Human Capital in the Domain of Community Wireless Networks

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Abstract
Community Wireless Networks (CWNs) not only provide free or affordable Internet access but also facilitate human capital formation. They facilitate human capital accumulation by serving as a venue for brokering knowledge, providing training and enhancing access to information. Previous literature, mostly case studies, shows that CWNs support schools, improve healthcare, provide training and facilitate access to information. However, this literature does not treat these outcomes as sources of human capital. A survey instrument is used to collect evidence on how CWNs facilitate human capital formation. The data shows that CWNs serve as venues for enhancing formal and informal education, providing access to information, facilitating training and brokering knowledge among participants. We provide some conceptual details, methodical insights and policy implications in order to construct this research stream and promote CWNs as engines for economic progress.

1. Introduction
Community Wireless Networks (CWNs), are closely linked to the deregulation of the 2.4GHz spectrum, are open telecommunication infrastructures built by communities for the purpose of providing shared, affordable or free Internet access to community members [1,2]. Hundreds of these collective telecommunication infrastructures have been built all over the world. They have grown to be at the vanguard of an emerging telecommunication revolution that reconciles the interactions between economies, social structures and technology. More specifically, they serve as engines for sustainable development, particularly in rural and developing societies [3, 4].

As with similar innovations (e.g., Open Source Software (OSS), Wikis), the development of CWNs requires the intellectual contributions of a motivated and committed group of people. Their contributions may include sharing access points, donating money and hardware, developing software for the system and/or providing manpower and technical expertise [1,2]. The participants of CWNs may include community activists, students, universities, municipalities, hospitals, underserved communities, OSS developers, local businesses and technology vendors. These actors collaborate for the purpose of building the network, including necessary software, hardware, applications and content. While doing so, they build and exchange experience, knowledge and ideas. In addition, the leaders of many CWNs provide training to community members and build their competency. These are typical activities for human capital formation that may not be possible with mainstream Internet Service Providers (ISPs). The novelty of CWNs lies in providing because most of these networks provide free or affordable Internet access. Therefore, they drive the creation of human capital outside the market mechanism.

Human capital is a fungible and intangible asset that increases via education, training, nutrition, healthcare and migration for better job opportunities [5]. Its theoretical account has evolved through scientific developments in economics of labor, public sector, welfare and economic development [5]. We are interested in the relationship between human capital and CWNs for the following reasons:

• CWNs serve as capacity building labs and information highways built by local communities or the third sector. However, it is not legal in many countries (e.g. the U.S.A., India and in Europe) for not-for-profit entities to develop these telecommunication projects.

• Emerging information technologies are transforming societies from resource-based to knowledge-based economies. As a result, investing in human capital has become one of the chief themes of economic reform [6].

• The theory of human capital is succinctly implied by its impressive record of scholarship [5]. Therefore, we use it as a theoretical framework to obtain the economic reasoning necessary to gain public support for such open systems.

• The human capital concept is so intellectual that it captures most of the technical capabilities, human capacity, and management competencies that contributors of CWNs use to successfully design, implement and manage such open networks.
Therefore, paying special attention to human capital in the realm of CWNs is warranted. The literature carried out thus far, mostly case studies, shows that CWNs have a positive impact on the key dimensions of human capital [2,3,7]. However, as with emerging phenomena, this literature has immature theoretical accounts. For example, it has a lack of conventional instruments and absence of careful empirical analysis. Drawing on previous literature, we use a survey instrument to show that CWNs serve as venues for human capital generation. This study is part of a large research project that investigates the relationship between CWNs and different forms of capital. In previous studies, we examined the role of these networks in the creation of social capital [1,21]. The specific question that leads this study is:

*How do community wireless networks facilitate the production of human capital?*

This study is not meant to propose a new perspective of human capital. Instead, its focus is investigating the role of CWNs in the production of human capital as attributed by scholars.

The rest of this paper proceeds as follows: in the following section, we provide a primer on the concept of human capital, its sources and its measures. Then, we provide an overview of related literature. After that, we present the adopted research approach and articulate on the constructed variables to study how CWNs facilitate the production of human capital. Afterward, we analyze the collected data and relate it to the mainstream sources of human capital. We conclude our study with research implications and suggestions for future work.

