Appendix B: Mathematical Model details

1 Model Overview

In this work, we develop a linear programming model to (a) quantify the financial worth of Health Information Exchange (HIE) information to each of its participating institutions and (b) analyze various HIE pricing policies. We consider a set of Agents (A) consisting of Health Care Providers (H), Payers (I), a Health Information Exchange (HIE) ($w \in A$), and the Government ($g \in A$). For each of these agents, we estimate expenses and revenues over operations significant to the HIE. We perform these evaluations in two independent settings, one with the HIE as an information provider and the other without. We measure differences in expenses and revenues of each agent in the above two scenarios to help understand the effect of HIE information on specific functions of each agent.

1.1 Methodology

For each agent ($a \in A$), we perform the following

1. Identify the specific functions of the agent that the HIE can effect (e.g Emergency department admissions).
2. Evaluate the sources of expenses (e.g performing medical procedures) and revenue (e.g insurance claims) concerning relevant operations of each agent without HIE's information.
3. Estimate the changes in the relevant functions (e.g reduced hospitalizations) due to HIE and its effect on the expenses and revenue of each agent.
4. Evaluate the sensitivity of the results to all modeling parameters used.

The rest of this work described the application of the above methodology on each agent ($a \in A$). An implementation of this mathematical model in the GAMS modeling language is freely available at `http://www.cs.wisc.edu/~srikris/NHII.tar`.

1.2 Study Population

We consider select patient entry points(X) of the health care provider as the focus of our modeling efforts. At each of the entry points, we focus on a specific set of patient diagnosis(J). Patients with these three conditions could be high consumers of clinical services, and therefore are likely to benefit from HIEs. Experience data for these diagnoses must be extensive and detailed enough that we can have confidence in a model constructed on these data.

We model three well documented effects of HIE on emergency care:

Symbol	Notation
A	Set of all agents
H	Set of Health Care Providers ($H \subset A$)
I	Set of Payers ($I \subset A$)
M	Set of HMOs ($M \subset I$)
g	Government ($g \in I$)
w	Health Information Exchange (HIE, $w \in A$)
P	Set of patient classes (e.g. commercial insurance, medicare etc.)
X	Set of patient entry points (e.g. emergency department)
J	Set of patient primary diagnosis (e.g. Asthma, Diabetes, etc.)
F	Set of patient visit frequencies
LT	Set of all medical procedures

Table 1: Set notations

- Reduction of unrequired hospitalizations that occur because there is insufficient information available to make a diagnosis and disposition decision (refereed to below by the shorthand UH);
- Reduction of duplicated test and imaging studies (Dup);
- Avoidance of repeat visits via case management (AED).

1.3 Notations

All decision variables and parameters with over-lining accents denote quantities measured or calculated with HIE influence while those without are measured without HIE influence. Table 1 provides notations describing sets used in the model. Table 2 summarizes notations for input data, Table 3 lists out parameters calculated from data while Table 4 details agent-wise decision variables.

2 Health Care Provider

We now apply Methodology (1.1) on the functions of health care providers at each of the specific patient entry points. For each patient, we measure the frequency $f \in F$ of admission at a specific entry point $x \in X$ over a fixed time period. Upon aggregation, we obtain $N_{h,x,f}$: the total number of patients admitted at entry point $x \in X$ of a provider $h \in H$ with frequency $f \in F$.

Each patient admitted to an ED is first stabilized after which they are either hospitalized for further treatment or discharged. Hence, we divide the total number of patient admissions into the following categories:

Symbol	Notation
$N_{h,x,f}$	Number of patients admitted to the provider $h \in H$ with frequency $f \in F$ through entry point $x \in X$.
$E_{h,x,f}$	Number of patient hospitalized at entry point $x \in X$ of provider $h \in H$ with frequency $f \in F$.
$T_{h,x,f}$	Number of patients discharged after stabilization at entry point $x \in X$ of provider $h \in H$ with frequency $f \in F$.
$\beta_{h,x,j}$	Fraction of all admitted patients at $x \in X$ of provider $h \in H$ and eventually diagnosed with illness $j \in J$.
$\alpha_{h,x,j,i}$	Fraction of all admitted patients, signed up with payer $i \in I$, showed up for treatment at $x \in X$ of provider $h \in H$ and eventually diagnosed with illness $j \in J$.
$SC_{h,x,j,p}$	Average claim reimbursed to a provider $h \in H$ for stabilizing a patient of class $p \in P$ diagnosed with illness $j \in J$ at entry point $x \in X$.
$C_{h,j,p}$	Average claim reimbursed to a provider $h \in H$ for treating a hospitalized patient of class $p \in P$ diagnosed with illness $j \in J$.
$\text{CLab}_{h,l,t}$	Average cost to a provider $h \in H$ for a lab test $lt \in LT$.
$\text{CapCost}_{h,m,j}$	Average assigned payment provided by the HMO $m \in M$ to provider $h \in H$ to treat a patient with illness $j \in J$.
$e_{h,x}$	Number of patients admitted at entry point $x \in X$ of provider $h \in H$ and are hospitalized due to lack of medical information.
$t_{h,x,f}$	Number of patients admitted at entry point $x \in X$ of provider $h \in H$ with frequency $f \in F$ that could be assigned a primary care physicians outside the concerned entry point.
NI_i	Total number of patients signed up with the payer $i \in I$.
FI_i	Average monthly premium for patients signed up with the payer $i \in I$.
NG_m	Total number of patients signed up with the HMO $m \in M$.
FG_m	Average monthly premium for patients signed up with the HMO $m \in M$.
χ_f	Multiplier for the frequency class (Frequency class of 4 ED visits p.m has multiplier 4).

Table 2: Data (exact and calculated) used in the model

Symbol	Notation
TotalProfit_a	Net cash flow for an agent $a \in A$.
$\text{InsuranceClaims}_{h,i}$	Net insurance claims payed by payer $i \in I$ to provider $h \in H$.
$\text{HospitlizationClaims}_{h,i}$	Net insurance claims payed by payer $i \in I$ to provider $h \in H$ for the treatment of hospitalized patients.
$\text{StabilizationClaims}_{h,i}$	Net insurance claims payed by payer $i \in I$ to provider $h \in H$ for stabilizing patients.
$\text{CostLab}_{h,l}$	Average cost to a provider $h \in H$ for performing a medical procedure $lt \in LT$.
$\bar{z}_{h,x,j}$	Fraction of patients admitted to provider $h \in H$ through entry point $x \in X$ with illness $j \in J$ that are referred out to primary care physicians outside the provider and do not visit the provider again.
$\bar{m}_{h,x,f}$	Fraction of patients that showed up at entry point $x \in X$ of provider $h \in H$ with frequency $f \in F$ whose hospitalization could have been avoided as determined by HIE information.
$\bar{\beta}_{h,x,j}$	Fraction of hospitalized patients (with HIE) that showed up for treatment at $x \in X$ of provider $h \in H$ was eventually diagnosed with illness $j \in J$
$\bar{\alpha}_{h,x,j,i}$	Fraction of (with HIE) hospitalized patients, signed up with payer $i \in I$, showed up for treatment at $x \in X$ of the provider $h \in H$ and were eventually diagnosed with illness $j \in J$.
$\bar{N}_{h,x,f}$	Number of patients (with HIE) admitted to the provider $h \in H$ through entry point $x \in X$ with frequency $f \in F$.
$\bar{E}_{h,x,f}$	Number of patients (with HIE) who showed up for treatment at entry point $x \in X$ of provider $h \in H$ with frequency $f \in F$ and are hospitalized.
$\bar{e}_{h,x,f}$	Number of patients (with HIE) who showed up for treatment at entry point $x \in X$ of provider $h \in H$ with frequency $f \in F$ and are hospitalized.
$\bar{T}_{h,x,f}$	Number of patients (with HIE) who showed up for treatment at entry point $x \in X$ of provider $h \in H$ with frequency $f \in F$ that are discharged after stabilization.
$\bar{t}_{h,x,f}$	Number of patients (with HIE) who showed up for treatment at entry point $x \in X$ of provider $h \in H$ with frequency $f \in F$ and do not hold their assigned appointment with the primary care physician outside the provider.
$\bar{q}_{l,f}$	Fraction of medical procedures $l \in LT$ can be reused on a patient admitted with frequency $f \in F$.

