$$
\begin{array}{rcl}
x & \in & \textit{Variables} \\
\textit{eff} & \in & \textit{Effects} \\
\\
v & ::= & x \mid h \mid \lambda x.e \mid \textit{eff} \\
e & ::= & v \mid v\ v \mid \texttt{let}\ x = e\ \texttt{in}\ e \\
 & \mid & \texttt{inst}\ () \mid \texttt{with}\ v\ \texttt{handle}\ e \\
 & \mid & \texttt{perform}\ e\ e \\
h & ::= & \texttt{handler}\ \ v\ \ (\texttt{val}\ x \to e)\ \ ((x, k) \to e) \\
\\
F & ::= & \square\ v \mid \texttt{let}\ x = \square\ \texttt{in}\ e \\
 & \mid & \texttt{with}\ v\ \texttt{handle}\ \square \mid \texttt{perform}\ \square\ e \mid \texttt{perform}\ v \square \\
s & ::= & [] \mid F :: s \mid s @ s
\end{array}
$$

Figure 1: the syntax of $\lambda_{\textit{eff}}$

$$
\begin{array}{rcl}
\textit{flatfn}\,([]) & = & \lambda x.x \\
\textit{flatfn}\,(F :: s) & = & \lambda x.\,(\textit{flatfn}\,(s))\ \ F\,[x]
\end{array}
$$

Figure 2: utils for the semanticcs

$$\langle e;\ s;\ es\rangle \mapsto \langle e';\ s';\ es'\rangle$$

$$\langle F\,[e]\,;\ s;\ es\rangle \mapsto \langle e;\ F :: s;\ es\rangle \qquad \text{(Push)}$$

$$\langle v;\ F :: s;\ es\rangle \mapsto \langle F\,[v]\,;\ s;\ es\rangle \qquad \text{(Pop)}$$

$$\langle v;\ [];\ es\rangle \mapsto \langle v;\ [];\ es\rangle \qquad \text{(Result)}$$

$$\langle \lambda x.e;\ (\square\ v) :: s;\ es\rangle \mapsto \langle e\,[x = v]\,;\ s;\ es\rangle \qquad \text{(Apply)}$$

$$\langle \texttt{inst}\ ()\,;\ s;\ es\rangle \mapsto \langle \mathit{eff};\ s;\ es\rangle \qquad \text{(Instanciate)}$$

$$\langle \texttt{perform}\ \mathit{eff}\, v;\ F :: s;\ es\rangle \mapsto \langle \texttt{perform}\ \mathit{eff}\, v;\ s;\ F :: es\rangle \qquad \text{(Rethrow)}$$

$$\left\langle \begin{array}{c} \texttt{perform}\ \mathit{eff}\, v; \\ F :: s; \\ es \end{array} \right\rangle \mapsto \langle e_{\mathit{eff}}\,[x = v, k = \mathit{flatfn}\,(es)]\,;\ F :: s;\ []\rangle \qquad \text{(Handle)}$$

where $F = (\texttt{with}\ h\ \texttt{handle}\ \square)$

$h = \texttt{handler}\ \mathit{eff}\ (\texttt{val}\ x \to e_v)\ ((x, k) \to e_{\mathit{eff}})$

$$\langle \texttt{perform}\ \mathit{eff}\, v;\ []\,;\ es\rangle \mapsto \text{abort} \qquad \text{(Leak)}$$

Figure 3: the semantics of λ_{eff}