2. Literature Review

Despite its importance, the relationship between CWNs and human capital is not well studied or understood. The following is a brief account on this literature.

2.1 The Notion of Human Capital

Human capital has been defined as “the aggregation of the innate abilities and the knowledge and skills that individuals acquire and develop throughout their lifetime” [6]. Innate abilities capture the individual’s inherited potential (e.g. physical, intellectual, and psychological capacities) to acquire skills. These abilities (different and varied) are possessed by individuals at their time of birth as gifts without any action or choice of their own. Acquired knowledge is obtained over one’s lifetime through intergeneration or transfer of knowledge, personal contacts, work experience, on-the-job-training, education and socialization. Both dimensions of human capital enhance the capabilities of individuals to produce goods, services and ideas. One of the interesting aspects of our study is researching human capital formation in a non-market environment.

The notion of human capital, as a source of economic progress, has roots in the classical economic theory in the work of Adam Smith [5]. Its modern rebirth, however, conducted by Becker [8]. Becker emphasizes that the society’s endowment of educated, trained and healthy workers determines the productivity of the classical production factors.

Some scholars identify the distinctive properties of human capital [6]. As described, human capital is a non-tradable good; individuals do not always control the channels and the pace through which it is acquired; it has qualitative as well as quantitative aspects; it could be either general or specific; and it generates external effects. They also stress that the definition of human capital, its measurements and its specifications in economic models should capture most of its inherited features. The same groups of scholars note that human capital has social impacts on the institutions (e.g. families and communities) where it is created.

Sweetland [5] notes that human capital could be generated through formal or informal education, on-the-job training and/or apprenticeships. Another set of scholars state that human capital is formed by interaction of individuals and the exchange of ideas [6]. Our study explores both formal and informal training occurring in the domain of CWNs. Sobel [9] emphasizes that training, education, technology and institutions are necessary to complement physical capital. According to Sobel, the absence of such capacities, particularly in developing societies, hinders the efficiency of the available physical capital. For a thorough review of the historical developments of the human capital theory, we refer readers to Sweetland [5] and Sobel [9].

2.2 CWNs and Human Capital

The literature indicates that CWNs contribute to the facets of human capital attributed above. But it does not treat them as such. For instance, Purbo [10] states that these networks enable knowledge sharing among community members in a way that creates knowledge-based societies. According to Purbo, CWNs have the potential to transform users from being consumers of information and knowledge to producers. The author also points out that these networks are essential for integrating schools and universities with the Internet and online resources.
One of the activities that create human capital is \textit{node building parties} (sometimes are called hack nights). Unlike traditional ISPs, during these events volunteers work with technicians to plan, design, and build a new network node \cite{1,2}. Quinn \cite{2} notes that leaders of CWNs provide hands-on technical training on network design and operation, and also teach computer skills to community members and volunteers. Along this line of thought, we consider CWNs as open networks where technical, social, financial, and computer resources are brokered and shared among participants.

Siochrú and Girard \cite{11} view wireless networks owned by communities as a form of “commons,” similar to community-owned water facilities and bridges. The authors highlight the following advantages of community ownership of such telecommunication infrastructures: 1) empowering local communities; 2) mobilizing community resources to develop the project; 3) addressing the specific needs and circumstances of the community; 4) providing better maintenance to the infrastructure; and 5) accruing local technical expertise through accessing information and sharing experience of peers while building and maintaining the network. In addition, Siochrú and Girard provide useful insights into the role of CWNs in enhancing education, training, and healthcare but they do not consider these benefits as sources of human capital.

Sandvig, Young, and Meinrath \cite{12} note that the most significant aspect of CWNs is providing users the opportunity to create new services and applications. Similarly, Powell \cite{13} points out that CWNs provide community members the opportunity to contribute to their communities, build social capital, develop innovative applications, and improve economic relationships. Due to their open nature, CWNs serve as venues for bridging knowledge between community members when participants with different capacities and expertise collaborate to build and maintain these networks. According to Powell, community contributions may include conducting site surveys, hacking hardware, developing software and creating content, providing technical support and carrying out research.