Table 3: Static parameters evaluated from data

Symbol	Notation
HIE	
$\overline{\text{ChargeHIE}}_a$	Cost of HIE's services to agent $a \in A$
Insurance Company	
$\overline{\text{InsuranceClaims}}_{h,i}$	Average insurance claim payment (with HIE) for a payer $i \in I$ towards the provider $h \in H$
General	
$\overline{\text{HIEEffect}}_a$	Average benefit (with HIE) of HIE to agent $a \in A$
$\overline{\text{TotalProfitHIE}}$	Net cash flow (with HIE)for HIE
$\overline{\text{TotalProfit}}_a$	Total Cash flow (with HIE) for agent $a \in A$ with HIE in the system
$\overline{\text{InternalCost}}_a$	Internal Costs (with HIE) incurred by an agent $a \in A$

Table 4: Agent-wise decision variable notations

Agent	Revenue	Expenditure
Health Care Provider	Insurance Claims	HIE subscription fee Medical procedures on patients
Private Insurance	Patient premium	HIE Subscription fee Reimbursing medical claims
HMO	Patient premium	HIE Subscription fee Reimbursing medical claims
Government		HIE Subscription fee Reimbursing medical claims
HIE	HIE Subscription fee	Internal costs

Table 5: Agent-wise revenue and expenditure list

- $E_{h,x,f}$ is the number of patients admitted to provider $h \in H$ with frequency $f \in F$ through entry point $x \in X$ and hospitalized for further treatment.
- $T_{h,x,f}$ is the number of patients admitted to provider $h \in H$ with frequency $f \in F$ through entry point $x \in X$ and discharged after stabilization.

Based on previously collected patient information specific to each provider, we categorize patient admission based on illness and insurer. We define two quantities:

- $\beta_{h,x,j}$ is the fraction of patients admitted at entry point $x \in X$ of provider $h \in H$ and diagnosed with illness $j \in J$.
- $\alpha_{h,x,j,i}$ is the fraction of patients who are signed up with payer $i \in I$, admitted at entry point $x \in X$ of provider $h \in H$ and diagnosed with illness $j \in J$.

Each provider $h \in H$ provides a set of medical procedures $t \in T$ to treat patients diagnosed with an illness $j \in J$.

2.1 Expenditure and Revenue

Each provider interacts with a certain subset of payers and the HIE. Providers sustain the costs incurred for the care of patient by reimbursing claims from payers. Table 5 lists out the expenditure and revenues for providers and all other agents in the HIE system.

2.1.1 Insurance Claims: Fee for Service

We define patient classes ($p = \{i_1, i_2 ...\}$) as the set of insurance companies ($i_1 \in I, i_2 \in I ...$) whose customers are charged in a similar manner by a provider $h \in H$. We assume that providers might charge patients covered by different insurance classes differently but do not distinguish between patients from the same insurance class. Hence, the insurance claims covering medical procedures depend only on the entry point ($x \in X$), the patient class ($p \in P$) and the illness ($j \in J$).

The total reimbursements received by a provider $h \in H$ from a payer $i \in I$ for stabilizing patients is:

$$(\text{StabilizationClaims})_{h,i} = \sum_{f \in F, x \in X, j \in J} (\chi_f)(N_{h,x,f})(\alpha_{h,x,j,i})(SC_{h,x,j,p}) \; p \ni i, \forall i \in I, h \in H \tag{1}$$

Here, $SC_{h,x,j,p}$ denotes the average claim reimbursed by a provider $h \in H$ to stabilize a patient of class $p \in P$ diagnosed with illness $j \in J$ at entry point $x \in X$ and χ_f is the multiplier for the frequency class (e.g. 4 ED visits per year will have a multiplier 4 because the provider spends four times the resources on the same patient).

After a patient is stable, the ED decides whether or not to hospitalize patients for further treatment. Hence, the total insurance claimed by the provider $h \in H$ from a payer $i \in I$ for treating hospitalized patients is:

$$(\text{HospitalizationClaims})_{h,i} = \sum_{x \in X, j \in J} (\chi_f)(E_{h,x})(\alpha_{h,x,j,i})(C_{h,j,p}) \ p \ni i, \forall i \in I, h \in H \tag{2}$$

Here, $C_{h,j,p}$ denotes the average claim reimbursed by a provider $h \in H$ to treat a hospitalized patient of class $p \in P$ diagnosed with illness $j \in J$. We assume that claims on hospitalized patients is independent of the entry point of admission. We calculate the net insurance claims as

$$(\text{InsuranceClaims})_{h,i} = (\text{StabilizationClaims})_{h,i} + (\text{HospitalizationClaims})_{h,i} \ \forall i \in I, h \in H \tag{3}$$

