motion and applied it to the prices of assets traded on Paris Stock Exchange. Financial network models study a walk on the set of possible transactions, not an abstract random walk that can wander anywhere on the real line as Bachelier proposed. The activities of economic actors are highly constrained due to their financial situation and the institutional arrangements through which they interact. For example: people without much money cannot pay high prices; huge banks do not park billions of dollars overnight in tiny third world countries. All transactions are governed by law and institutional arrangements that limit what transactions can occur. Human behavior provides additional restrictions as to what transactions are likely to occur. Models need not waste time simulating events that are impossible or improbable. Similarly models need to consider possibilities that never have been observed but are possible, e.g. the risk that asset prices can fall considerably or go to zero in a market crash. Such rare, extreme events are called “black swans’’ by Taleb (2010). Companies often go bankrupt and totally disappear but the popular lognormal distribution has a zero

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probability that price goes to zero. Numerous ad-hoc patch-ups for such model deficiencies have been made over the years but such patch-ups were shown to be inadequate by global crash of 2008, the flash crash of 2010, and other extreme events that lost trillions of dollars. The financial network model below takes into account the structure of trading to move from a naive random walk model to a more realistic random transaction model.

Network flow models have a long history in economics with the most related Nobel Prize won by Tobin (1981). Classic early papers on flow-of-funds modeling include Brainard & Tobin (1968), Backus & Tobin (1980), and Backus & Purvis (1980). These were limited to rather aggregate (temporal and sectoral) analysis due to the limited databases and computing power available in those early days. Financial network models are closely related to the input-output analysis of Leontif (1936, 1953, 1973) that was focused on the flow of real commodities rather than financial assets. Leontif arrived at a sparse matrix of commodity flows similar to the sparse matrix of funds flows in the financial trading network model developed here. Sir Richard Stone (1960, 1986) advanced the most general models that include both financial and real trading networks. Stone's models are the basis for the worldwide SNA System of National Accounts prepared by every country in the world. In this paper we focus on financial trading models and the flow-of-funds but realize that with additional effort our analysis can be extended to all trading somewhat along the lines laid out by Stone and Leontif.

Macroeconometric models incorporated an aggregative flow-of-funds sector at least as early as Eckstein, Green and Sinai (1974). More recent models such as that of economy.com have fewer flow-of-funds variables so those accounting identities are not rigorously enforced. Ironically the Federal Reserve Board model has few flow-of-funds variables even though they produce the flow-of-funds database! (Brayton 1996) None of the macroeconometric models can price derivatives nor do they do a very good job on flow-of-funds. Further, many modern models still have pitfalls that early writers warned against: "failure to respect some elementary interrelationships -- for example, those enforced by balance-sheet identities --- can result in inadvertent but serious errors..." (Brainard & Tobin 1980). The model in this paper overcomes some of those pitfalls with powerful new computing technologies such as FPGA that were not available to earlier modelers. But we do not discuss empirical estimation of models which is a major activity of macroeconometrics. Estimation difficulty is one reason why previous models make unaesthetic oversimplifications.

First we present our own model in Section 1 that delves deeply into the accounting details of financial networks. Then we review current working papers and recent publications in Sections 2 and 3 to show how our model combines the important elements from these papers with Field Programmable Gate Array (FPGA) technology to better solve the problems of the financial industry. Our attention to microscopic accounting details parallels our attention to microscopic chip layout details. The problem to be solved dictates the computing technology that needs to be used.

Puzzle from the news: "Suppose a company has 1 million shares of stock priced at $100 each, giving it a market value of $100 million. Over the next few days, someone buys $5 million worth of stock. Speculation drives the share price to $140, and suddenly, the company has a market value of $140 million. In this case, a $5 million investment has created a $40 million increase in market value. Is the company really worth $140 million? It is not if everyone tried to sell their stock at once. The first person might get $140, but everyone else would get less, probably much less. ... Multiply that by every asset class in the world, and you'll get a sense of what happened in 2008. The perceived value evaporated." (San Francisco Chronicle 2009)

This sad puzzle illustrates the fact that there is not enough liquidity in the system to support