Another group of scholars has contended that community-owned computer networks are particularly important for the economic progress of developing communities which usually lack human capital, physical capital and infrastructures \cite{11}. Best and Maclay \cite{3} point out that community Internet in rural areas gives users basic computer skills. In addition, they state that CWNs build partnerships with schools which provide them with volunteers in return for free Internet access. They also note that CWNs enhance communications, education, commerce, government services, entertainment and training. Therefore, they sustain economic development by creating opportunities for technical training, web design, computer repair services, and research. According to Best and Maclay, this is mainly because these networks reduce cost, generate revenue for local communities, create jobs, improve training and build community capacity. Similarly, another study concludes that community-based Internet access can improve the quality of life of the rural poor by creating new opportunities for education, healthcare, and economic development \cite{4}. For instance, farmers can use voice or text communications to obtain information about the best agriculture practices and farming techniques. Our study adds another breadth to the role of CWNs in sustaining economic development which is human capital creation.

A multiple case study by Sandvig, Bar, Galperin, Cannon and Hoag \cite{14} describes CWNs as cooperative actions created by developers whose objectives is to obtain technical expertise. However, according to the authors of this study, the goal of these developers has been redirected to achieve social objectives such as digital inclusion and civic engagement. Crow, Miller and Powell \cite{15} describe CWNs as venues for engaging users and transferring their skills and knowledge to other networks around the world. For instance, one of the important venues for knowledge exchange among participants of CWNs is the International Summit for Community Wireless Networks (IS4CWN) where activists exchange ideas and expertise in this regard. In other words, CWNs are instruments that disseminate human capital among community members, between communities and across countries.

One of the interesting aspects of CWNs is their grassroots implementation model. More specifically, they are open telecommunication infrastructures built by the contributions of technology savvies whose objective is to acquire new technical skills \cite{16,17}. These contributions include personal knowledge, expertise, equipment and time. Similarly, Shin and Venkatesh \cite{17} argue that the inputs of community members, as lay designers, are necessary for successful implementation of effective CWNs.

Another line of research addresses the role of wireless networks in delivering healthcare. In particular, healthcare practitioners can use mobile devices to track, updated and store patient information for the purpose of improving the overall quality of

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1 The International Summit for Community Wireless Networks was held in Washington, DC, U.S., May 28th to the 30th, 2008. Its objective was to explore the opportunities and challenges of CWNs.
healthcare [18]. The study also notes that these
networks provide on-site staff training, research and
end-user education. Similarly, Kawasumi [7] explores
the applications of wireless networks in the rural areas
of Japan. Kawasumi adds that their key applications
include e-education, e-healthcare, e-administration,
and environmental and monitoring services. According
to Kawasumi, the benefits of using these networks in
healthcare include: on-demand and real-time access to
system resources and information, efficiency and
accuracy in operations, and patient satisfaction.
Likewise, Varshney [19] discusses the role of these
networks in supporting applications of pervasive
healthcare. These applications include health
monitoring, intelligent emergency management
system, data access, and ubiquitous mobile
telemedicine. Having a careful look at this abbreviated
record of scholarship, we can deduce the following:
1. Human capital is a multifaceted, intangible asset
   that is difficult to measure;
2. The literature, mostly case studies, indicates that
   CWNs provide access to information, support
   education, provide training, broker knowledge and
   sustain healthcare. However, it does not treat these
   outcomes as facets of human capital;
3. There is no agreed conventional wisdom nor
   research approaches addressing the human capital
   accumulation in the domain of CWNs.