2.1.2 Insurance Claims: HMO

We assume that HMO-Hospital contracts are assigned costs, paid by to the provider, per admission over a defined scope of services for a defined population set, regardless of actual number or nature of services provided. Let $\text{CappedCost}_{h,m,j}$ denote this contracted rate payed by the HMO $m \in M$ to the provider $h \in H$ to treat a patient with illness $j \in J$. We determine the total amount reimbursed by a provider from a HMO as

$$(\text{HMOClaims})_{h,m} = \sum_{f \in F, x \in X, j \in J} (N_{h,x,f})(\chi_f)(\alpha_{h,x,j})(\text{CappedCost})_{h,m,j} \ \forall m \in M, h \in H \tag{4}$$

2.2 Estimating Profits

Internal costs require an examination of an organization's value-creating activities to determine sources of profitability and to identify the relative costs of different internal processes. Principal steps of internal cost determination include identifying those processes that create value for the organization, calculating the cost of each value-creating process against the overall cost of the product or service. Since a majority of the internal costs are extremely difficult to estimate, we propose a simple model that can approximate the profits generated by a provider. We assume the Internal costs as a fixed fraction of the Insurance claims received by the provider. Since different illnesses require varying levels of sophistication of treatment, they generate varying amounts of profit. Illnesses are grouped according to their expected return on investment. Illnesses which require more elaborate procedures are assumed to provide higher return on investments. If an illness $j \in J$ has a 4% return on investment, then we can calculate the cost incurred by the provider to treat a patient with the illness $j \in J$ as 96% of the average revenue generated by each patients. Data concerning return on investments are usually publicly available in hospital performance reports. We assume that the cost incurred to providers for the care of patients is independent of the payer type.

We calculate overall profit as the difference between overall revenue and expense

$$(\text{TotalProfit})_h = \sum_{i \in I} (\text{InsuranceClaims})_{h,i} + \sum_{m \in M} (\text{HMOClaims})_{h,m} - (\text{InternalCost})_h \tag{5}$$

2.3 Effect of HIE

The following section will elaborate the effect of each of the documented benefits of HIE (Section 1.2) on the health care providers.

2.3.1 Reducing Unrequired Hospitalizations

We define $e_{h,x}$ as the number of patients who showed up for treatment at entry point $x \in X$ of provider $h \in H$ and are hospitalized due to lack of medical information. Estimates of the fraction of avoidable hospitalizations are available from past studies. We assume that a certain fraction $\bar{m}_{h,x}$ of thees unnecessary hospitalizations could have been avoided in with HIE information. Hence, the total number of hospitalizations effects the HIE in the following manner:

$$\bar{e}_{h,x} = (e_{h,x})(\bar{m}_{h,x}) \; \forall h \in H, x \in X \tag{6}$$

$$\bar{E}_{h,x} = E_{h,x} - \bar{e}_{h,x} \; \forall x \in X, h \in H \tag{7}$$

This change in the number of hospitalizations effects both the reimbursements from payers and the internal expenditures of the provider. Hence we re-evaluate Equation (2) as:

$$(\overline{\text{HospitalizationClaims}})_{h,i} = \sum_{x \in X, j \in J} (\bar{E}_{h,x})(\alpha_{h,x,j,i})(C_{h,j,p}) \; p \ni i, \forall i \in I, h \in H \tag{8}$$

Clearly, the fraction of unnecessary hospitalizations is not a parameter that a provider has any control over. Sensitivity analysis on $\bar{m}_{h,x}$ will overcome the difficulty in evaluating whether a hospitalization could have been diverted with HIE information.

2.3.2 Avoiding ED visits

We define $t_{h,x,f}$, as the number of patients admitted to hospital $h \in H$ at entry point $x \in X$ with frequency $f \in F$ more than once during a short time period (e.g 15 days). These ED visits are likely to be related to each and could potentially be avoided with proper follow up care . We define $\bar{z}_{h,x,f}$ as the fraction of patients admitted to provider $h \in H$ through entry point $x \in X$ with frequency $f \in F$ diagnosed with a chronic illness $j \in J$ that are forwarded for managed care. Some of these patients may not choose to hold these appointments for various economic and personal reasons. Hence, we calculate the total number of patients $\bar{t}_{h,x,f}$ that show up for treatment at entry point $x \in X$ of provider $h \in H$ but do not hold their assigned appointments with the primary care physicians.

$$\bar{t}_{h,x,f} = (t_{h,x,f})(\bar{z}_{h,x,f}) \; \forall f \in F, h \in H, x \in X \tag{9}$$

We assume that patients who hold their managed care appointments do not show up again at the ED for the same reason. Hence, we calculate the total number of patients (with HIE) that show up at an entry point $x \in X$ of provider $h \in H$:

$$\bar{N}_{h,x,f} = N_{h,x,f} - \bar{t}_{h,x,f} \; \forall h \in H, x \in X \tag{10}$$

We calculate the net reimbursements for stabilizing patients by re-evaluating Equation (1)as:

$$(\bar{\text{StabilizationClaims}})_{h,i} = \sum_{f\in F, x\in X, j\in J} (\bar{N}_{h,x,f})(\chi_f - 1)(\alpha_{h,x,j,i})(SC_{h,x,j,p}) \;\; p \ni i, \forall i \in I, h \in H, f \in F \tag{11}$$

Similarly, we modify (12) as

$$(\bar{\text{HMOClaims}})_{h,m} = \sum_{f\in F, x\in X, j\in J} (\bar{N}_{h,x,f})(\chi_f - 1)(\alpha_{h,x,j})(\text{CappedCost})_{h,m,j} \;\; \forall m \in M, h \in H \tag{12}$$

2.3.3 Reducing Duplicate Testing & Imaging

As mentioned earlier, one of the goals of the HIE is to reduce health care costs by reusing test results of patients that are admitted multiple times within the fixed time frame. We define $\bar{q}_{t,f}$ as the fraction of medical procedures $t \in T$ can be avoided while diagnosing a patient with frequency $f \in F$. We measure the effect of reusing test results using

$$(\bar{\text{InternalCost}})_h = (\hat{\text{InternalCost}})_h - \sum_{f\in F, x\in X, j\in J, l\in LT} (\chi_f)(\bar{E}_{h,x,f})(\text{CLab}_{h,j,l})(\bar{q}_{t,f}) \;\; \forall h \in H \tag{13}$$

Note that $(\hat{\text{InternalCost}})_h$ is the cost incurred by provider $h \in H$ to care for $\sum_{x\in X, f\in F} \bar{N}_{h,x,f}$ admissions and $\sum_{x\in X} \bar{E}_{h,x}$ hospitalizations.

2.4 Effect of HIE

We measure the effect of HIE on the functions of the provider by first calculating the profit in the scenario with the HIE

$$(\bar{\text{TotalProfit}})_h = \sum_{i\in I} (\bar{\text{InsuranceClaims}})_{h,i} + \sum_{m\in M} (\bar{\text{HMOClaims}})_{h,m} \tag{14}$$

$$- (\bar{\text{InternalCost}})_h - (\text{ChargeHIE})_h \tag{15}$$

and then calculating the difference in profit in the two settings.

$$\bar{\text{HIEEffect}}_h = \bar{\text{TotalProfit}}_h - \text{TotalProfit}_h \;\; \forall h \in H \tag{16}$$

Notice that the system with HIE in it has an additional cost incurred by the provider. We do not enforce $(\text{ChargeHIE})_a > 0$, hence if the optimal "charge" turns out to be negative, it is a subsidy.

3 FFS Insurance

FFS Payers sustain their on reimbursing claims from providers by collecting premiums from patients. Some of these FFS payers are commercial enterprises while the rest are government funded.

We calculate the net profit of FFS payers using:

$$\text{TotalProfit}_i = (NI_i)(FI_i) - \sum_{h\in H}(\text{InsuranceClaims})_{h,i} \ \forall i \in I \tag{17}$$

The first term is the net premium collected from patients while the second term is the total claims that the insurance company covers as calculated in Equation(3).

3.1 Effect of HIE

HIE's information hopes to have the following effects on all payers (Insurance Companies, HMOs and the State).

- Insurance claims savings by reducing unrequired hospitalizations.
- Insurance claims savings by avoiding ED visits.
- Insurance claims savings by reducing duplicate testing & imaging.