3. Research Approach

The movement of CWNs is young, large, diverse,
geographically dispersed and informally structured. In
addition, their socioeconomic outcomes (e.g. human
capital, social capital) are intangible, multifaceted
outputs which are difficult to measure. Sweetland [5]
notes that the types and means of producing human
capital greatly affect the design of related research
studies. One of the common ways to measure human
capital is to calculate the direct expenditures on
schools and universities and add it to the opportunity
cost of students attending school [6]. Physical capital
is best measured by calculating the magnitude of
expenditures on capital goods [20]. These measures
are plausible but they are difficult to use in the domain
of CWNs for six reasons: (1) it is difficult to
distinguish expenditures on consumption from
investment in human beings, according to Schultz; (2)
most of the contributions of CWNs’ participants are
provided for free; (3) most of CWNs are loosely
affiliated groups with not-for-profit status; (4) human
capital could be an input of and output of the same
activity or process; (5) human capital includes
quantitative and qualitative aspects, and (6) some of its
aspects are inherently difficult to measure and convert
to marketable values. For instance, it is difficult to
measure how migration for better jobs creates human
capital [20]. Therefore, our research design is set to
consider most of these challenges.

We use both qualitative and quantitative data in our
study. The qualitative data was collected through
informal interviews with developers of CWNs during
their summits, participatory research in the
development of Omaha Wireless Network, and
literature review. The quantitative data was collected
via a survey instrument. The questions were designed
to obtain data about the number of participants, the
activities that build human capital, the motivations of
participants, and the forms of technical expertise they
provide. We considered three distinctive activities (or
variables) for human capital creation. These activities
are providing technical support to develop the system;
developing necessary OSS; and providing training to
volunteers and community members. These variables
are used as proxies for measuring informal education.
It is important to remember that one of our objectives
is to explore the capacity of CWNs in redistributing
knowledge and expertise among community members.
 Receivers of knowledge, in this context, include
volunteers, Internet users, and students whose
universities use these networks to deliver education.
Therefore, we collected data about the number of
universities associated with the investigated networks
for the purpose of examining to what extent these
networks support formal education. Once more,
education is the mainstream source of human capital.
To make our task manageable, we did not collect data
about the number of students served by these
networks. The capacity of these networks in
supporting access to information is measured by the
size of the network or number of users it serves.

The data was collected during the IS4CWN
mentioned above through a survey instrument. We
chose this population for data collection because of
their diversity and domain expertise. They include
managers of CWNs, volunteers, donors, community
activists, policy makers and technology vendors. The
collected data show that 13 percent of the survey
respondents donate money, 51 percent are volunteers
and 15 percent are other advocates. In addition, the
data represents 25 CWNs from different parts of the
world and this is another quality aspect. Although this
data set is limited, we believe that it is acceptable for
this exploratory study on this emerging innovation.
We posted the survey online and sent its link to those
who could not complete it during the summit. A group
of seven researchers tested the clarity of the survey
questions. Out of 175 individuals, who attended the
summit, we received 41 responses representing 26
projects. We eliminated the inconsistent responses.
4. Data Analysis

Due to the open nature of CWNs, people, with their skills and knowledge, are their most valuable and productive asset. Table 1 shows the collected data about the variables used as proxies for measuring sources of human capital in the domain of CWNs. Column 2, in this table, presents the names of the investigated networks. We relate the collected data about these variables to these sources in Table 2. The following is a brief analysis of the collected data:

### 4.1 Formal Education

CWNs contribute to the development of computer-literate and knowledge-based societies in different ways. One of these ways is supporting education and research in schools [1,3,10,11,13]. The collected data, column 7, shows that 40 percent of the networks have partnerships with universities. For example, the Omaha Wireless project is built and maintained by voluntary students from the University of Nebraska at Omaha. This project began as an extension of a research project, aimed at achieving “digital inclusion.” It provides free Wi-Fi access at the university campus and its neighborhoods, Elmwood Park, Washington Library, and Rosenblatt Stadium. Similarly, Nepal Wireless is associated with four universities. In addition, Wireless Ghana supports electronic education in rural areas of West Africa. In other words, these projects enhance human capital by supporting the academic environment. Yet again, formal education is the key engine for human capital creation [5,6,18].