We expect HIE to cause a large reduction in Insurance claims due to lowered costs of treatment. We measure the effect of HIE using

$$\text{Total}\bar{\text{P}}\text{rofit}_i = (NI_i)(FI_i) - \sum_{h\in H}(\text{Insuran}\bar{\text{c}}\text{eClaims})_{h,i} - (\text{ChargeHIE})_i \ \forall i \in I \tag{18}$$

$$\text{HIE}\bar{\text{E}}\text{ffect}_i = \text{Total}\bar{\text{P}}\text{rofit}_i - \text{TotalProfit}_i \ \forall i \in I \tag{19}$$

4 HMO

HMO Payers sustain their on reimbursing claims from providers by collecting premiums from patients.HMO reimbursements are assigned costs per visit based on number of patients irrespective of the nature or amount of services provided. Just as is the case with FFS, some of the HMO payers are commercial while the rest are government funded. Profit calculations are similar to that of FFS payers.

$$\text{TotalProfit}_m = (NG_m)(FG_m) - \sum_{h\in H}(\text{HMOClaims})_{h,m} \quad \forall m \in M \tag{20}$$

We evaluate the effect of HIE using the following:

$$\text{Total}\bar{\text{P}}\text{rofit}_m = (NG_m)(FG_m) - \sum_{h\in H}(\text{HMOClaims})_{h,m} - (\text{ChargeHIE})_m \quad \forall m \in M \tag{21}$$

$$\text{HIE}\bar{\text{E}}\text{ffect}_m = \text{Total}\bar{\text{P}}\text{rofit}_m - \text{TotalProfit}_m \ \forall m \in M \tag{22}$$

5 Government

Government profit calculations follow from previous sections. We evaluate the net profit with and without HIE as:

$$\text{TotalProfit}_g = -\sum_{m\in M} F\bar{G}_m NG_m - \sum_{h\in H} (\text{InsuranceClaims})_{h,g} \tag{23}$$

$$\text{Total}\bar{\text{P}}\text{rofit}_g = -(\text{ChargeHIE})_g - \sum_{m\in M} FG_m NG_m - \sum_{h\in H} (\text{Insuranc}\bar{\text{e}}\text{Claims})_{h,g} \tag{24}$$

The effect of HIE is

$$\text{HIE}\bar{\text{E}}\text{ffect}_g = \text{Total}\bar{\text{P}}\text{rofit}_g - \text{TotalProfit}_g \tag{25}$$

6 HIE

HIE sustain their internal costs by charging its participating agents. We calculate the net HIE profit as

$$\text{TotalPr}\bar{\text{o}}\text{fitHIE} = \sum_{a\in A\backslash w} (\text{ChargeHIE})_a - (\text{InternalCost})_w \tag{26}$$

The model ensures that the revenue obtained from all agents cover the internal costs of running HIE.

7 Model Objective

We define a multiplayer system in which each agent ($a \in A$) has control over a set of decision variables (D_a) while trying to maximize an objective which is a function of decision variables of all agents in the system ($D_A = \bigcup_{i\in A} D_i$). For example, a provider ($h \in H$) tries to maximize the benefit it gets from HIE. While this benefit depends on the charging scheme of HIE, case management policies etc. of other agents in the system, the provider can control only those decisions that pertain to itself. More precisely,

$$D_w^\star = \arg\max_{D_w} \quad \text{TotalPr}\bar{\text{o}}\text{fitHIE}(D_w, D_{A\backslash w}^\star) \qquad w \in A \tag{27a}$$

$$D_a^\star = \arg\max_{D_a} \quad \text{HIE}\bar{\text{E}}\text{ffect}(D_a, D_{A\backslash a}^\star) \qquad \forall a \in A\backslash w \tag{27b}$$

Solving the above stated problem to equilibrium is computationally intractable. Hence we take the perspective of HIE and assume that all other agents react to HIE's decisions. The LP tries to maximize the total benefit of HIE while making sure that each agent gets a fixed fraction of benefit. In addition, we require sustainability of HIE. We evaluate this using

$$\max_{D_w} \qquad \sum_{a \in A} \text{HIE}\bar{\text{E}}\text{ffect}_a \quad S.T \tag{28a}$$

$$\text{Total}\bar{\text{P}}\text{rofit}_a \geq (\eta_a)(\text{TotalProfit}_a)\ \forall a \in A \backslash w \tag{28b}$$

$$\text{TotalPr}\bar{\text{o}}\text{fitHIE}_w \geq 0 \tag{28c}$$