### 4.2 Informal Education

The literature shows that CWNs provide training to volunteers and end-users [2,11,18]. Training, or informal education, is an important source of human capital as it builds the competency of workers and makes them more productive. In addition, informal

<table>
<thead>
<tr>
<th>The network</th>
<th>Volun.</th>
<th>Users</th>
<th>Training</th>
<th>Build. resume</th>
<th>Universities</th>
<th>T.S.</th>
<th>OSS</th>
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</table>
education enables individuals to obtain higher wedges in the marketplace. Column 4 shows that 80 percent of the networks provide informal training to users and volunteers. The average number of volunteers in the investigated set of networks is 10 individuals. We assume that they participate for the purpose of obtaining technical expertise and building their resumes, in general, as discussed in the literature and shown in Table 1. Column 5 shows that 60 percent of the survey replies shows that participants volunteer for the purpose of building their resume. One of the motivations of volunteers is to obtain technical expertise. Column 6 shows that 92 percent of volunteers participate to learn new technical skills. For instance, the AirJaldi network has an academy that organizes programs for technical training and capacity building. This academy hosts computer related courses and workshops for the purpose of building skills and bridging the knowledge gap in rural areas of South India.

Participants of CWNs develop OSS and share it with other CWNs [15]. When volunteers collaborate to develop OSS, they learn new ideas, transfer competences and share skills. In other words, developing OSS is considered a form of informal education. Column 9 in Table 1 shows that 24 percent of the studied networks are active in developing OSS. During these activities, members share or transfer competences and principal skills. These skills include programming, troubleshooting, organization, leadership and management. In traditional ISPs, subscribers do not obtain the opportunity to have hands-on participation in the design, installation, troubleshooting, and maintenance of the network they use.

**4.3 Access to Information**

The Internet has grown to be an important venue for individuals to learn, experience, and garner information and knowledge on their predisposition. When individuals have computers and Internet access, they get the opportunity to build basic computer and Internet skills. In addition, the Internet enables them to find jobs, access online learning resources and obtain healthcare related information [3,4,11]. We use the number of regular users, column 3 in Table 1, served by these networks as a proxy to measure the role of CWNs in facilitating access to information. For instance, NYCwireless supports around 3000 users. In addition, Bristol Wireless served 500 users, at the time of data collection, which is June and May of 2008. The average number of users served by the investigated networks is 577, as shown in Table 2. Consequently, it would be useful to distinguish free networks from paid ones. The data shows that 77 percent of the investigated networks provide free Internet access to users.

Investing in human capital usually involves monetary cost [6]. The human capital produced in the domain of CWNs does not involve high cost because of their not-for-profit status. As noted before, CWNs are collective, or free, telecommunication infrastructures built on the notion of sharing, donation and volunteerism. We can easily calculate the opportunity cost of providing free Internet access to these users. This is particularly important to distinguish CWNs from regular ISPs. Similarly, some CWNs (e.g. Omaha Wireless) support public libraries and this is another venue for human capital creation through CWNs. But this variable is beyond the scope of our study. Once more, these restricted activities enable users to accrue human capital.

<table>
<thead>
<tr>
<th>The variable</th>
<th>Source of H.C.</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Training</td>
<td>Informal education</td>
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<tr>
<td>Building resume</td>
<td>Informal education</td>
<td>60%</td>
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<td>Providing technical support</td>
<td>Informal education</td>
<td>72%</td>
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<td>Partnerships with universities</td>
<td>Formal education</td>
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<td>Developing OSS</td>
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<td>Number of users</td>
<td>Access to information</td>
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</table>

**5. Research Implications**

Prior studies show that CWNs support education, provide training, facilitate knowledge exchange, and enhance healthcare [3, 7, 10, 11]. Although these are mainstream sources of human capital, the literature does not treat them as such. This poor conceptual treatment of this important topic does not enable policy makers or academicians to fully comprehend their broad socioeconomic effects.

Drawing on previous work, our study explores the capacity of these networks in producing human capital. It describes CWNs as open innovations where facets of human capital are produced, shared, brokered and/or reproduced among community members while building and maintaining such collective telecommunication infrastructures. More specifically, the developers and users of CWNs exchange ideas, skills and information. In addition, these networks serve as virtual highways used by community members to access information about job
opportunities, healthcare and nutrition. Moreover, the collected data shows that some of these networks support formal education through building partnerships with universities and supporting their academic activities.

These findings confirm previous studies indicating that CWNs drive different sources of human capital such as education, training, and healthcare [11,16]. Unlike previous studies, mostly qualitative, ours provides anecdotal evidence and conceptual insights on how CWNs facilitate human capital formation. In particular, it shows that CWNs serve as engines for producing (or carriers for distributing) human capital similar to schools and training centers. The mainstream engines (e.g. schools, hospitals, training centers, nutrition) for human capital usually create one single element of this intangible asset. The novelty of CWNs, however, lies in creating different types, or elements, of human capital.

The human capital generated in the domain of CWNs could be easily evaluated by its opportunity cost. Therefore, we suggest that CWNs should obtain the advocacy of governments, developing agencies and not-for-profit organizations, as with schools and training centers. We also provide new insights into how to quantify the sources of human capital and conceptualize them to guide future endeavors. In addition, we provide practical evidence from a set of working cases from different parts of the world. CWNs are particularly important for rural and developing societies. This specific setting usually has limited public facilities, scarcity of technical personnel, difficult geographical terrain, bad climate conditions, low income, limited business opportunities, and insufficient population density [7].

In general, investing in human capital could be done by public entities, private organizations or individuals. The elegancy of our study lies in investigating human capital formation on the community level where the investment in human capital is done collectively by the community. The underlying implication is that CWNs could serve as community solutions for human capital accumulation, particularly in economically divested areas. Such areas usually lack resources for investment in human capital.

This study may also serve as a step towards advancing the topic of CWNs as a research stream. For this reason, we crafted a new research approach and provided a rich set of conceptual insights. The main scientific contribution of this study is as follows:

1. It attributes the information and competencies shared, produced, or redistributed in the domain of CWNs as elements of human capital;
2. It also presents early insights into how to measure human capital in the domain of socio-technical structures.

We also provided sufficient literature review, conceptual details and suggestions to guide future endeavors. For instance, we attempted to quantify and measure the sources of human capital with respect to CWNs.

In addition, we suggest that the measures of the capacity of CWNs in human capital creation should include the number of users served by these networks. It could also include the opportunity cost of the provided service and the OSS developed for these networks.

Despite the soundness of our proposed research approach and its interesting analytical details, it is limited in range and scope. For example, as with similar intangibles, we did not quantify and aggregate all dimensions of human capital created in the domain of CWNs and convert them into marketable values.

In spite of these limitations, we hope that our work would serve as a foundation for future endeavors. Future work could include or exclude other facets of human capital. It could also focus on measuring forms of human capital created in a specific period of time by measuring the level of skills of volunteers in the beginning and at the end of this period. Human capital is a stock, as with other forms of capital, and its value is best estimated at a specific point in time. In addition, this work could be improved by focusing on selective case studies and using data about the number of knowledge beneficiaries and contributors. It could also include the learning and training hours and the level and type of skills exchanged or built in these particular cases. Moreover, we could explore the impact of the gained expertise on improving the productivity or earnings of participants and network users. Another potential improvement is converting the generated human capital into marketable values, maybe, by using its opportunity cost. It would be also interesting to extend this study to explore the role of CWNs in creating physical capital. Physical capital includes machinery, factories, plants, raw materials, inventories, and means of transportation and communication [6]. CWNs generate physical capital when they serve as venues for contributors to build computer networks, develop OSS and repair computers.
6. Conclusion

This study provides anecdotal evidence on the role of CWNs in facilitating human capital formation. It shows that CWNs facilitate human capital formation through supporting the academic environment, supplying training, brokering knowledge, providing access to information and enhancing healthcare. In addition, this paper offers early thoughts on some of the challenges facing the measurement of human capital, particularly within informal structures. Another elegant aspect of our study is exploring the production of human capital in a non-market setting. In addition, the used research approach could serve as a guide for studying human capital generated through OSS, Wikis, online forums and similar open innovations related to education, training, healthcare, knowledge and nutrition. Finally, CWNs need the advocacy of governments, developing agencies and academics. This advocacy is important to fully utilize their capacity in producing the capital necessary for achieving a broad sustainable development.

References

